MOVES OP Mode Emission Rate Extraction Tutorial

The tutorial here shows how to extract various pollutant emission rate for Diesel **Port HDT** (EMFAC Vehicle Type: 8 (Heavy-Heavy-Duty Trucks) equivalent to MOVES Vehicle Type: **62** (Combination Long-haul Trucks) using OP Mode approach which relies on modal binning based on vehicle specific power.

OpMode = 71 modes based on VSP, Speed bins and acceleration/deceleration rates. 23 are operating modes associated with emissions including cruising, acceleration/deceleration, idling, and braking.

Assumption for Data used in "Link.xls":

1. Link length = 1 mile
2. Link volume = 10,000 vehicles
3. Speeds = Median Speed of speed range defined by OpMode (Median Speed Column from the table below)

| OP Mode ID	Description	VSP	Speed Range	Median Speed
0	Braking	-	0	0
1	Idling	-	-1 <= U < 1	0
11	Low Speed Coasting	$VSP_t < 0$	1 <= U < 25	13
12	Cruise/Acceleration	$0 \leq VSP_t < 3$	1 <= U < 25	13
13	Cruise/Acceleration	$3 \leq VSP_t < 6$	1 <= U < 25	13
14	Cruise/Acceleration	$6 \leq VSP_t < 9$	1 <= U < 25	13
15	Cruise/Acceleration	$9 \leq VSP_t < 12$	1 <= U < 25	13
16	Cruise/Acceleration	$12 \leq VSP_t$	1 <= U < 25	13
21	Moderate Speed Coasting	$VSP_t < 0$	25 <= U < 50	37.5
22	Cruise/Acceleration	$0 \leq VSP_t < 3$	25 <= U < 50	37.5
23	Cruise/Acceleration	$3 \leq VSP_t < 6$	25 <= U < 50	37.5
24	Cruise/Acceleration	$6 \leq VSP_t < 9$	25 <= U < 50	37.5
25	Cruise/Acceleration	$9 \leq VSP_t < 12$	25 <= U < 50	37.5
27	Cruise/Acceleration	$12 \leq VSP_t < 18$	25 <= U < 50	37.5
28	Cruise/Acceleration	$18 \leq VSP_t < 24$	25 <= U < 50	37.5
29	Cruise/Acceleration	$24 \leq VSP_t < 30$	25 <= U < 50	37.5
30	Cruise/Acceleration	$30 \leq VSP_t$	25 <= U < 50	37.5
33	Cruise/Acceleration	$VSP_t < 6$	50 <= U	60
35	Cruise/Acceleration	$6 \leq VSP_t < 12$	50 <= U	60
37	Cruise/Acceleration	$12 \leq VSP_t < 18$	50 <= U	60
38	Cruise/Acceleration	$18 \leq VSP_t < 24$	50 <= U	60
39	Cruise/Acceleration	$24 \leq VSP_t < 30$	50 <= U	60
40	Cruise/Acceleration	$30 \leq VSP_t$	50 <= U	60

Pollutant Considered for this tutorial:

- Carbon Monoxide (CO) – MOVES Code: 2
- Oxides of Nitrogen (NOx) – MOVES Code: 3
- Total Energy Consumption – MOVES Code: 91
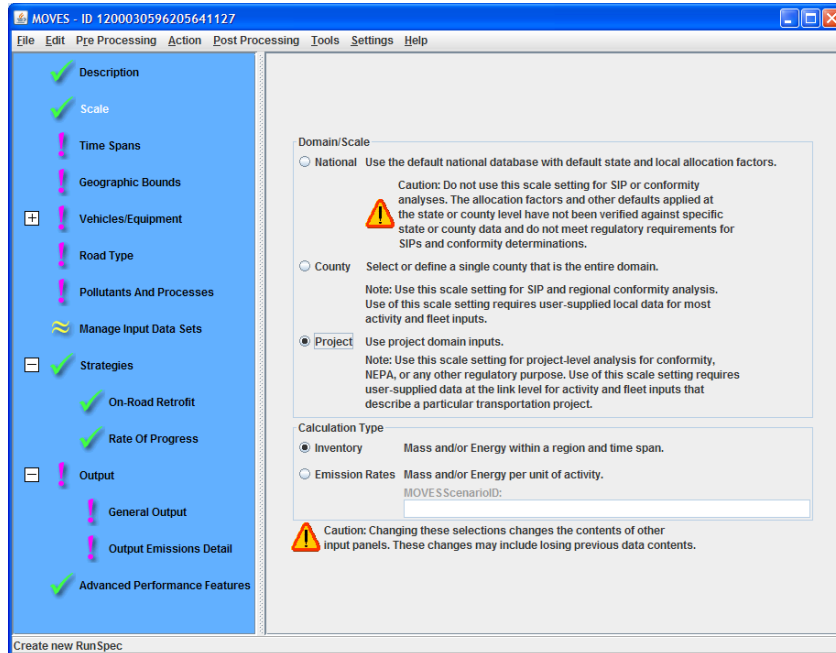
MOVES 2010-B Steps

Step-1

Open New File and save it.
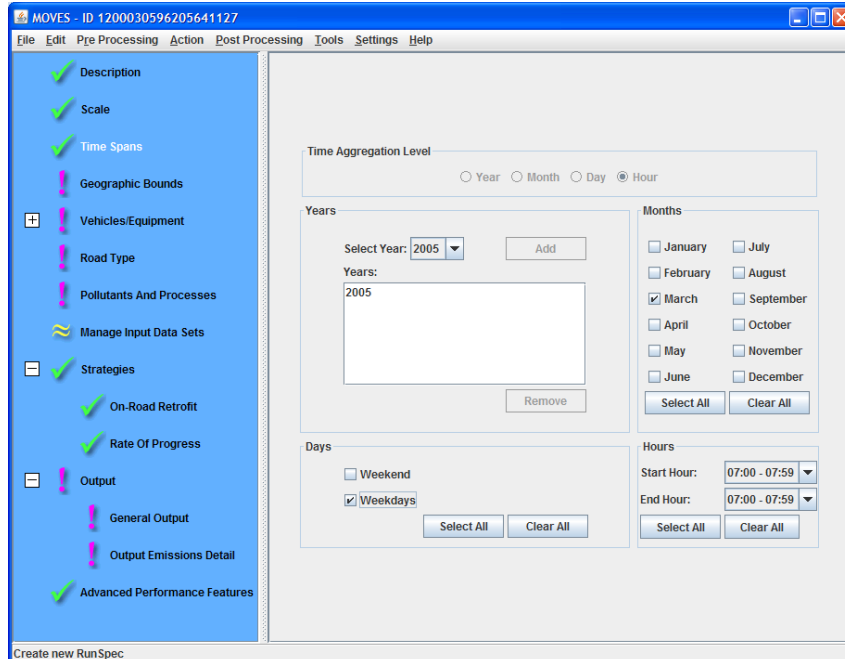
Description: Enter description.
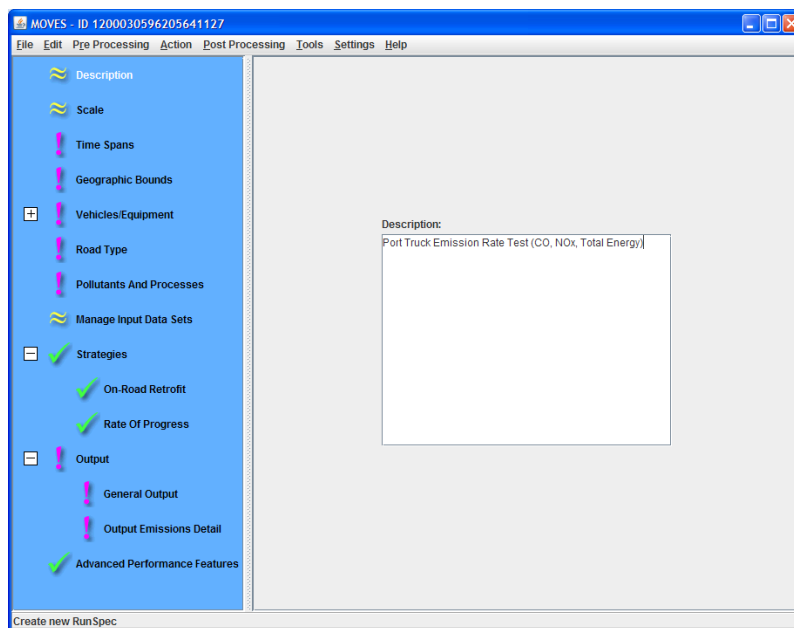
Step-2

Scale: Set Domain/Scale as Project and Calculation Type as Inventory

Step-3

Time Spans: Enter the data as shown in the figure below – Year = 2005, Month = March, Days = Weekday, Start Hour = 07:00 – 07:59, End Hour = 07:00 – 07:59

Step-4

Geographic Bounds: Select Region = County (default), State = California, highlight Counties = California – Los Angeles County to select, and add, as shown in the figure below.
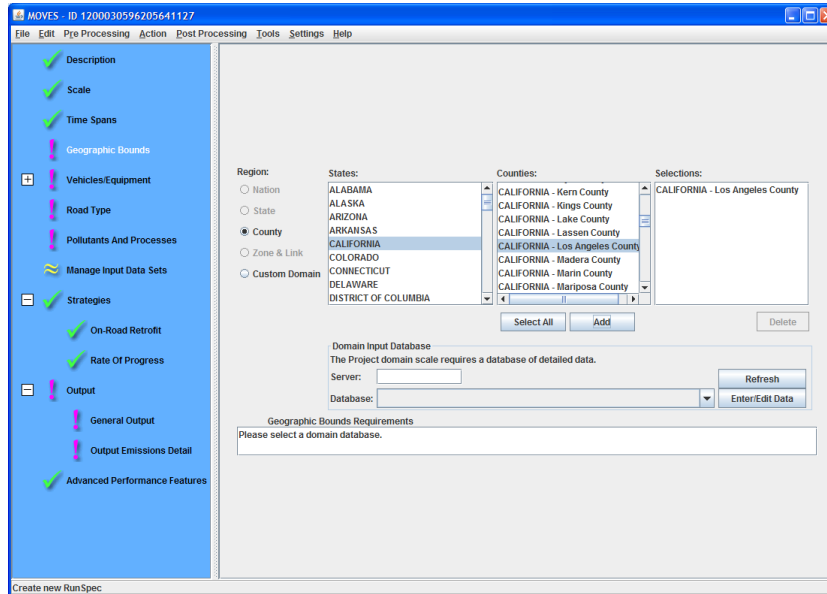

Step-5

Vehicles/Equipment > On Road Vehicle Equipment: Select Fuels = Diesel, Source Use Types = Combination Long-haul Truck (i.e. MOVES ID = 62) then Add Fuel/Type Combinations as shown in the figure below.
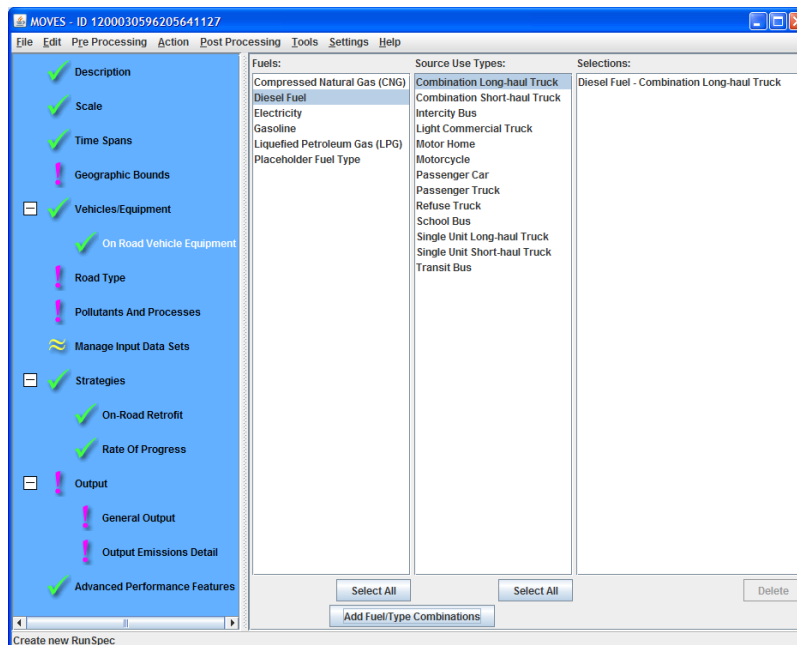
Step-6

Road Type: Select "Urban Restricted Access" from Available Road Types and add as shown in the figure below. Restricted access roadtypes are usually used to model freeways and interstates; ramps are considered part of restricted access road type. Note: "Off Network" is automatically selected when start or extended idle processes are selected on the "Pollutants and Processes" panel.
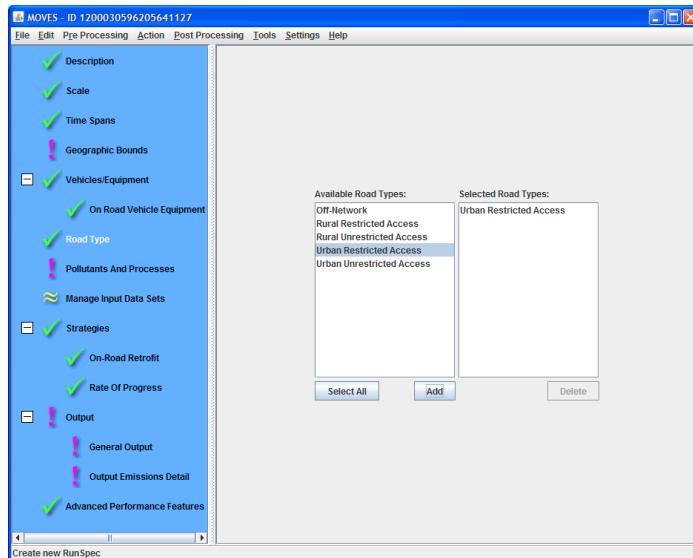

Step-7

Pollutants And Processes: Check box for CO, NOx and Total Energy Consumption "Running Exhaust" only as shown in the figure below.

Important – Just check box for "Running Exhaust" otherwise "Off-Network" gets selected in Road Type.
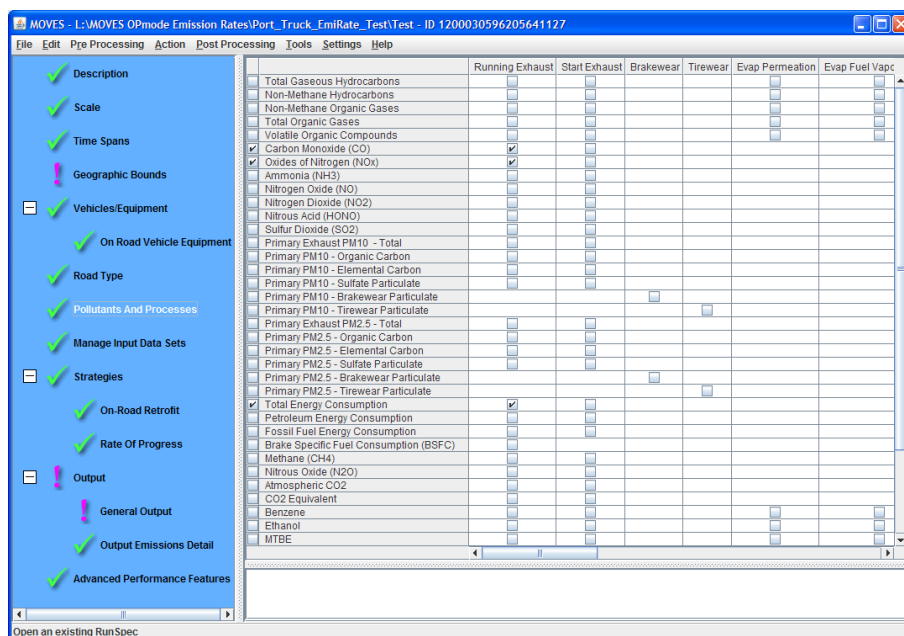
Step-8

Manage Input Data Sets: In Database field enter the name of input database (for example "port_test_in"), then click on Create Database. When input database is created click on Add as shown in the figure below.
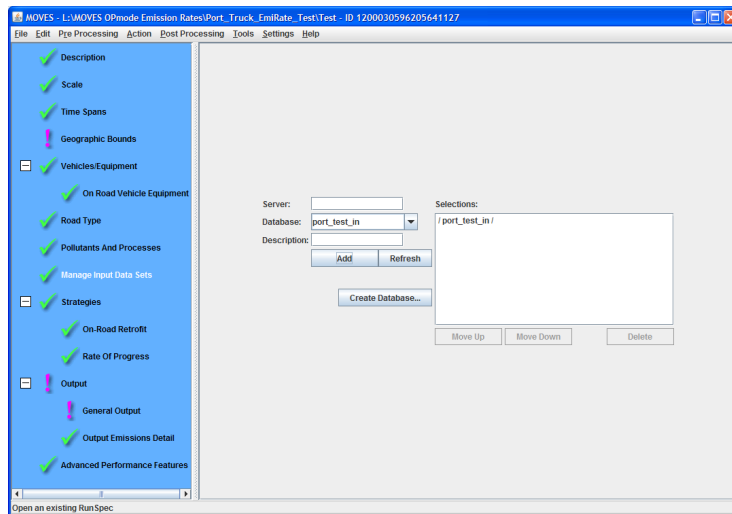

Step-9

Strategies >> On-Road Retrofit and Strategies >> Rate of Progress will have green ticks. Do not have to change anything here so proceed to Output.

Output >> **General Output**: In Database field enter the name of output database (for example "port_test_out"), then click on Create Database. Select Units as follows: Mass Units = Grams, Energy Units = Joules, Distance Units = Miles. In Activity field check boxes for Distance Traveled, Source Hours, Source Hours Operating, and Population, as shown in the figure below.
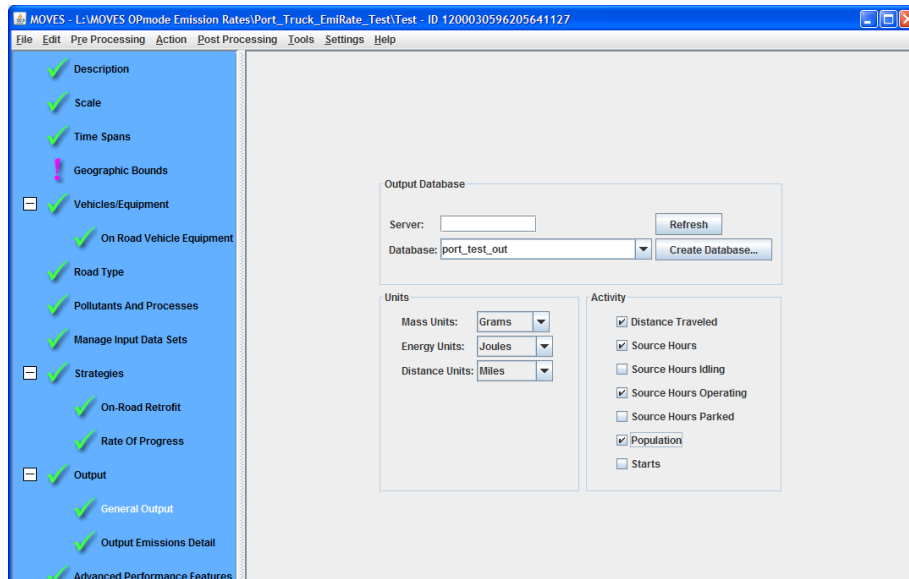
Output >> **Output Emissions Detail**: In "for All Vehicle/Equipment Categories" field select Fuel Type (if Gasoline and Diesel fuels are selected) and Emission Process. In "On Road" field select Road Type, as shown in the figure below.
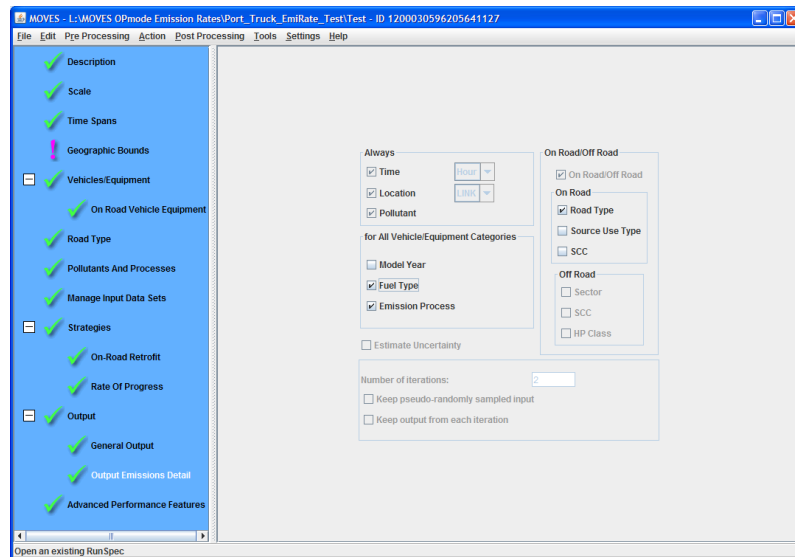
Advanced Performance Features panel does not need any changes unless you need some special result.

Step-10

Now go back to "Geographic Bounds" Panel. Select input database "port_test_in" from dropdown list. Then click on Enter/Edit Data, a new window "MOVES Project Data Manager" will be opened.

Input for generating OpMode Lookup table we need to enter and modify:

- Fuel – Fuel supply and Fuel formulation data source
- Meteorology Data – Temperature and Humidity
- Age distribution by vehicle class. Note: MOVES considers vehicle model years up to 30 years from our 2005 baseline, so aggregate vehicles with model years earlier than 1975.
- Links – Here Link ID (needs to be named based on Vehicle Class and OP Mode ID), Link Length = 1 mile, Link Volume = 10000 vehicles, Link Average Speed = Median Speed for each OP Mode (shown in the Assumption section on first page), Link Description = Enter OP Mode definition, and Link Average Grade = 0), details will be discussed in the next few pages.
- Link Source Types – Details will be discussed in the next few pages.
- Operating Mode Distribution – Note: For each link's "opModeID" set "opModeFraction" = 1, details will be discussed in the next few pages.

Fuel (Create Template > Modify Template based on Project/Export Default > Browse and Open > Import)

Fuel Supply information based on fuel type chosen (Tutorial – Diesel)

countyID	fuelYearID	monthGrou	fuelFormul	marketSha	marketShareCV
6037	2005	3	20116	1	0.5

Fuel Formulation information – Export default data (Exports fuel formulation based on County (Tutorial – Los Angeles) then copy & paste FuelFormulation steet data from exported default file to "fuelformulation.xls" file sheet FuelFormulation.

fuelFormul	fuelSubtyp	RVP	sulfurLevel	ETOHVolu	MTBEVolu	ETBEVolu	TAMEVolu	aromaticC	olefinConta	benzeneC	e200	e300	BioDieselE	CetaneInd	PAHConte	T50	T90
20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20011	20	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20043	20	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20100	20	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20110	20	0	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20113	20	0	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20115	20	0	115	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20116	20	0	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Meteorology (Create Template > Modify Template based on Project/Export Default > Browse and Open > Import) Need to make changes in tab "zoneMonthHour"

monthID	zoneID	hourID	temperatur	relHumidity
3	60370	8	50	73

Age Distribution (Create Template > Modify Template based on Project > Browse and Open > Import) Note: Need to make changes in tab "sourceTypeAgeDistribution"

sourceTyp	yearID	ageID	ageFraction
62	2005	0	0.04553
62	2005	1	0.01198
62	2005	29	0.00166
62	2005	30	0.02144

Need to enter 30 year ageFraction. The age fraction used here Port Truck Engine Age shown below.
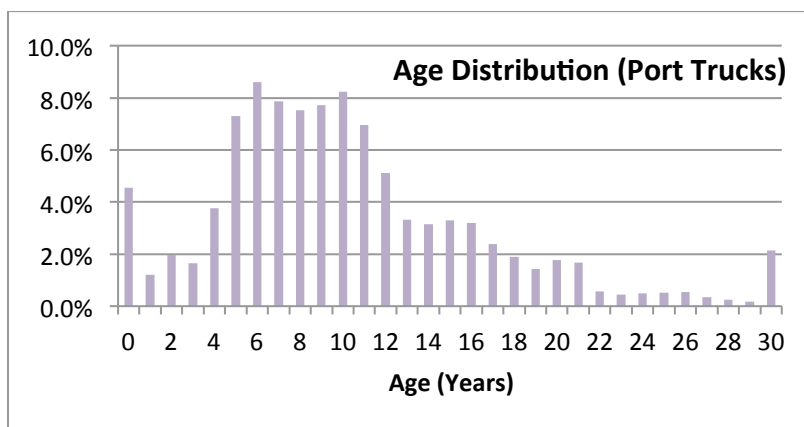
Links (Create Template > Modify Template based on Project > Browse and Open > Import)

Note: Need to make changes in tab "link". Port Truck Tutorial excel file data is too large to show so I will be showing data for Links, Link Source Type, Operating Mode Distribution using a small example.

linkID – Create Link ID using this formula "LinkID = VehCode * 100 + OpMode ID"

> *Example*: MOVES Vehicle Type: **62** (Combination Long-haul Trucks) and suppose you want to find emission rates for OpMode: Braking (OpMode-0), Idling (OpMode-1), Low Speed Coasting (OpMode-11), Moderate Speed Coasting (OpMode-21), and Cruise/Acceleration(OpMode-40)
>
> Link ID (1) = 62*100 + 0 = 6200
> Link ID (2) = 62*100 + 1 = 6201
> Link ID (3) = 62*100 + 11 = 6211
> Link ID (4) = 62*100 + 21 = 6221
> Link ID (5) = 62*100 + 40 = 6240
>
> Suppose we are extracting emission rates for two pollutants: Carbon Monoxide (CO) and Oxides of Nitrogen (NOx). **Important Note**: Since we are extracting emission rates for 5 OpModes and 2 pollutants, we need 5*2 = 10 rows as shown in the figure below. First prepare the data in green cells, then copy and paste it one more time (for two pollutant case), if 3 pollutants considered then paste it two times.

linkID	countyID	zoneID	roadTypeID	linkLength	linkVolume	linkAvgSpe	linkDescription	linkAvgGrade	
6200	6037	60370	4	1	10000	0	OpMode 0 - Braking	0	
6201	6037	60370	4	1	10000	0	OpMode 1 - Idling	0	
6211	6037	60370	4	1	10000	13	OpMode 11 - Low Speed Coasting	0	Pollutant # 1
6221	6037	60370	4	1	10000	37.5	OpMode 21 - Moderate Speed Coa	0	
6240	6037	60370	4	1	10000	60	OpMode 40 - Cruise/Acceleration;	0	
6200	6037	60370	4	1	10000	0	OpMode 0 - Braking	0	
6201	6037	60370	4	1	10000	0	OpMode 1 - Idling	0	
6211	6037	60370	4	1	10000	13	OpMode 11 - Low Speed Coasting	0	Pollutant # 2
6221	6037	60370	4	1	10000	37.5	OpMode 21 - Moderate Speed Coa	0	
6240	6037	60370	4	1	10000	60	OpMode 40 - Cruise/Acceleration;	0	

linkLength – 1 mile assumed

linkVolume – 10000 vehicles assumed

linkAvgSpeed – Median Speed of speed range defined by OpMode (Median Speed Column from the first table in this document) assumed

linkDescription – Here OpMode ID and its definition is used to define LinkID (Sort of Matching)

linkAvgGrade – 0% grade assumed

Link Source Type (Create Template > Modify Template based on Project > Browse and Open > Import)

Note: Need to make changes in tab "linkSourceTypeHour"

Example for two pollutant case is shown below.

linkID	sourceTyp	sourceTypeHourFraction	
6200	62	1	
6201	62	1	
6211	62	1	Pollutant # 1
6221	62	1	
6240	62	1	
6200	62	1	
6201	62	1	
6211	62	1	Pollutant # 2
6221	62	1	
6240	62	1	

Operating Mode Distribution Create Template > Modify Template based on Project > Browse and Open > Import)

Note: Need to make changes in tab "opModeDistribution"

Example for two pollutant case is shown below.

sourceTyp	hourDayIC	linkID	polProces	opModeIC	opModeFraction	
62	85	6200	201	0	*1*	
62	85	6201	201	1	*1*	
62	85	6211	201	11	*1*	Pollutant # 1
62	85	6221	201	21	*1*	
62	85	6240	201	40	*1*	
62	85	6200	301	0	*1*	
62	85	6201	301	1	*1*	
62	85	6211	301	11	*1*	Pollutant # 2
62	85	6221	301	21	*1*	
62	85	6240	301	40	*1*	

Important: Each Link ID will have one operating mode and opModeFraction = 1, i.e. one vehicle will be running on one link and only one OpMode for an hour.

Once the data is imported and there are green checks in the MOVES side panel go to Action > Execute. MOVES run will be executed and output will be generated for further processing.

Open MySQL to access MOVES output "port_test_out". Sample output is shown below.

Export raw output as an Excel file. Process the output.

Link ID	OpMode ID	CO	Nox
6200	0	648984	1509970
6201	1	347361	1484360
6211	11	87360.8	107597
6221	21	32130.9	27810.7
6240	40	105983	904668

Unit Conversion:

According to MOVES software design and reference manual (2009) http://www.epa.gov/otaq/models/moves/420b09007.pdf, "movesoutput" **emissionQuant** field units are specified in MOVES runspec – Mass = grams, Energy = Joules

Energy content in fuels: http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf

Source Hours Operating (SHO) - Total hours, of all sources within a source type, spent operating on the roadway network for the given time and location of the run spec. The same as number of sources per-source hours operating.

$$SHO = \frac{\text{Link Volume (\# of vehicles)} \times \text{Link Length (miles)}}{\text{Link Average Speed (mph)}}$$

For **Braking and Idle emissions**, SHO = Link Volume (# of Vehicles) x Time Specified

SHO unit: Vehicle-Hours

$$SHO = \frac{\text{Link Volume (\# of vehicles)} \times \text{Link Length (miles)}}{\text{Link Average Speed (mph)} \times (\frac{1}{3600})}$$

SHO unit: Vehicle-Seconds

Pollutant Emission unit: Grams-Vehicle in one hour

$$Emission\ Rate\ (\frac{Grams}{second}) = \frac{Pollutant\ Emission\ (Grams - Vehicle)}{SHO\ (Vehicle - Seconds)}$$

$$Energy\ Rate\ (\frac{Joules}{second}) = \frac{Pollutant\ Emission\ (Joules - Vehicle)}{SHO\ (Vehicle - Seconds)}$$

Emission Rate for two pollutant example:

Link ID	OpMode ID	Median Speed	CO	NOx	Conversion Factor	CO (g/s)	Nox (g/s)
6200	0	0	648984	1509970	36000000	0.018027	0.041944
6201	1	0	347361	1484360	36000000	0.009649	0.041232
6211	11	13	87360.8	107597	2769230.769	0.031547	0.038854
6240	40	60	105983	904668	600000	0.176638	1.507780