Travel Model Application for Highway Vehicle Emission Estimation

Ho-Chuan Chen, Ph.D., P.E.

King County
Department of Transportation
Seattle, Washington

21st Annual International Emme Users' Conference
Toronto, Canada, October 10-12, 2007

Overview

1. Introduction

- Global climate change
- Greenhouse gas (GHG) emission

2. Common Approaches to Apply Travel Demand Model for Highway Vehicle Emission Estimation

- Frequently used processes
- Emission factor approaches

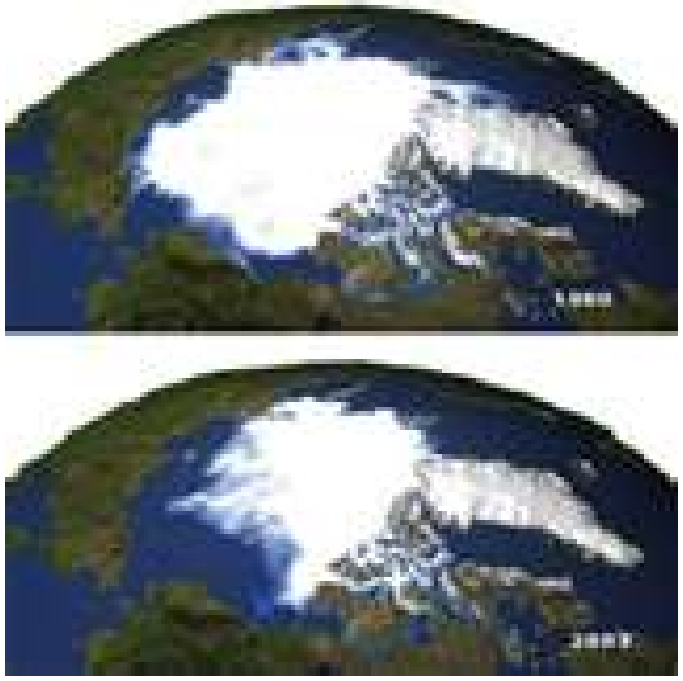
3. Vehicle Emission Estimation Discussion

- Vehicle emission model
- Speed-emission curves & tables
- Fuel-emission curves & tables
- Vehicle emission estimation practice

4. Conclusions and Recommendations

1. Introduction

- Global Climate Change



1. Introduction

- Need to reduce greenhouse gas (GHG) emission from human activities
  - carbon dioxide (CO_2)
  - methane (CH_4)
  - nitrous oxide (N_2O)

- The highway vehicle emission is the main source for CO_2

1. Introduction

- The emissions produced by a vehicle

  - tailpipe emissions
  - evaporative emissions
  - life cycle emissions

- The tailpipe emissions

  - hydrocarbons
  - nitrogen oxides (NOx)
  - carbon monoxide (CO)
  - carbon dioxide (CO_2)

2. Common Approaches to Apply Travel Demand Model for Highway Vehicle Emission Estimation

A. Travel model vehicle emission estimation

- Frequently used process 1

  The link level emissions (CO, NOx, VOC and HC)
  = the emission factor * traffic volumes on the link

  $E^k_i = \sum len_i * I_i * e^k * v_i$

  Where

  E^k_i : emission of pollutant *k* on link *i*

  len_i : length of link *i*

  I_i : vehicle flow on link *i*

  e^k : emission rate of pollutant *k*

  v_i : average speed on link *i*

- Frequently used process 2

  Total vehicle emissions

  = emission factor * vehicle travel activity (speed, VMT) * other correction factors

- Frequently used process 3

  Total vehicle fuel consumption

  = vehicle travel activity * fuel intensity (e.g.,litres/100km)

  Total vehicle emissions

  = Fuel consumption * emission equivalences

B. Emission factor approaches

- ***Approach 1***

  Emission Factors – generated from a vehicle emission model (MOBILE, MOVES, EMFAC)

- ***Approach 2***

  Emission Factors – derived from a speed-emission curve, table or equation

- ***Approach 3***

  Emissions – estimated from vehicle fuel consumptions

2.1 Emission Factors - from a vehicle emission model (MOBILE, MOVES, EMFAC)

- MOBILE

  - emission factors of HC, NO_x, CO, air toxics, gaseous SO_2, ammonia, and direct particulate matter (PM)

  - MOBILE6 has been EPA's officially approved model for HC, NO_x, and CO estimation in SIP development and transportation conformity analysis

2.1 Emission Factors - from a vehicle emission model (MOBILE, MOVES, EMFAC)

- MOVES (Motor Vehicle Emission Simulator)

  - a model currently under development at EPA to estimate air pollution emissions (e.g., CH_4 and N_2O) and energy consumption

  - the date of the draft model release is estimated to be in the fall of 2008

2.1 Emission Factors - from a vehicle emission model (MOBILE, MOVES, EMFAC)

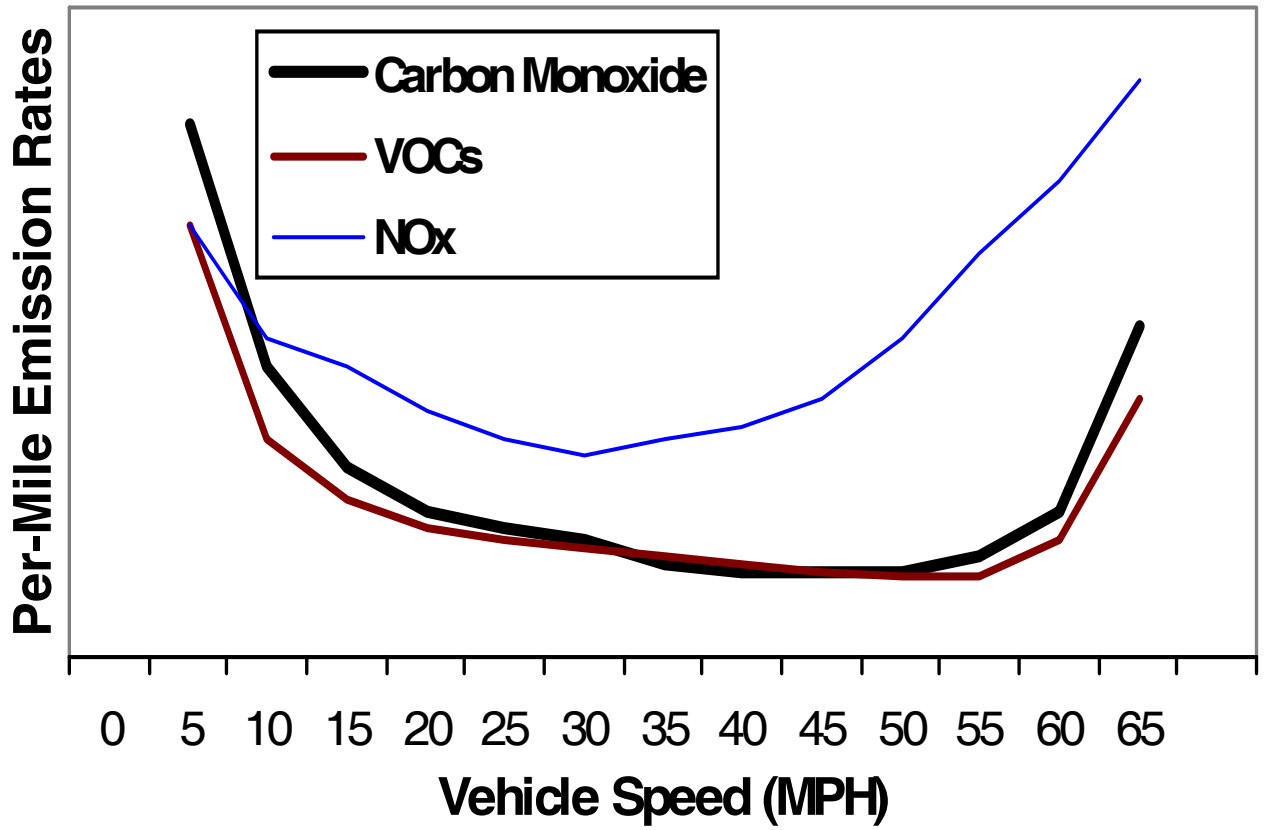
- EMFAC (EMission FACtors)

  - calculates emission factors for HC, CO, NO_x, CO_2, PM, fuel consumption, oxides of sulfur (SO_x), and lead (Pb)

  - developed and used in California

2.2.1 Emission Factors - from a speed-emission curve (1995 TRB, 2005 FHWA, Finland)

- 1995 TRB vehicle speed-emission curve



2.2.1 Emission Factors - from a speed-emission curve (1995 TRB, 2005 FHWA, Finland)

- FHWA vehicle speed-emission curve

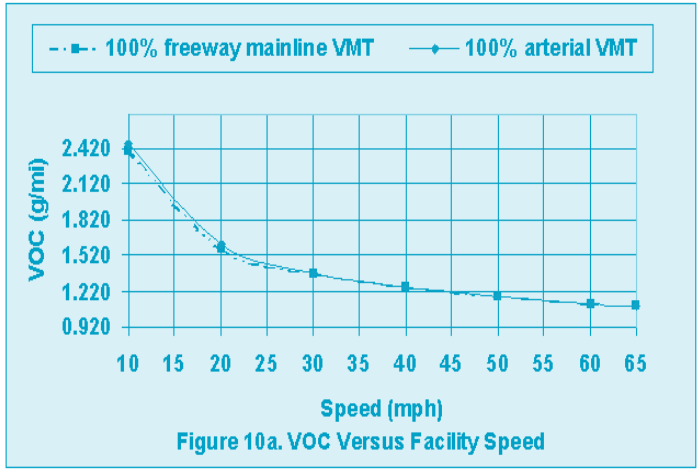


Figure 10a. VOC Versus Facility Speed

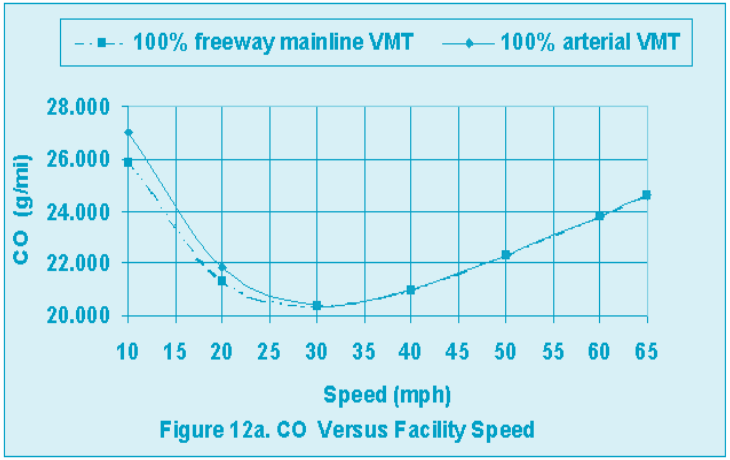


Figure 12a. CO Versus Facility Speed

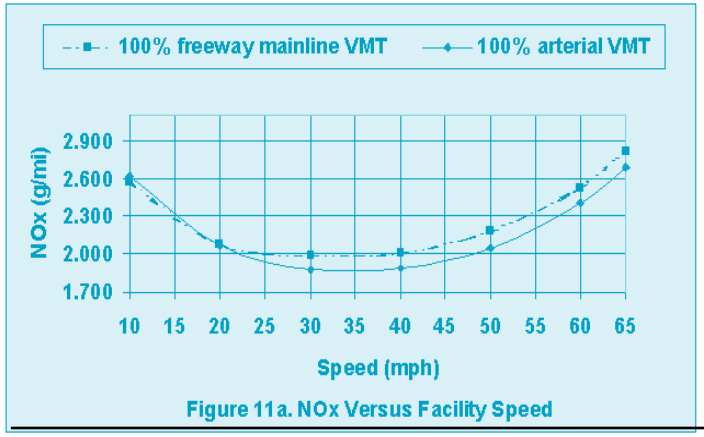
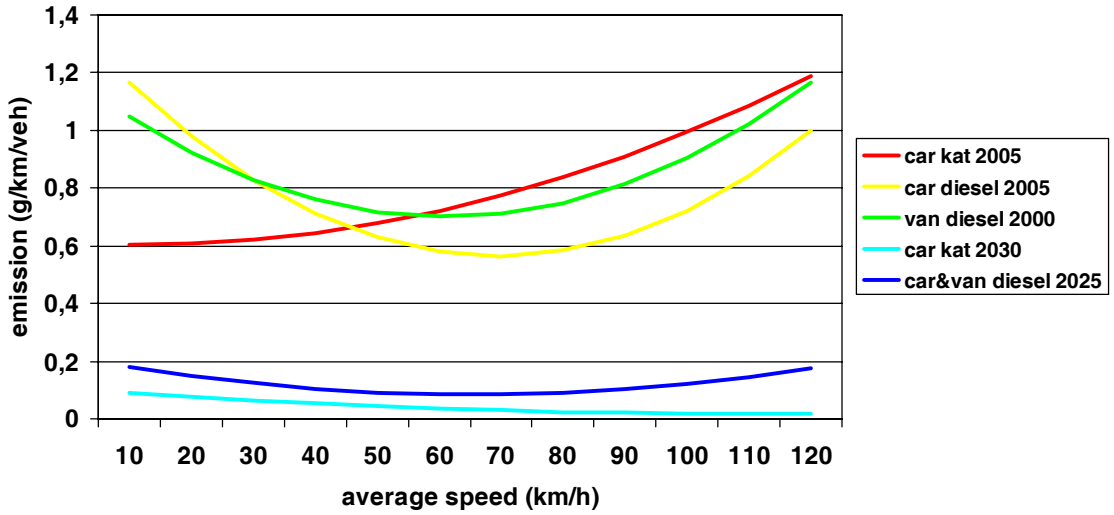
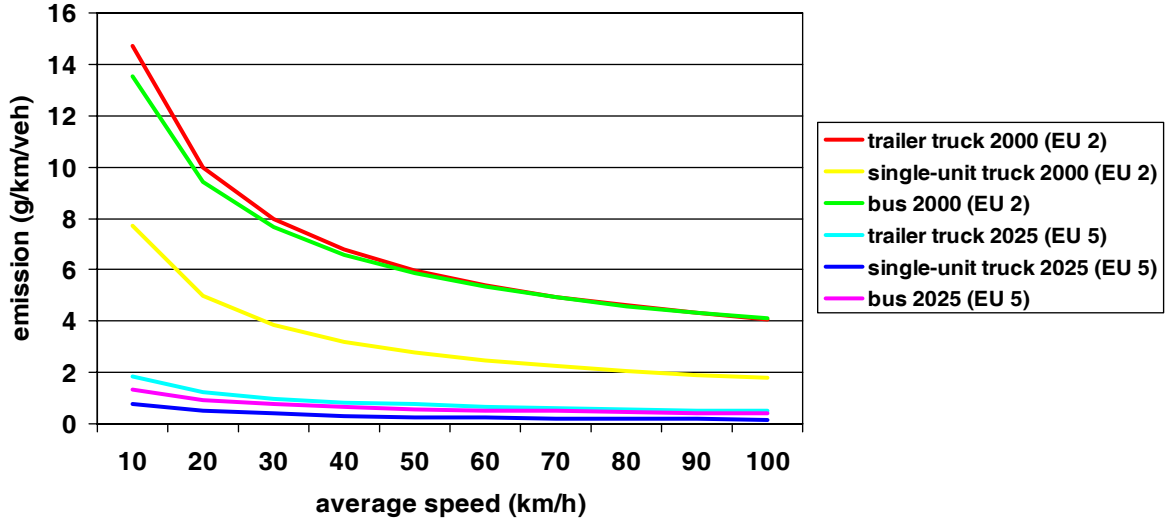


Figure 11a. NOx Versus Facility Speed

2.2.1 Emission Factors - from a speed-emission curve (1995 TRB, 2005 FHWA, Finland)

- Finland vehicle speed-emission curve (NO_x)





2.2.2 Emission Factors - from a speed-emission table

- STEAM speed-emission table

FUEL CONSUMPTION RATES(g/mile)	AUTO	TRUCK	LOC.BUS	EX.BUS	L.RAIL	H.RAIL
					(KWhr/Vehicle Mile)	
5 MPH	0.066	0.481	-	-	-	-
10 MPH	0.042	0.314	-	-	-	-
15 MPH	0.039	0.255	-	-	-	-
20 MPH	0.029	0.223	-	-	-	-
25 MPH	0.027	0.203	-	-	-	-
30 MPH	0.025	0.189	-	-	-	-
35 MPH	0.024	0.179	-	-	-	-
40 MPH	0.023	0.171	-	-	-	-
45 MPH	0.023	0.165	-	-	-	-
50 MPH	0.022	0.160	-	-	-	-
55 MPH	0.021	0.157	-	-	-	-
60 MPH	0.020	0.153	-	-	-	-
65 MPH	0.019	0.150	-	-	-	-
Average	-	-	0.377	0.235	11.090	7.630

HC EMISSION RATES (gr./mile)	AUTO	TRUCK	BUS	RAIL
5 MPH	1.700	4.000	-	-
10 MPH	1.100	3.140	-	-
15 MPH	0.900	2.520	-	-
20 MPH	0.790	2.070	-	-
25 MPH	0.690	1.730	-	-
30 MPH	0.620	1.490	-	-
35 MPH	0.570	1.300	-	-
40 MPH	0.530	1.170	-	-
45 MPH	0.490	1.070	-	-
50 MPH	0.480	1.000	-	-
55 MPH	0.480	0.960	-	-
60 MPH	0.510	0.940	-	-
65 MPH	0.550	0.940	-	-
Average	-	-	2.520	0.000

2.2.3 Emission Factors - from a speed-emission equation

- Emission rate formula or equation

$E^{co} = 42.4531 * v^{-0.1185}$

Where
E^{co} : emission rate (CO)
v : average speed

Or

VOC emission factor = $- 0.0002 * v^3 + 0.0238 * v^2 - 0.9346 * v + 13.157$
NOx emission factor = $0.0015 * v^2 - 0.0926 * v + 3.7832$

Where
v : speed

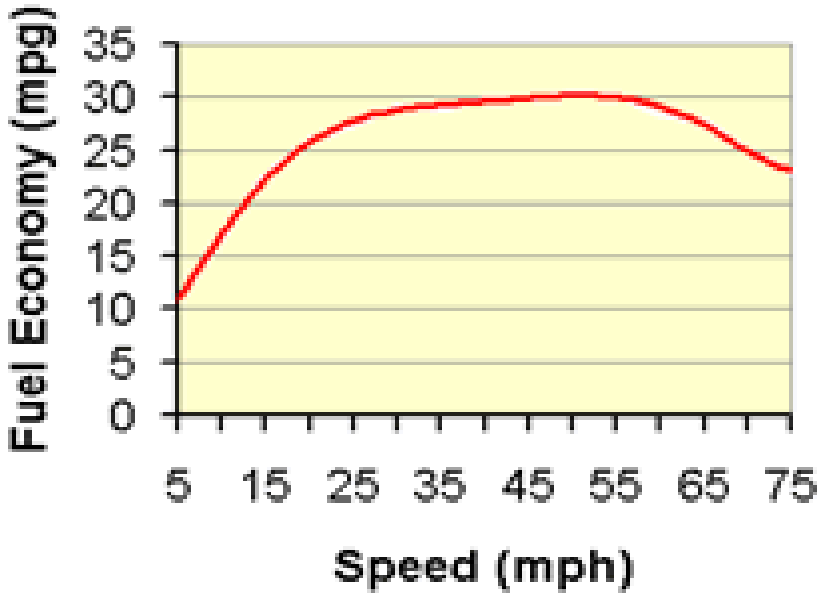
2.3 Emission estimated from vehicle fuel consumption

Travel model outputs
VMT/VKT, vehicle type, average speed

➔ Fuel consumption
by fuel type

➔ GHG emissions
CO_2, CH_4, N_2O

- Speed-fuel consumption curve



2.3 Emission estimated from vehicle fuel consumption

Travel model outputs
VMT/VKT, vehicle type, average speed

➔ Fuel consumption
by fuel type

➔ GHG emissions
CO_2, CH_4, N_2O

- Emission Equivalences Table

Table 2. Carbon Dioxide Equivalences (Grams Per Liter)[15]

Fuel Type	CO_2	CH_4	NO_2	Total CO_2 Equivalent
CO_2 Equivalent	1	21	310	
Gasoline	2,360	0.2273	0.3358	2,469
Diesel	2,730	0.0605	0.2	2,793
Ethanol 10	2,124	0.2273	0.3358	2,233
Ethanol 85	531	0.2273	0.358	640
Conventional Aircraft Fuel Jet Fuel	2,330	2.19	0.23	2,447
	2,550	0.08	0.25	2,629

3. Practice Discussions

- Vehicle emission model

  - CO_2 can not be estimated using MOBILE6.2

  - The MOVES release is estimated to be in the fall of 2008

  - The EMFAC model is developed and used only in California

3. Practice Discussions

- Speed-emission curves and tables

  - The 1995 TRB speed-emission rate curve and STEAM speed-emission table developed in 1990's need to be updated to the current

3. Practice Discussions

- Speed-fuel consumptions curves and equivalences tables

  - The GHG emissions CO_2 can be quickly and easily computed

  - Curves need to be updated for each vehicle type and each fuel type

  - Equivalences tables need also to be updated to the current

3. Practice Discussions

- Vehicle emission estimation practice

  - Travel model is good for the system wide vehicle emission estimation

  - The link speed data or the emission rate equations may need to be refined or developed for the signalized intersections (acceleration, deceleration, stop & go, etc.)

  - The highway vehicle emissions can be reduced either by reducing the amount of travel (e.g., fewer trips or vehicle miles travel), or by reducing the rate of emissions though vehicle technology

  - The trip rates due to pricing in the trip generation process should also be modified in the land use, pricing, and TDM, etc. alternatives evaluation

4. Conclusions

- Integration of land use, transportation, emission, and energy savings

  - GHG CO2 can be reduced significantly through VMT, vehicle trip, and fuel consumption reduction

  - The integration of land use, transportation, emission, and energy savings is the right direction to achieve this goal