EMFAC-HK Vehicle Emission Model

Training Materials

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What is EMFAC-HK

- Computer model written in FORTRAN which is adapted from ARB's EMFAC model
- Calculates emission factors (g/km) for a "Fleet Average Vehicle" and Total emissions (tons/hr, tons/day)
- Used for gasoline, diesel, LPG on-road vehicles
- Calculates Emissions for All HK Vehicle Types
- Exhaust and Evaporative Hydrocarbon Emissions (HC)
- Exhaust Carbon Monoxide (CO)
- Exhaust Nitrogen Oxides (NOx)
- Exhaust PM

Vehicle Classification Chart

V3.x Index	Vehicle Class Description	Gross Vehicle Weight (tonnes)	V2.6 (old) Index
1	Private Cars	ALL	1
2	Taxi	ALL	3
3	Light Goods Vehicles (<=2.5t)	<=2.5t	4
4	Light Goods Vehicles (2.5-3.5t)	>2.5-3.5t	5
5	Light Goods Vehicles (3.5-5.5t)	>3.5-5.5t	6
6	Medium & Heavy Goods Vehicles (5.5-15t)	>5.5-15t	7
7	Medium & Heavy Goods Vehicles (>=15t)	>15t	8
8	Public Light Buses	ALL	11
9	Private Light Buses (<=3.5t)	<=3.5t	12
10	Private Light Buses (>3.5t)	>3.5t	13
11	Non-franchised Buses (<6.4t)	<=6.36t	14
12	Non-franchised Buses (6.4-15t)	>6.36-15t	15
13	Non-franchised Buses (>15t)	>15t	16
14	Single Deck Franchised Buses	ALL	17
15	Double Deck Franchised Buses	ALL	18
16	Motor Cycles	ALL	19

What Can the Model Do?

- Analytical Tool that can be applied for local and regional Air Quality Planning
- Can be used to estimate emission impacts from:
  - Future Vehicle Fleets
  - Diesel/Alternate Fuel Use
  - Vehicle Speeds
  - Ambient Temperature
  - Fuel properties - RVP/Oxygen content/Sulfur content/RFG
  - Air Conditioning
  - Cold Starts
  - Inspection/Maintenance Programs
  - New Vehicle Standards
  - Other Strategies
    - Evaporative Controls
    - Refueling Controls

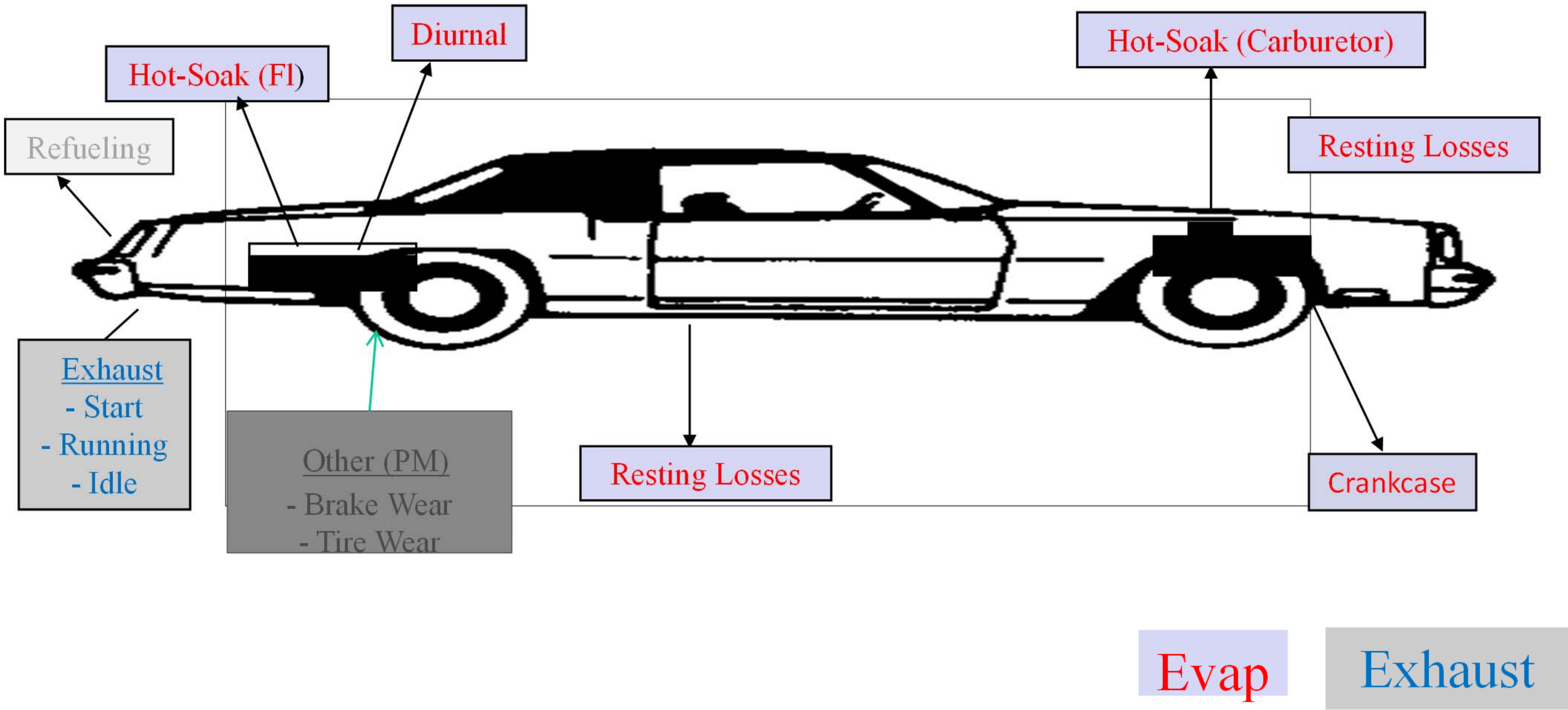
Uses of Model

- Project Specific Vehicle emissions impact
- National Implementation Plan Inventories and Control Strategy Analysis
- Conformity Demonstrations
- National Inventories
- New Regulation Development
- Local/fleet-specific analyses
- Impact on local roadways/intersections
- Setting up of Roadway Network Speed Limits

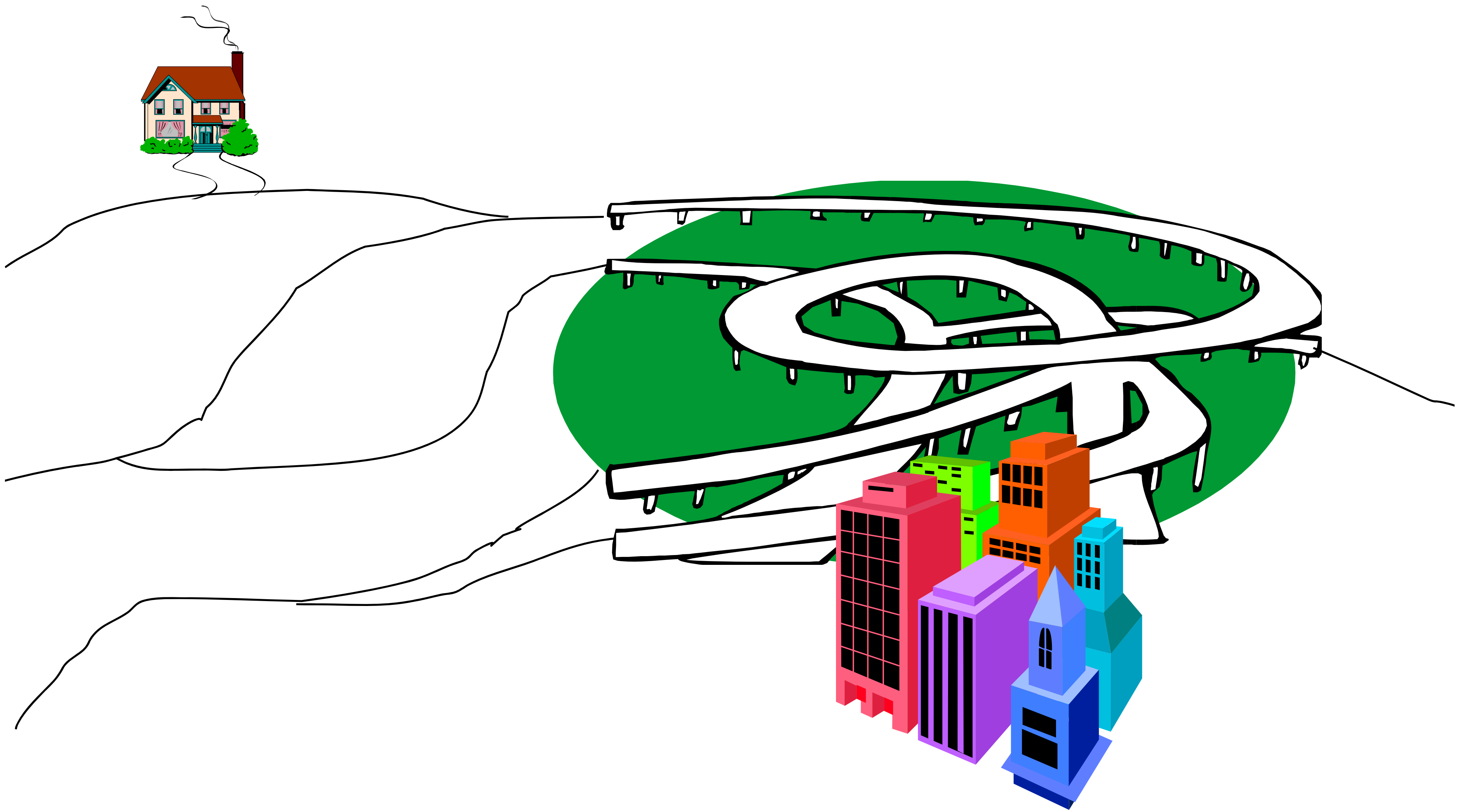
Vehicle Emissions Data Used for Development of Model

- Hong Kong PEMS and activity data
- Vehicles tested in real Hong Kong conditions
- Estimates made for new vehicles and as they age
- Changes in emissions for temperatures, fuel labs, cold start conditions, mileage, etc.
- Vehicles of various technologies tested in as use state
- Developed emission relationships
- Remote Sensing data can be used to characterize (eg. Emission Regime fractions)

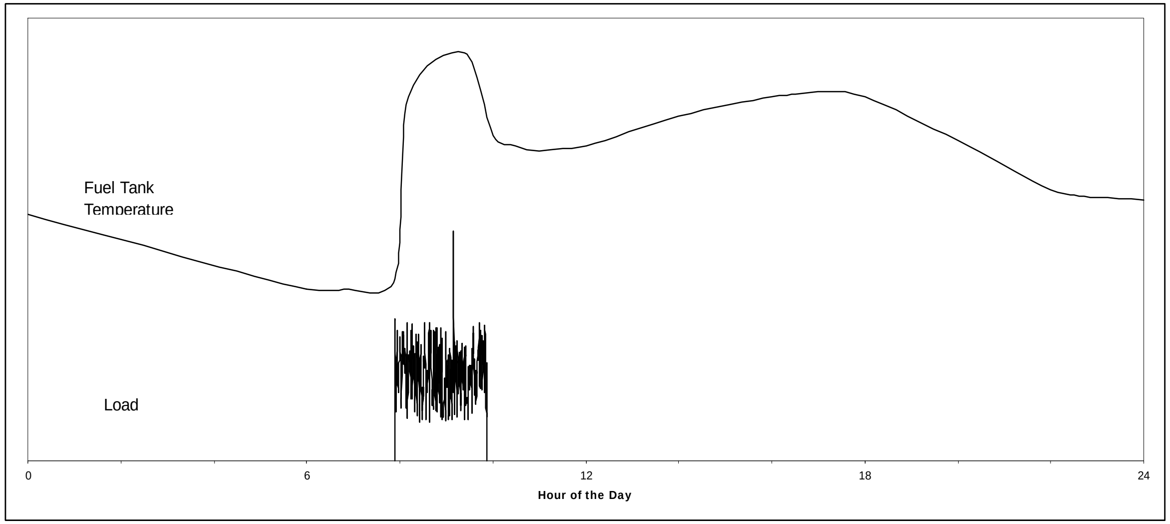
Emissions Processes

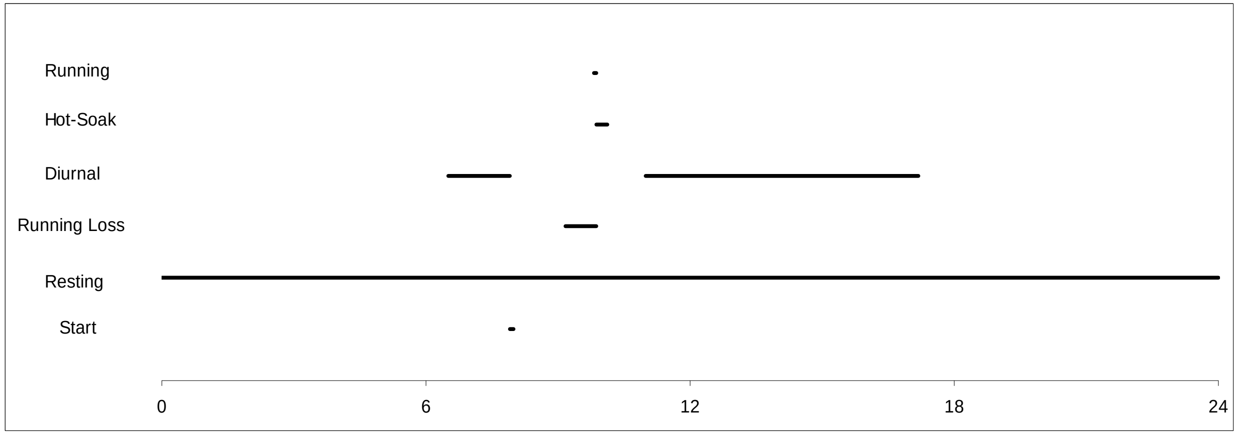


Are you aware of your driving/emissions?



When Do Emissions Occur?





Calculation Methodology

Main Exhaust Calculations

Primary Groups

Technology/Emission Status	Many groups
Emissions Status	Super/ High/Normal
Emissions Type	Start/Running/idle/Evap

2-Step Process

Emissions Calculations; and

Activity Matrices

EMFAC-HK Technology Group Indexes

Exhaust Technology Group Indexes

Examples of TG Revisions.

Motorcycles (MC)

Vehicle Emission Standards	Version 3.09 Beta Technology Group Index
pre-Euro	263
Euro I	266
Euro III	277

Petrol Private Cars (PC)

Vehicle Emission Standards	Version 3.09 Beta Technology Group Index
pre-ULP	1
Unleaded Petrol Vehicles	8
Euro I	10
Euro II	13
Euro III	23
Euro IV	24
Euro V & VI	29

Diesel Private Cars (PC)

Euro	Version 3.09 Beta Technology Group Index
pre-Euro	170
pre-Euro with Traps Retrofitted	171
pre-Euro with DOC Retrofitted	172
Euro I	173
Euro IV	176
Euro V - SCR	175
Euro V – DPF & SCR	174
Euro VI	177

LPG Taxis (TAXI)

Vehicle Emission Standards	Version 3.09 Beta Technology Group Index
Euro III	25
Euro III CAT Replaced	19
Euro IV	22
Euro IV CAT Replaced	20
Euro V & VI	27
Euro V & IV CAT Replaced	21

Diesel Taxis (TAXI)

Vehicle Emission Standards	Version 3.09 Beta Technology Group Index
pre-Euro	70
pre-Euro with Traps Retrofitted	71
pre-Euro with DOC Retrofitted	72
Euro I	73
Euro II	74

- Loop over all SCENARIOS in input file
  - Loop over all CALENDAR YEARS in scenario
    - Loop over all AREAS in scenario
      - Call Area_Average for activity
        - Calculate activity for all GAIs
        - For area-average case, calculate weighted-average activity for area
      - Loop over all VEHICLE CLASSES in scenario
        - Loop over all AGES allowed by scenario and calendar year
          - Age and calendar year specify MODEL YEAR.
          - Loop over EXHAUST TECH GROUPS
            - Calculate exhaust BERs
              - Running, start, and idle basic emission rates
            - Calculate I/M benefit
            - Calculate exhaust correction factors
            - Calculate and accumulate tons [Burden mode]
            - Write tech-group report detail [Burden mode]
          - Loop over EVAP TECH GROUPS
            - For six evap processes...
            - Calculate evap BERs
            - Calculate I/M benefit
            - Calculate evap correction factors
            - Calculate and accumulate tons [Burden mode]
            - Write tech-group report detail [Burden mode]
          - Write model year and speed report detail [Burden mode]
          - Calculate and accumulate grams [Emfac mode]
        - Write vehicle class and speed report detail [Burden mode]
        - Write vehicle class report [Emfac mode]
      - Write area and speed report detail [Burden mode]
      - Write area-based report(s) [Burden mode]
      - Write area-based report(s) [Emfac mode]

Exhaust Calculations

- For Each Calendar Year and Vehicle Type
  – Calculate emissions (each Pollutant) for each Age- three primary steps
    - Estimate Exhaust emissions
    - Estimate impact of Inspection program
    - Use correction factors to model local situation
  – Combine emissions for all Ages

Exhaust Calculations

Exhaust subroutine

- Each Age is associated with a particular Model year
- In each model year there are few technology groups assigned (TF_EX_Assign)
- For each technology groups
  - Estimate emitter category Regime Fraction
  - Estimate emitter category Regime Emissions

Emitter Category-
Regime Fractions

- For each Age and Vehicle type the odometer is assigned
- Regime Size Calculated for Super, High, and Normal Emitters
- Regime Size is calculated as (data in Reg_Size):

$$\text{RegSize} = f(\text{Odometer})$$

Regime growth rates developed based on local data

Exhaust Calculations
Emitter Category Emissions

- For Each Myr, Age, Tech group :

$$E_{emit\_cat} = E_{zero} + Det\_rate * Odo$$

$$E_{emit\_cat} = f\,(\text{poll, mode, tech group})$$

Data included in BER_Data

Data developed from Hong Kong PEMS testing

Vehicles Used for Updating the EMFAC-HK Model

Vehicle Class	Fuel Type	Emission Standard							Total
		Pre-Euro	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI	
Cars	Petrol			3	10	18	3		34
Taxis	LPG				17	5	1		23
Public light buses	LPG				6	4			10
	Diesel			1	2	1			4
Private light buses	Diesel		1	1	3	1			6
Light goods vehicles <= 5.5t	Diesel	5	4	11	22	16	6	1	64
Heavy goods vehicles > 5.5t	Diesel	4	1	4	18	10	6	1	44
Single Deck Coaches	Diesel			2	9	18	10		39
Franchised Buses (w DPF)	Diesel			4	2		6	6	18
Total		9	6	26	89	73	32	7	242

Euro III & IV Diesel Vehicles
Used for Updating the EMFAC-HK Model

Vehicle Class	Euro III					Euro IV				
	Nil	DOC	DOC & EGR	DPF	EGR	DOC & EGR	POC & DOC, EGR	DPF & EGR	SCR	SCR & DOC/ EGR
Public light buses		2						1		
Private light buses		1	2					1		
Light goods vehicles <=5.5 t		5	17			7	4	5		
Heavy goods vehicles > 5.5t	5	5	6		2	4	2	2		2
Single Deck Coaches	2		6		1	2		4	10	2
Franchised Buses				2						
Total	7	13	31	2	3	13	6	13	10	4

Euro V & VI Diesel Vehicles
Used for Updating the EMFAC-HK Model

Vehicle Class	**Euro V**					**Euro VI**	
	DOC & EGR	**EGR**	**DPF & EGR**	**DPF, EGR & SCR**	**SCR**	**DOC, DPF & SCR**	**DPF, EGR & SCR**
Public light buses							
Private light buses							
Light goods vehicles <=5.5 t			**4**	**2**			
Heavy goods vehicles > 5.5t	**1**		**4**	**1**		**1**	
Single Deck Coaches		**1**	**6**		**3**		
Franchised Buses					**6**		**6**
Total	**1**	**1**	**14**	**3**	**3**	**1**	**6**

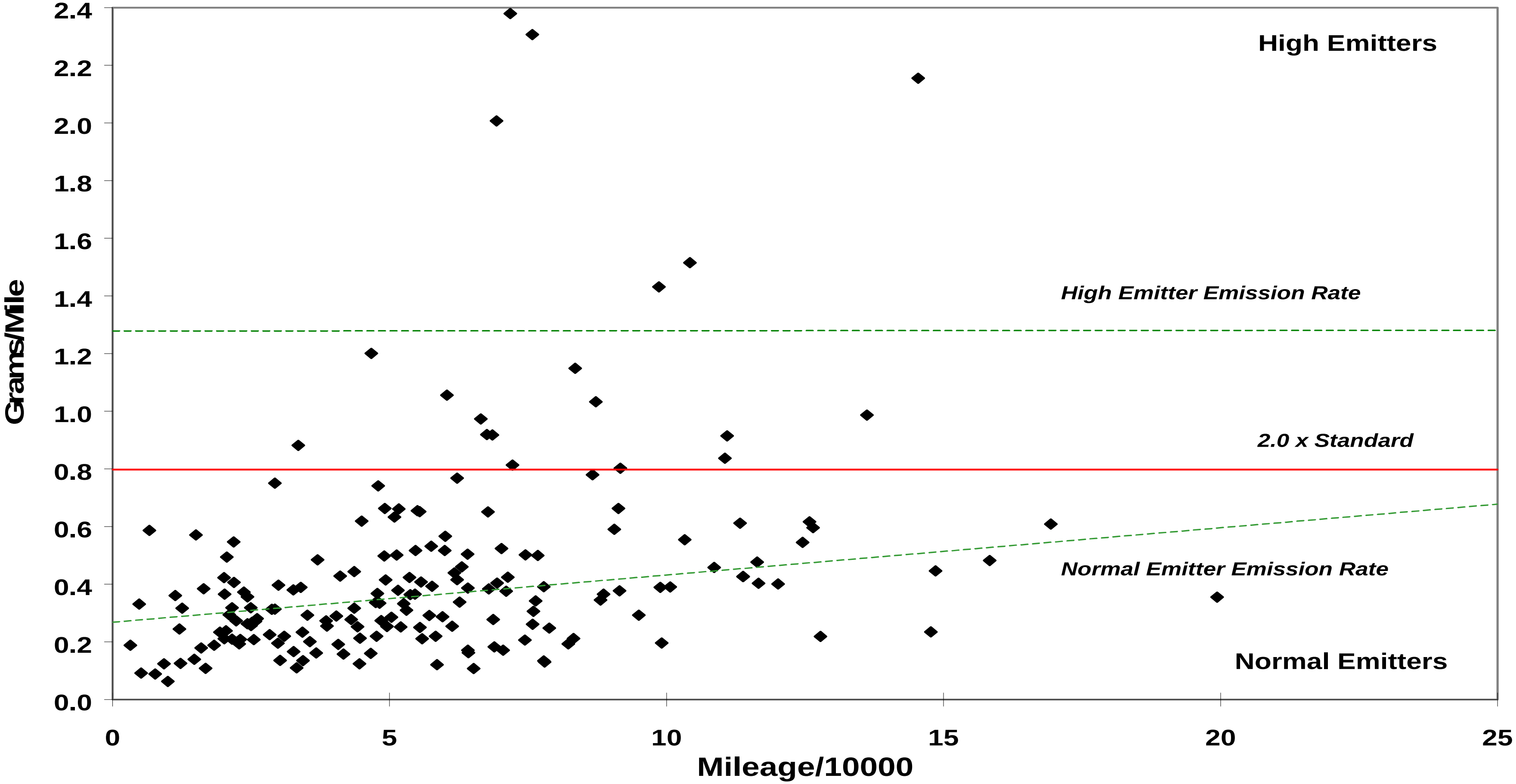
Zero Mile Emission Factors (ZMEF) and (Deterioration Rates (DR)

- Calculated emission factors (EF) at 1-minute, 8-minute and 1-hour averages of PEMS data of each vehicle;

- For each Tech Group, estimated the ZMEF and DR by median of EFs of vehicles at average speed between 25 km/hr and 35 km/hr.

- For Speed Correction Factors, conducted statistical analysis on the ratios of median emission factors (in g/km) for all 8-km/hr average speed bins over basic emission rates obtained from ZMEF & DR by linear regression model.

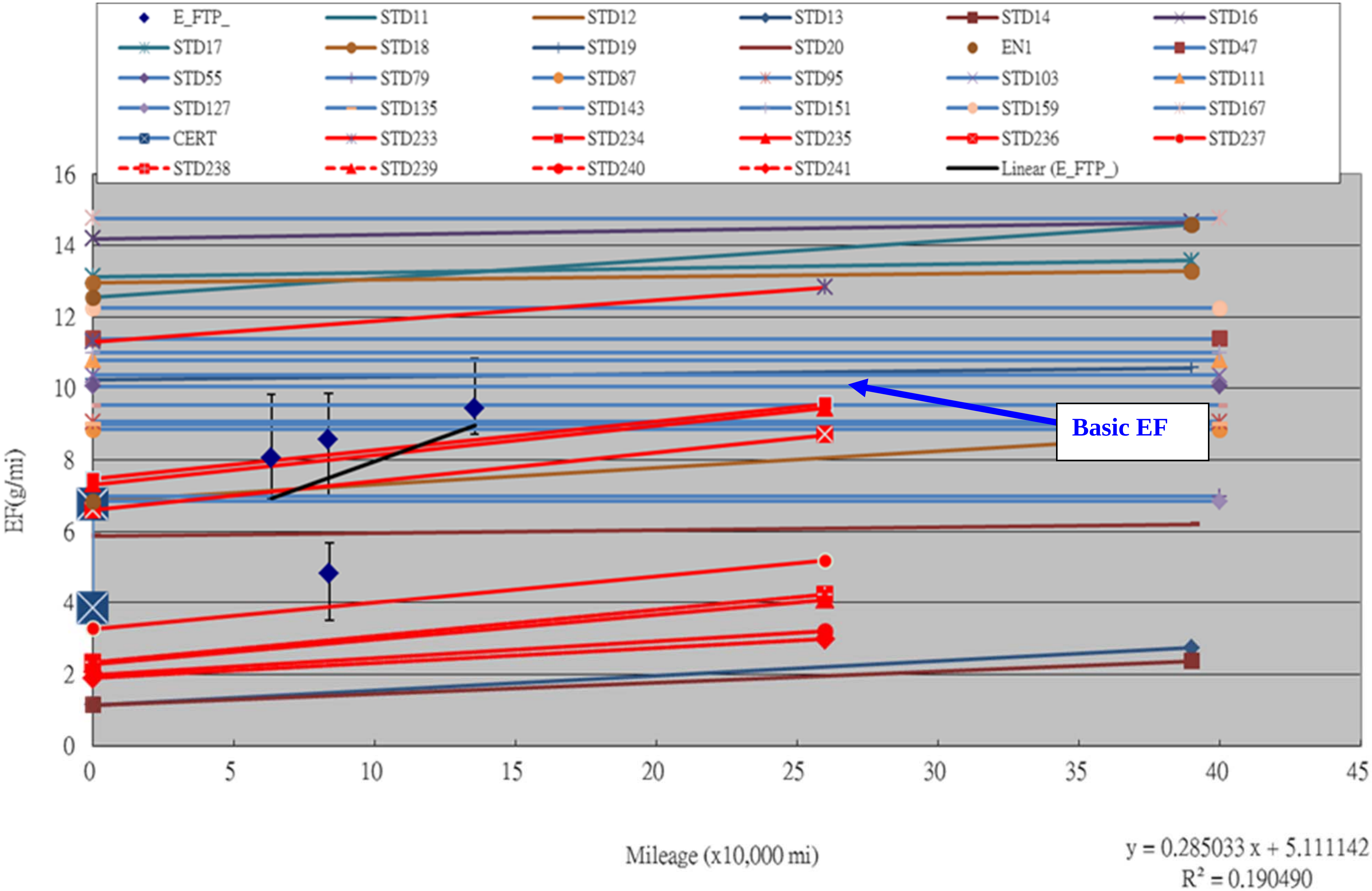
No_x -for particular technology



Source: California Air Resources Board

NOx emission factors for Euro IV SCR Heavy Goods Vehicles > 15t and Non-Franchised Bus > 15t

EMFAC2014 Diesel HHDT 2008 for these vehicle classes is used.



Exhaust Emissions

Tech Group/ Model Year Emissions
For Each Pollutant – Before I/M

$$E_{tech\_group} = E_{super} * RegSize_{super} + E_{high} * RegSize_{high} + E_{normal} * RegSize_{normal}$$

$$E_{model\_year} = \sum E_{tech\_group}(my, tg) * Tech\_Frac\ (my)$$

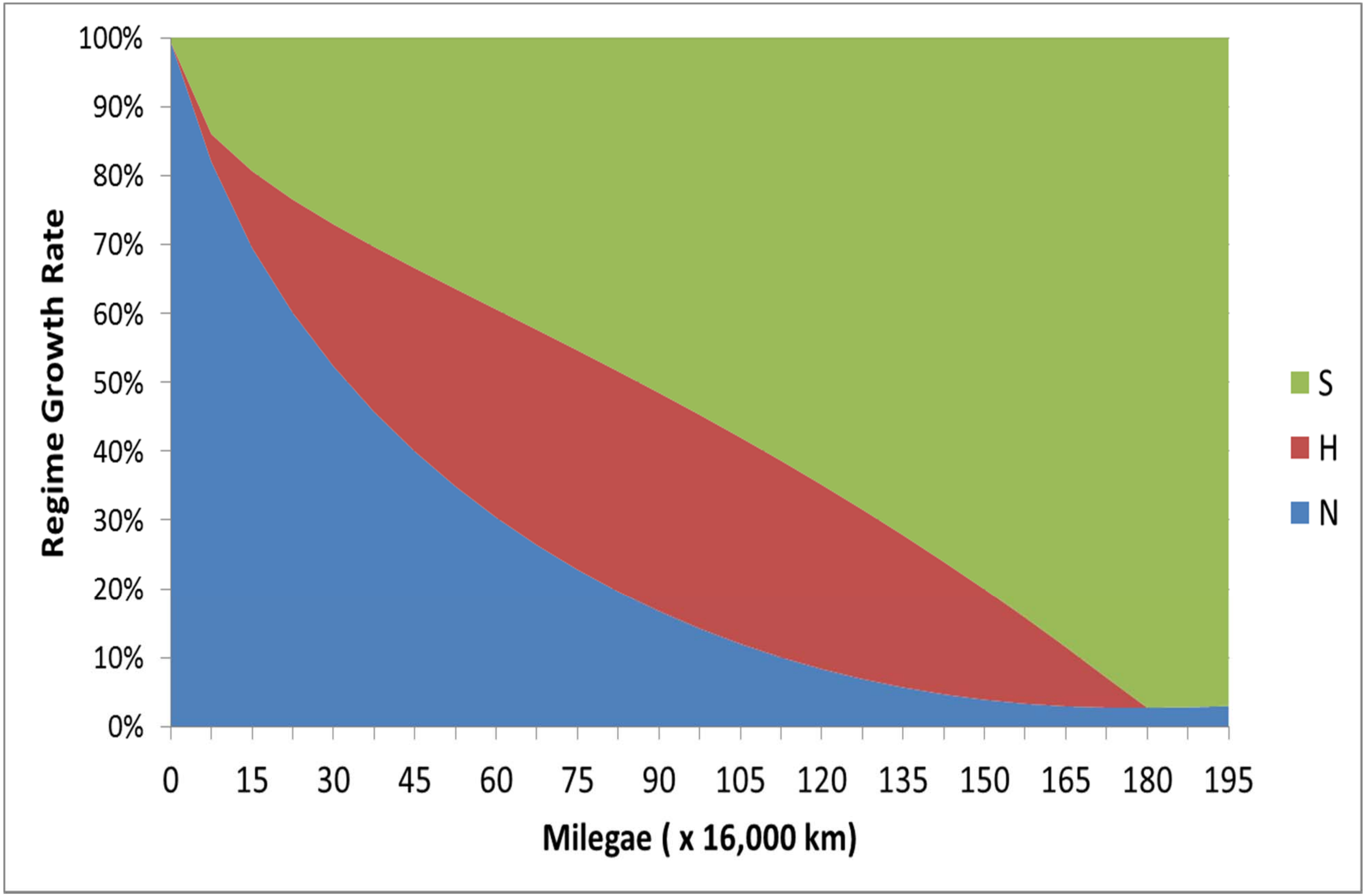
Gross Emitter Model for Diesel Vehicles in Hong Kong

Diesel vehicles were subdivided into 2 regimes:

- normal & super

The percentages of super emitters are estimated from annual smoky vehicle numbers

LPG Taxi Regime Growth Rates



Exhaust Emissions
Calculation of Calendar Emission Rates

$$E_{cal\_year} = \sum E_{model\_year}(my) * \text{travel fraction (age)}$$

Where,

$$\text{Travel fraction} = \text{reg fraction (age)} * \text{annual miles (age)} / \sum \text{reg fraction} * \text{annual miles}$$

LDGV Model Year Specific Emission Rates for Calendar Year 2005							
						Model Year Emission Rates (g/mi)	
Model Year	Age	REG_dist	Annual MILES	REG*MILES	Travel Fraction	VOC	NOx
2005	0	0.053	40.853	2.169	0.0803	0.156	0.105
2004	1	0.071	39.341	2.781	0.1030	0.177	0.207
2003	2	0.071	37.400	2.644	0.0979	0.215	0.327
2002	3	0.071	35.555	2.510	0.0929	0.276	0.475
2001	4	0.070	33.801	2.380	0.0881	0.333	0.618
2000	5	0.070	32.133	2.246	0.0831	0.575	0.833
1999	6	0.069	30.548	2.108	0.0780	0.677	0.934
1998	7	0.068	29.041	1.966	0.0728	0.859	1.031
1997	8	0.066	27.608	1.811	0.0670	1.198	1.118
1996	9	0.063	26.246	1.648	0.0610	1.504	1.205
1995	10	0.059	24.950	1.470	0.0544	2.213	1.374
1994	11	0.054	23.720	1.281	0.0474	2.650	1.638
1993	12	0.046	22.549	1.035	0.0383	3.126	1.925
1992	13	0.036	21.436	0.778	0.0288	3.595	2.007
1991	14	0.029	20.378	0.587	0.0217	4.062	2.109
1990	15	0.023	19.373	0.442	0.0164	4.604	2.191
1989	16	0.018	18.418	0.333	0.0123	5.153	2.263
1988	17	0.014	17.509	0.252	0.0093	5.588	2.366
1987	18	0.011	16.645	0.190	0.0070	6.675	2.690
1986	19	0.009	15.824	0.142	0.0053	7.172	2.739
1985	20	0.007	15.043	0.107	0.0040	8.373	3.001
1984	21	0.006	14.300	0.080	0.0030	8.873	3.080
1983	22	0.004	13.595	0.060	0.0022	9.396	3.147
1982	23	0.003	12.923	0.044	0.0016	10.219	3.242
1981	24	0.010	12.287	0.118	0.0044	10.606	3.293
				Calendar Emission Rate:		1.419	1.022

Exhaust I/M calculations

- I/M only causes the regime size fractions to change
- Apply % Reduction to change in Super and High emitters
- Emissions changes are caused as vehicles go from super and high emitting regimes to normal emitting regime

Vehicle Mileage Surveys

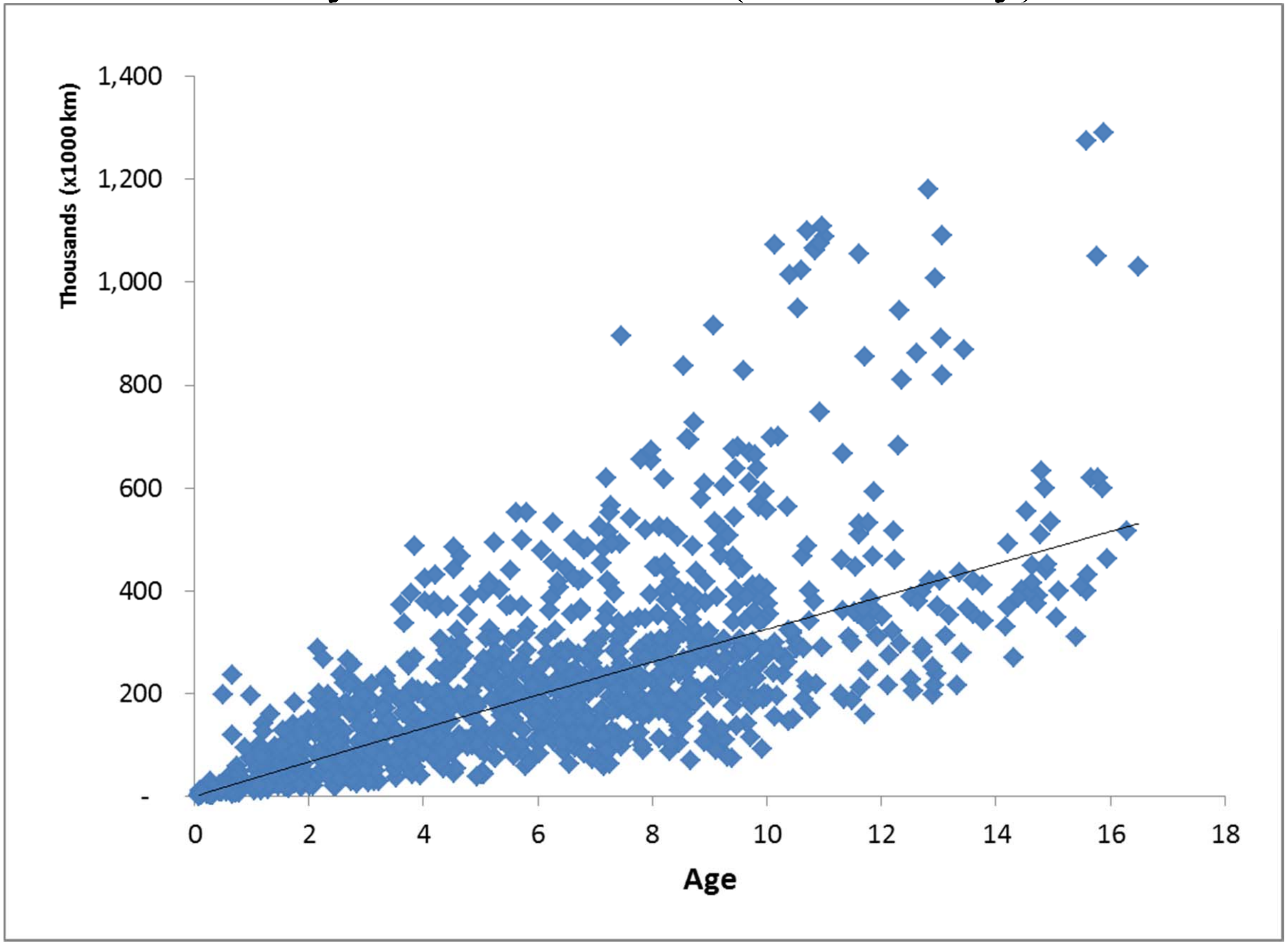
The sources included:

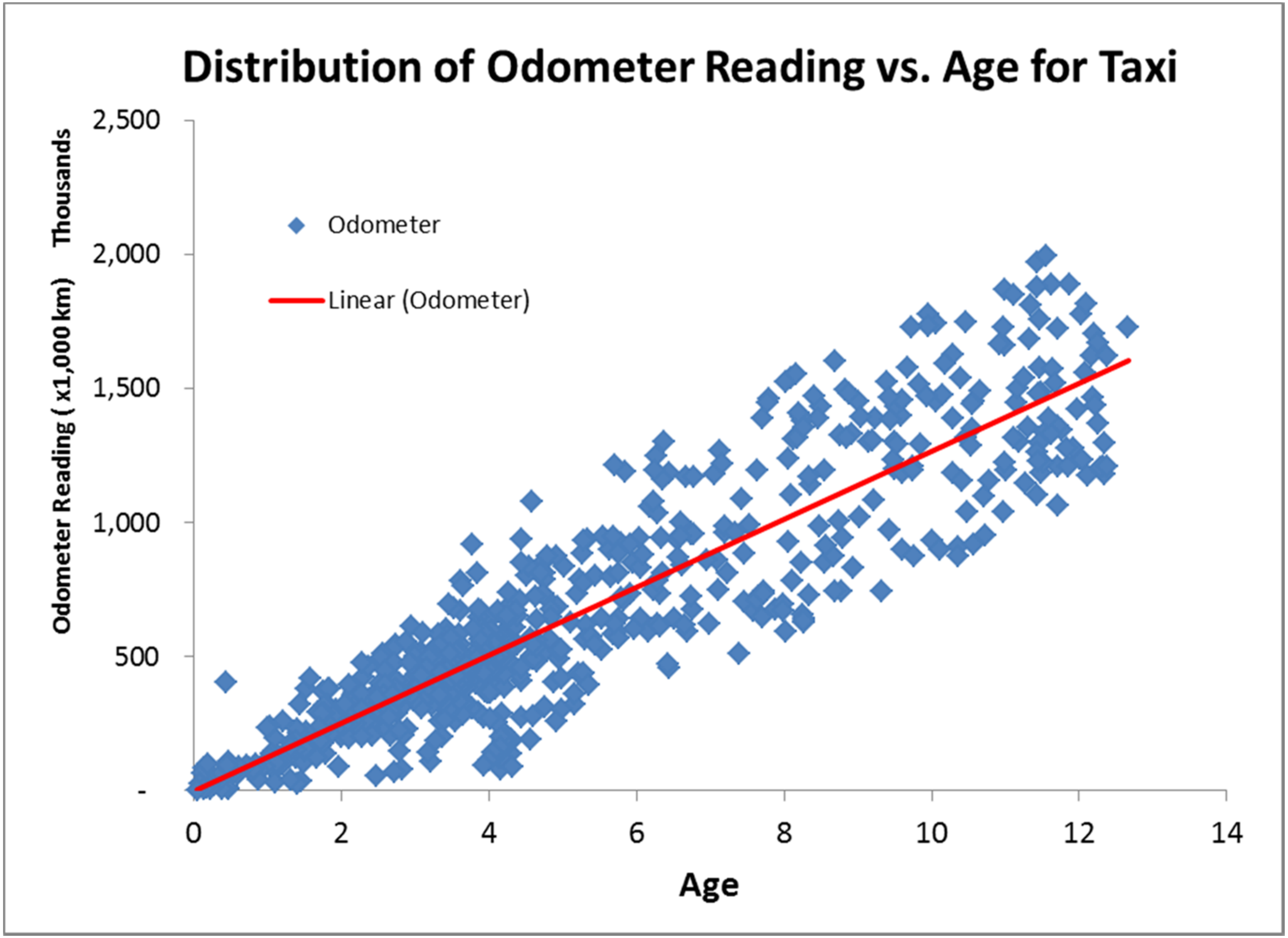
- Surveys conducted at petrol filling stations, car parks, and vehicle examination centres.
- Data provided by franchised bus companies.

Analysis:

- Screen out those with too low mileage for certain age for commercial vehicles.
- Estimates the relationship between accrual rates and age using PROC REG or PROC NLIN in SAS for the variation of vehicle mileage and age.

Distribution of Odometer Reading vs. Age for Medium and Heavy Goods Vehicles (2011 Survey)





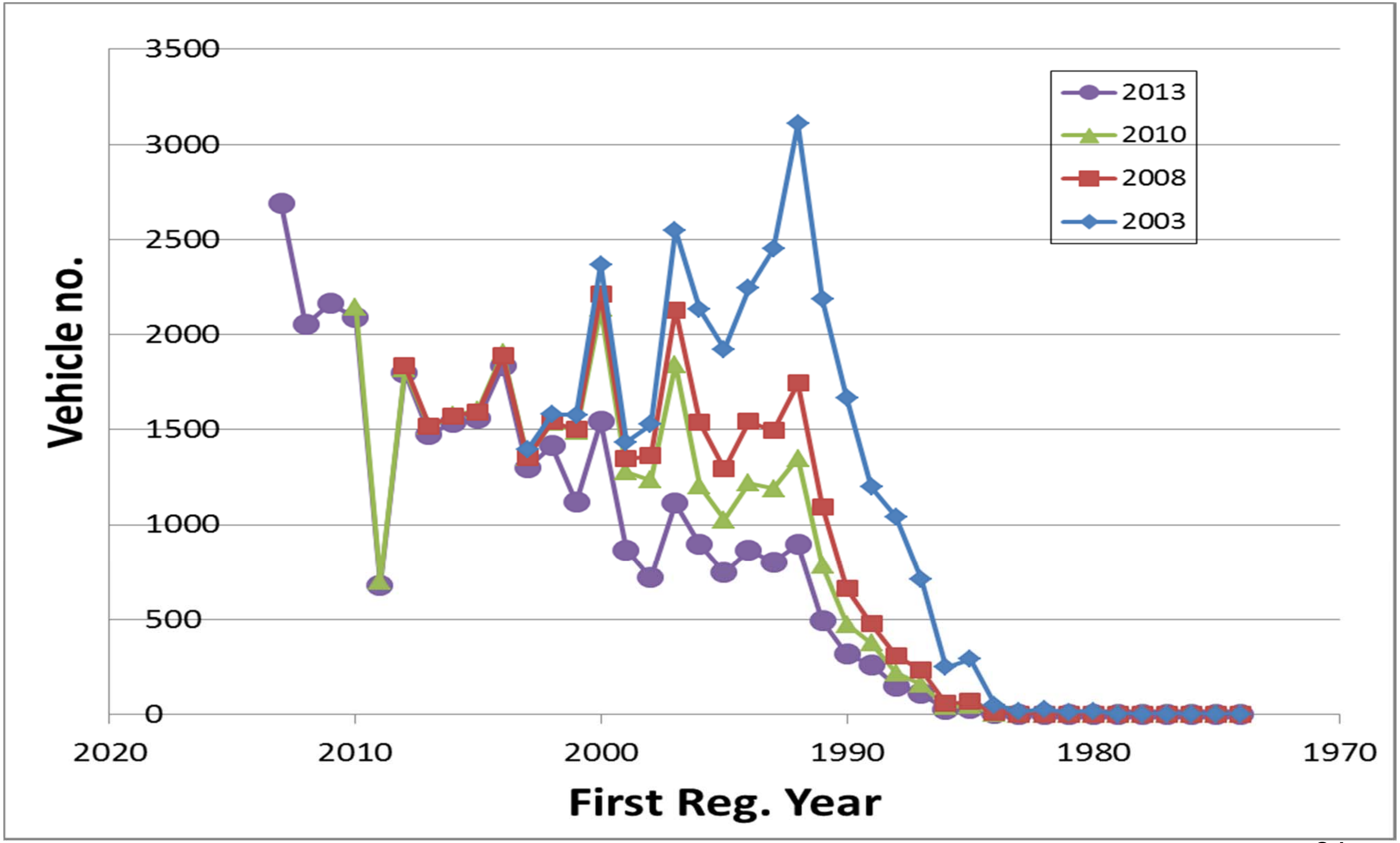
Distribution of Odometer Reading vs. Age for Taxi
Thousands
Odometer Reading (x1,000 km)
2,500
2,000
1,500
1,000
500
-
Odometer
Linear (Odometer)
0
2
4
6
8
10
12
14
Age

Forecast of Vehicle Population

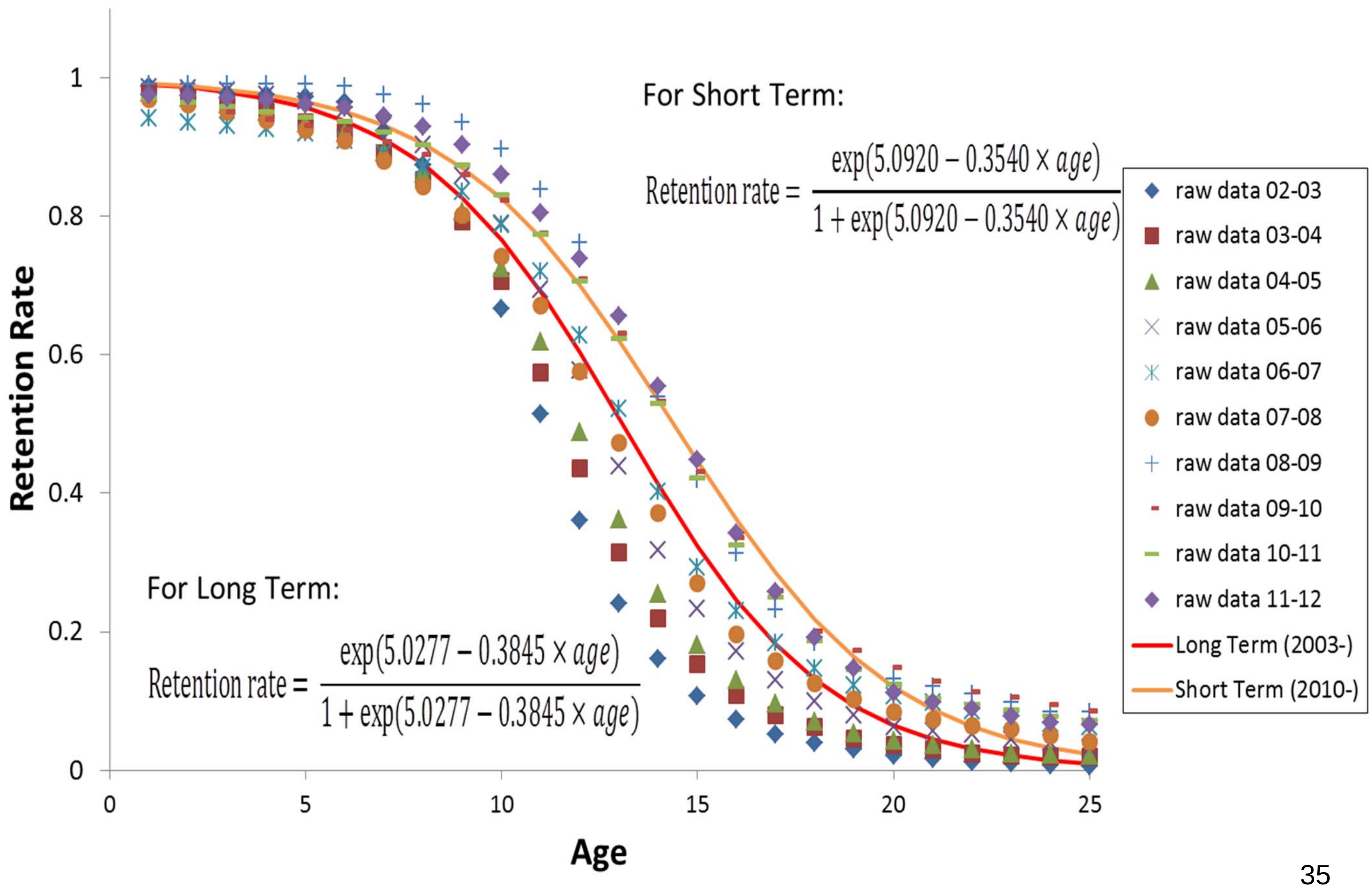
- EMFAC uses the population of a specific model of vehicles for consecutive calendar years to derive a variation curve of the percentage of vehicles sold still remain in the fleet after a specified amount of time has elapsed – retention rate. The curve is then used to forecast vehicle population.

- Retention rates is used in EMFAC for both forecasting to future calendar years and back-casting for those years where vehicle registration information is unavailable.

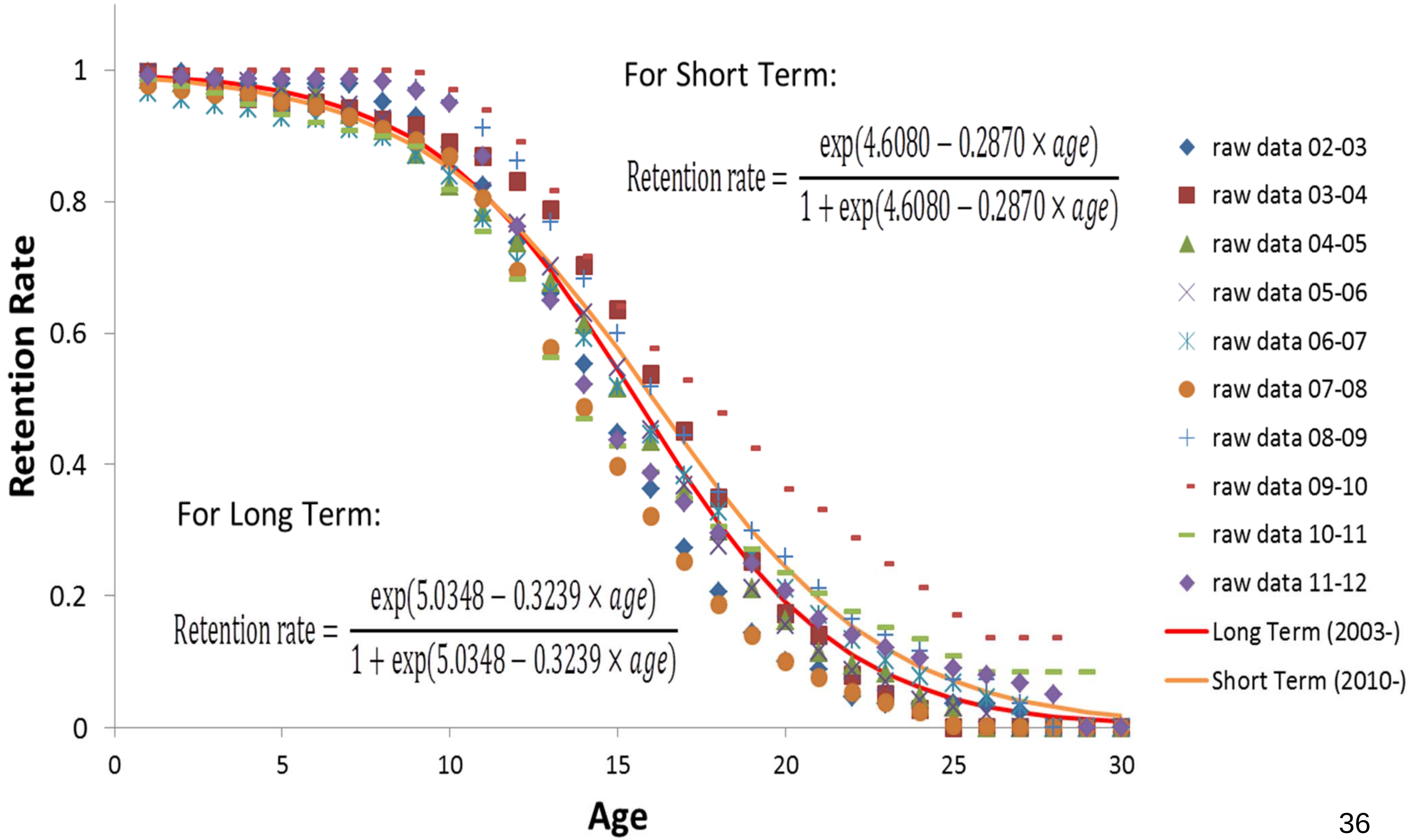
Distribution of Goods Vehicles > 15 t Population vs. 1st Reg. Year



Retention Rates for Private Cars



Retention Rates for Heavy-duty Goods Vehicles



EMFAC-HK Population Growth Rates from TD

EMFAC-HK V2.6

Year	Private Vehicles (private cars and motor cycles)	Goods Vehicles
	Average annual growth rates (up to the Year)	
2011	2.5%	0.0%
2016	2.0%	0.5%
2021	1.5%	0.5%
2026	1.5%	0.5%
2031	1.5%	0.5%

EMFAC-HK V3.1

Year	Private Vehicles (private cars and motor cycles)	Goods Vehicles
	Average annual growth rates (up to the Year)	
2011	2.5%	0.0%
2015	3.5%#	0.5%
2016	4.0%#	0.5%
2021	3.0%	0.5%
2026	3.0%	0.5%
2031	3.0%	0.5%

#Note that TD's rates are given as 3% and 5% for mid-2015 to mid-2016 and mid-2016 to mid-2017. EMFAC-HK's growth rates work by year-end to year-end.

Exhaust Correction Factors

- Calculate each of the correction factors
- Call ExhCF_Altitude()
- Call ExhCF_Load()
- Call ExhCF_Speed()
- Call ExhCF_Temperature()
- Call ExhCF_NOx()
- Call ExhCF_AC()
- Call ExhCF_Fuel()
- Call ExhCF_HighIdle()
- ! Combine them into AllCF

- Call ExhCF_Finalize()

Speed and Grade Correction Factor

Speed correction Factors are calculated on the emission by speed bin

For each speed bin by area (time spent in each spped bin 2.5-87.5 by

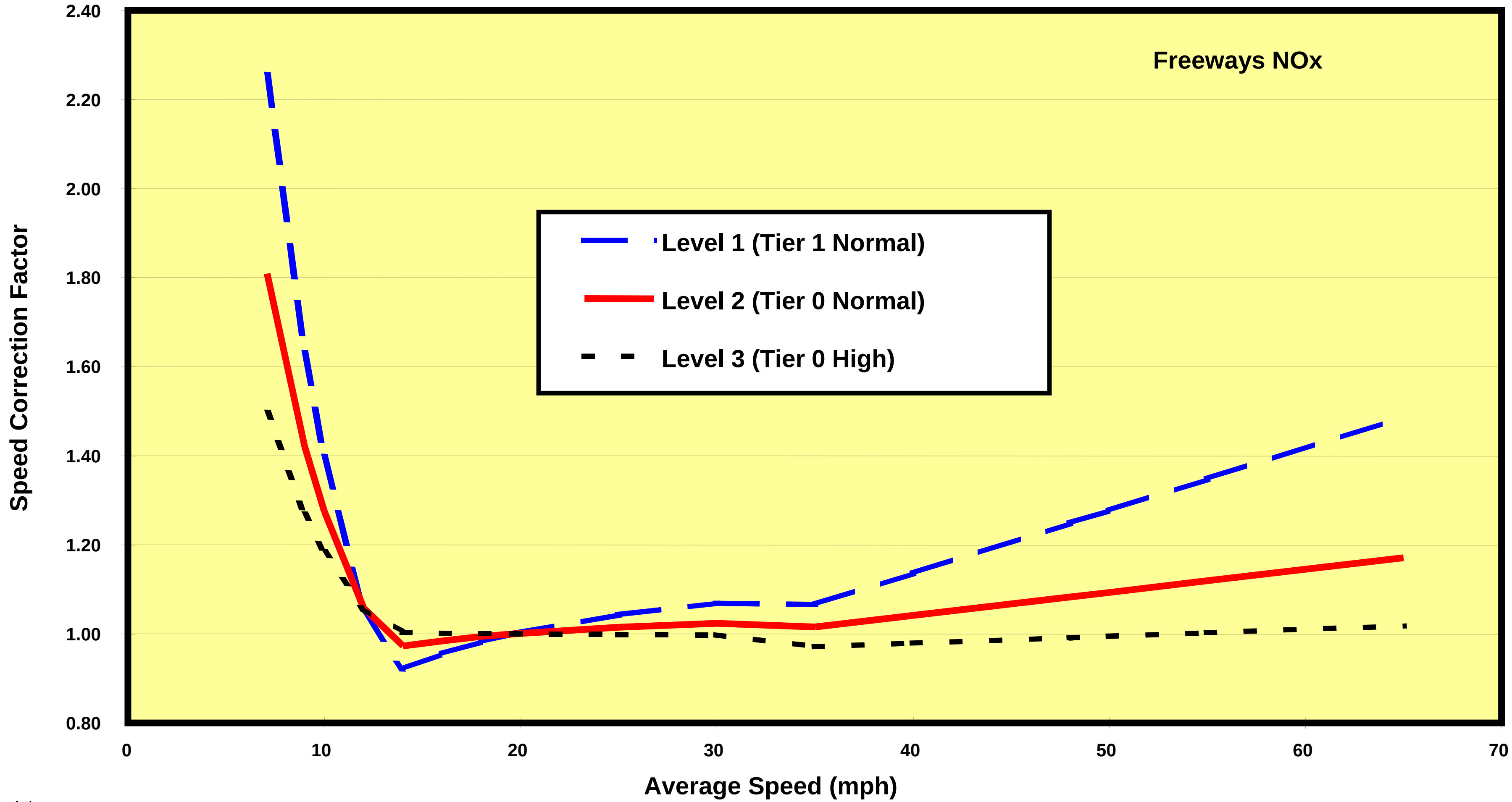
```
SCFactor = 0.0
         + SCF%Coefs(1) * (Speed - SAdj)
         + SCF%Coefs(2) * (Speed - SAdj)**2
         + SCF%Coefs(3) * (Speed - SAdj)**3
         + SCF%Coefs(4) * (Speed - SAdj)**4
```

AvgSCF = Time spent in each bin by area* SCFactors

Calculation of Speed Correction Factors

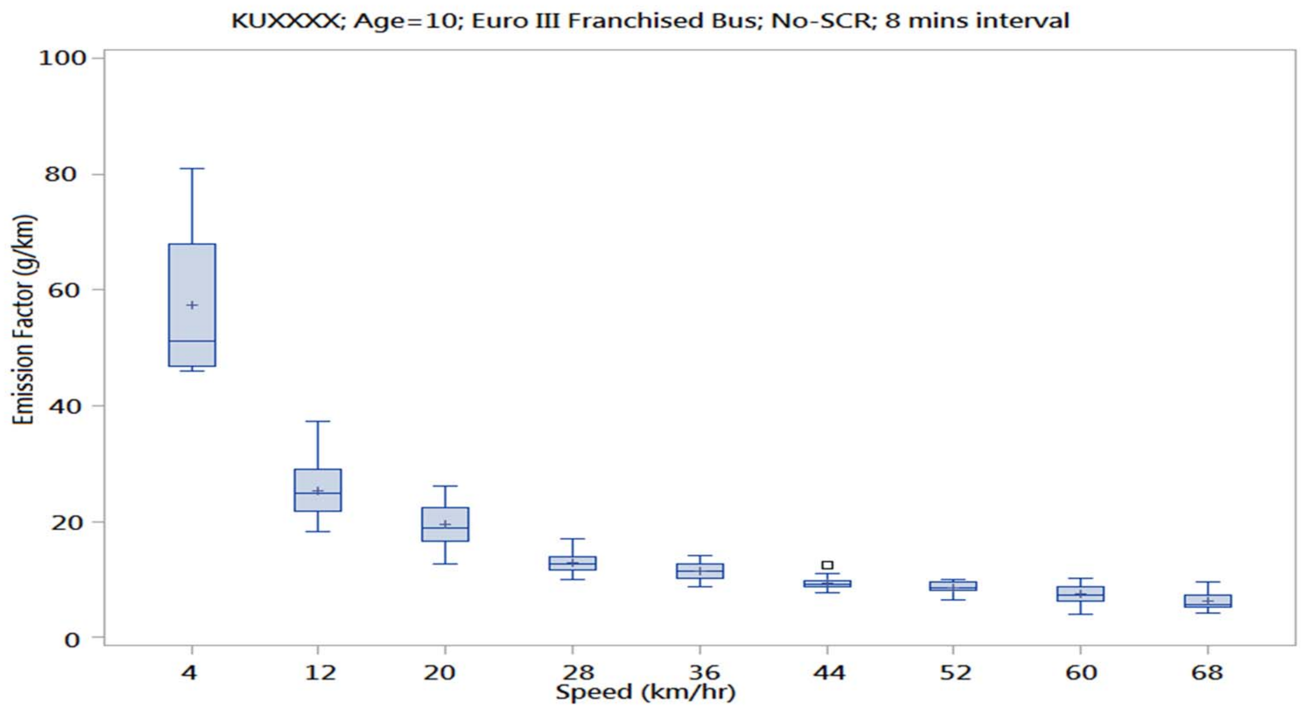
$$SCF_{speed} = \frac{Emissions_{speed}}{Emission_{ref\ mph}}$$

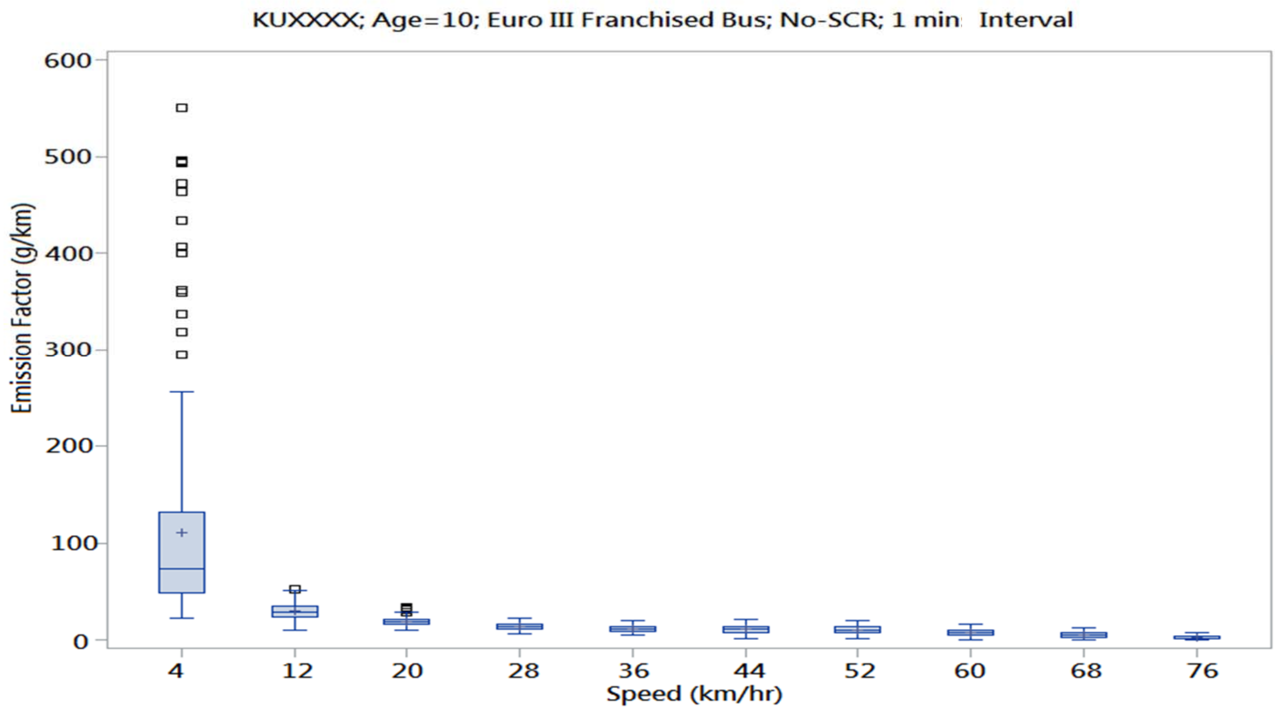
Example Speed Correction Factors



U.S. EPA Example

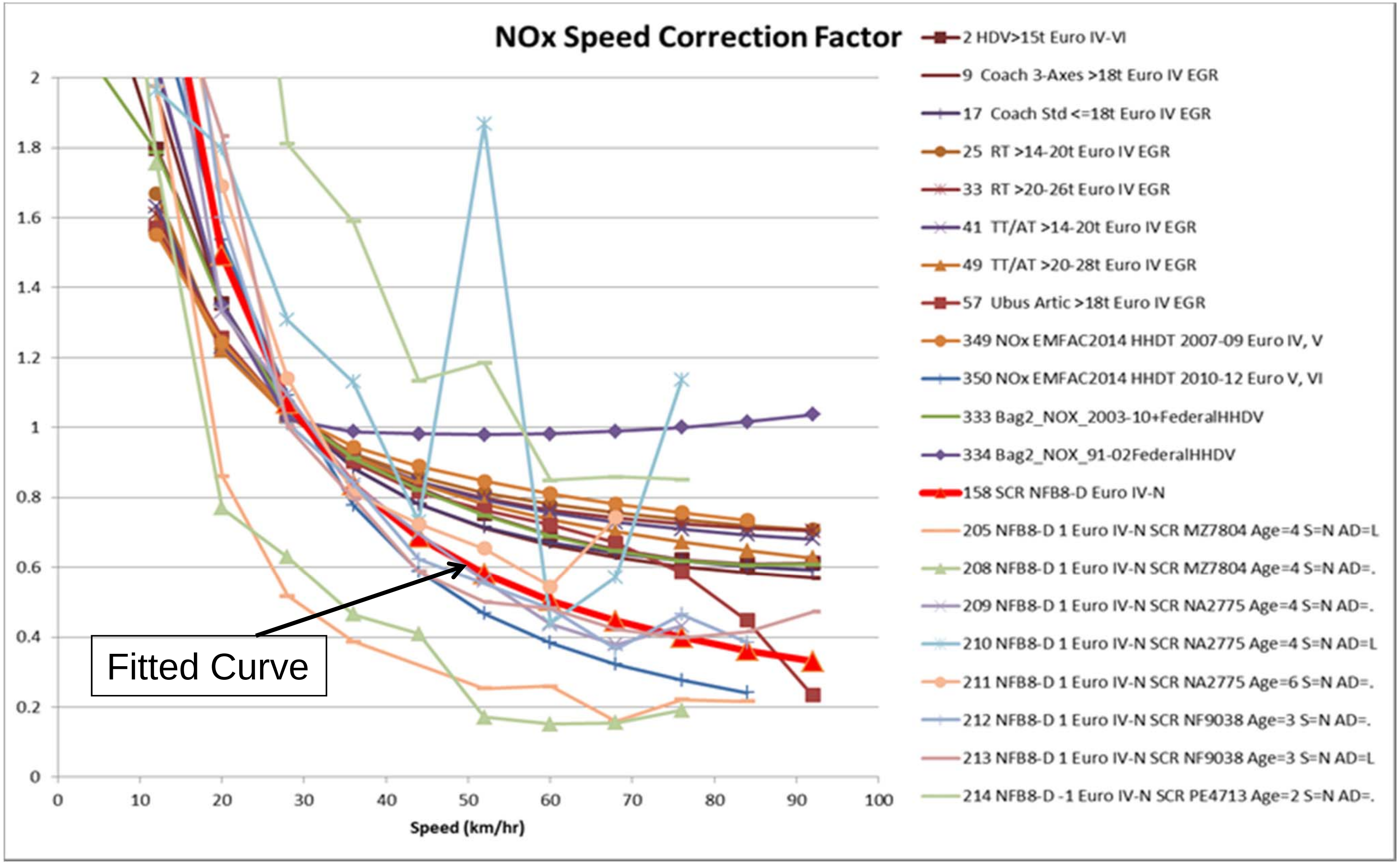
A Euro III Franchised Bus: 8-minute average NOx emission factors





The same Euro III Franchised Bus: 1-minute average NOx emission factors

NOx Speed Correction Factor: Euro IV Heavy Goods Vehicles and Non-Franchised Bus >15t with SCR

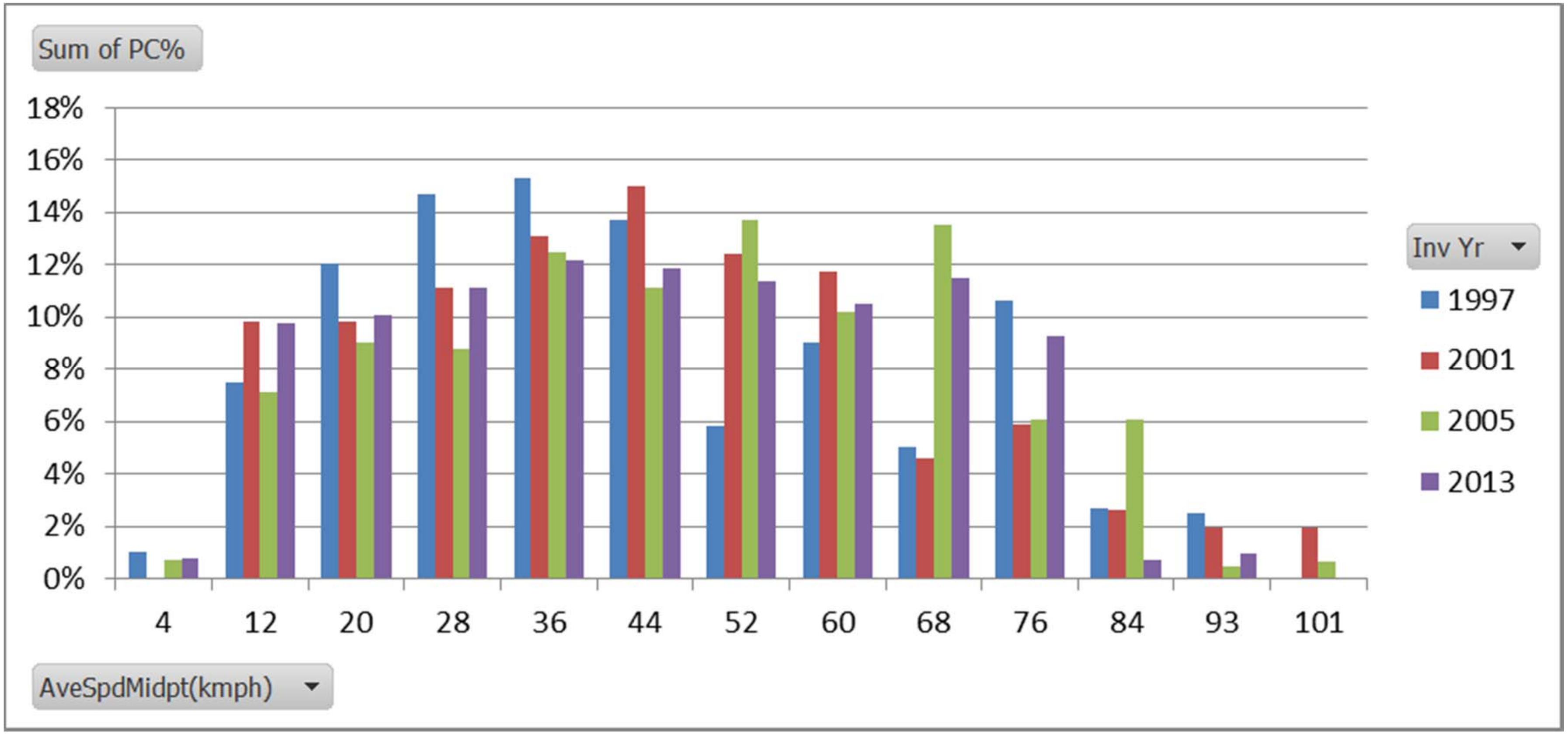


Speed Fractions

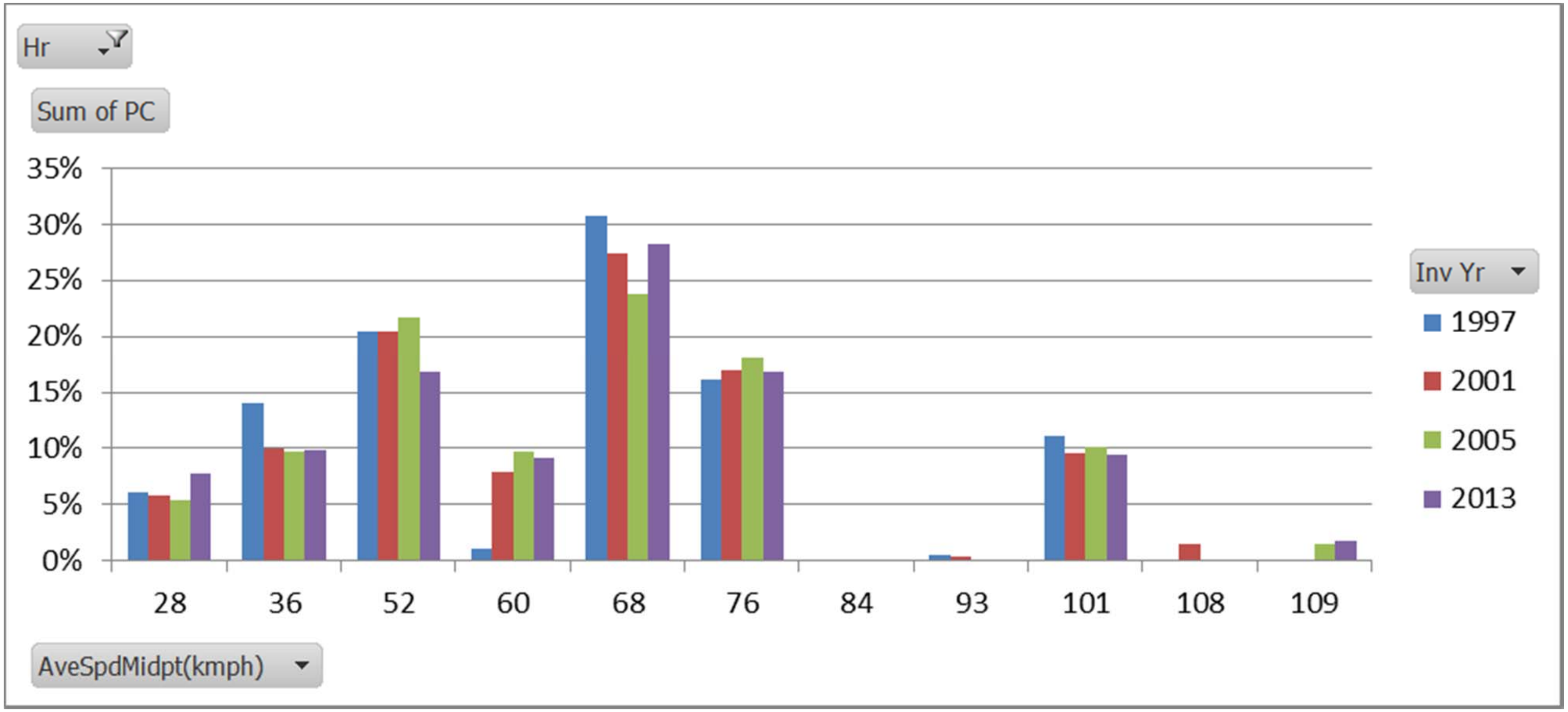
Data Sources:

- Congested speeds at 0800-0930 (TD)
- Speed limits (Highway Department)
- Speed vs. volume / capacity ratio from Travel Demand Model Study in Hong Kong (TD)

Speed Fractions for Private Cars at Peak Hours



Speed Fractions for Petrol Cars at Daytime non-peak Hours

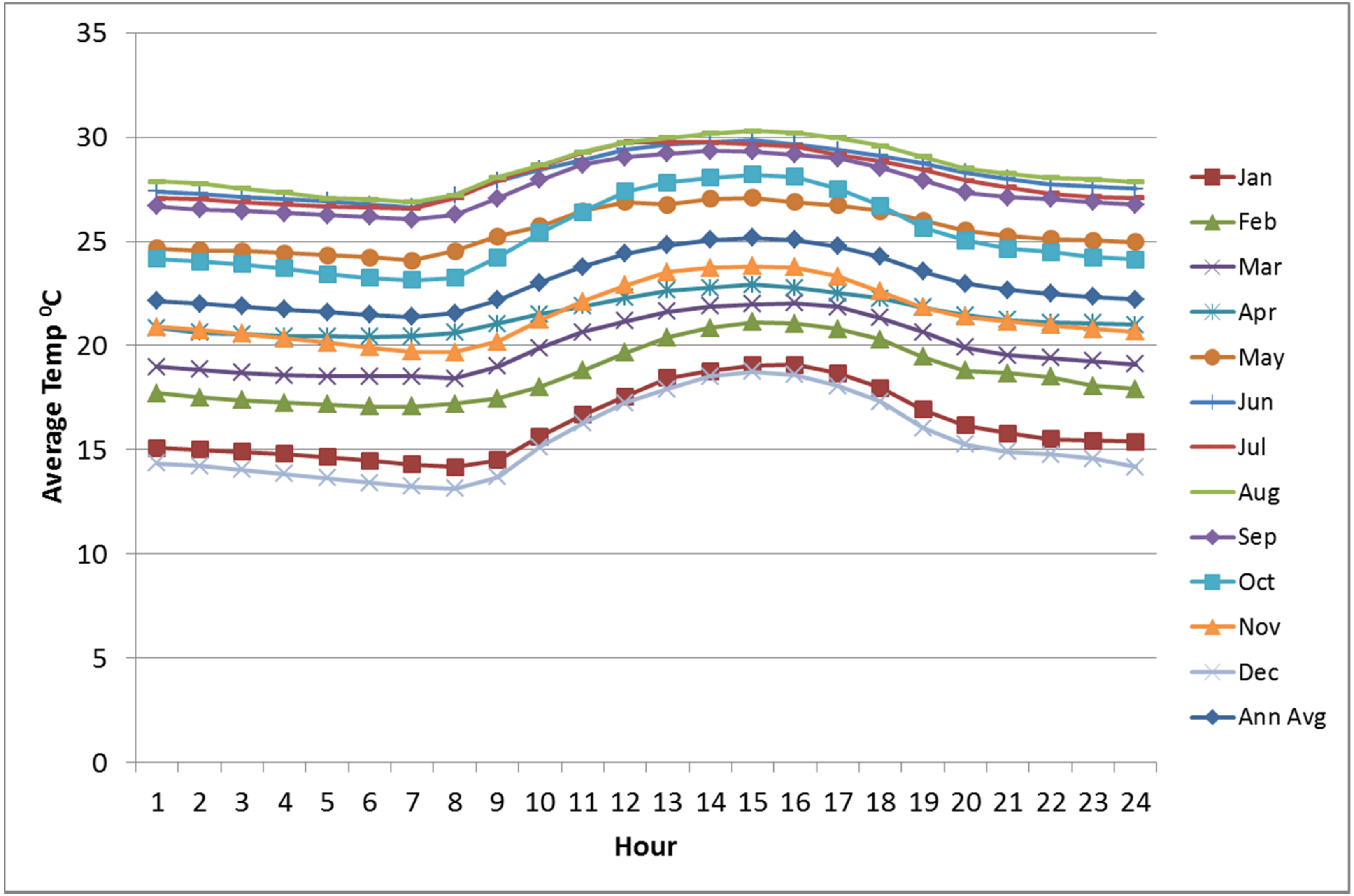


Temperature Correction Factor

- Temperature correction based on the temperature for area and hour
- Coefficients A, B ,C are for Pollutant, driving mode, and tech group
- Form for equation cat vehicles is :

TCF = 1 + A * (TEMP-75) + B * (TEMP-75)**2 + C * (TEMP-75)***3

Monthly Average Temperature by Hour in 2013



Humidity for Nox

The basic form of the correction factor is as follows:

```
                 (1 + (M_MANOS * (Ht - Hs)) ) * (1 + (M_CLASS * (H - Hs)) )
RHUM_CF = -------------------------------------------------------------
                  1 + M_CLASS * (Ht - Hs)
```

where:

RHUM_CF = humidity correction factor (ratio)

M_MANOS = -0.0047, a constant derived by Manos et al (1972) in "Effect of Laboratory Conditions on Exhaust Emissions“

Ht = tech group specific base humidity (grains/lb) (different for Light and Heavy vehicles, stored in RHCFData.for)

Hs = 75 grains/lb, standard humidity

M_CLASS = tech group specific humidity correction factor constant (different for DSL and Petrol, stored in RHCFData.for)

H = scenario humidity to which correction is to be performed (grains/lb)

Absolute Humidity

H = RH * (A + B * T + C * T**2 + D * T**3)

where:

H = scenario humidity (grains/lb)

T = scenario temperature (deg F)

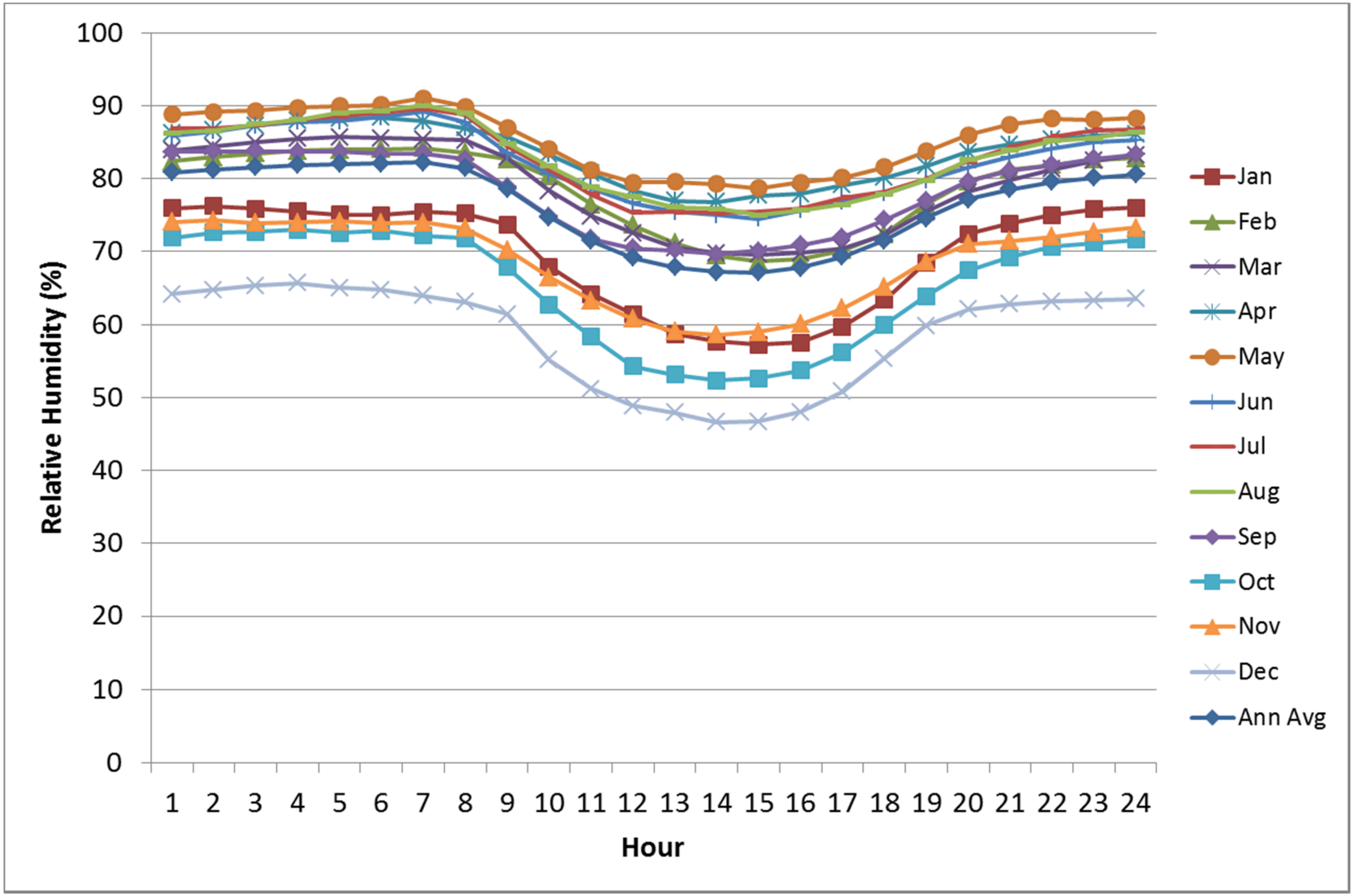
A = -0.09132

B = 0.01594

C = -0.00029

D = 4.37E-06

Monthly Average Relative Humidity by Hour in 2013



AC Correction

BERadj = (ACon) * (m * BER + C) + (1 - ACon) * BER

where:

BERadj = base emission rate adjusted for A/C usage

ACon = air conditioning activity factor

m = slope of regression equation

BER = base emission rate

C = constant from regression equation

AC On Fraction

ACon = ACfrac * ACfunc * COMPon

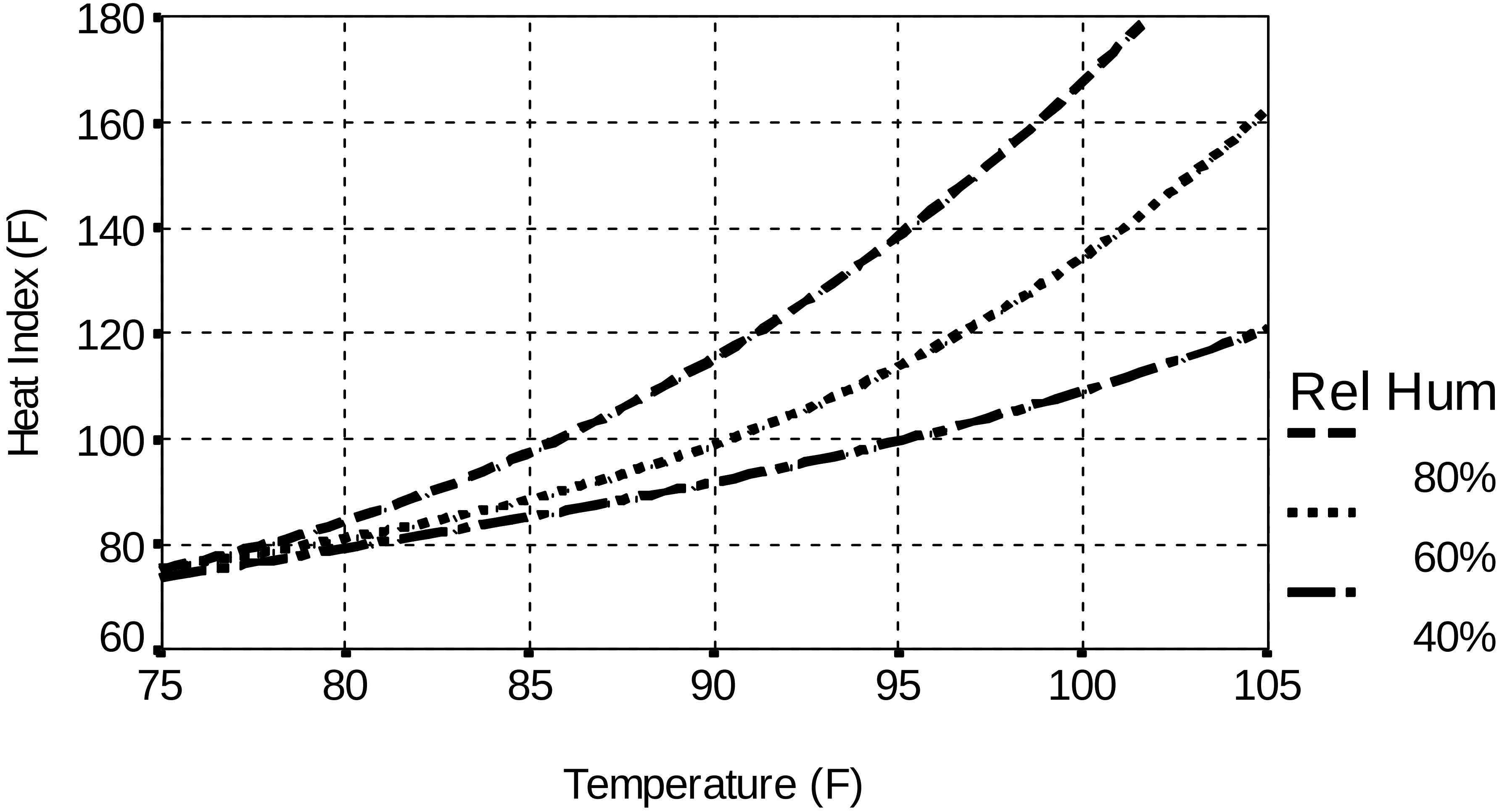
where:

ACfrac = Fraction of vehicles equipped with A/C units

ACfunc = Fraction of A/C units functional

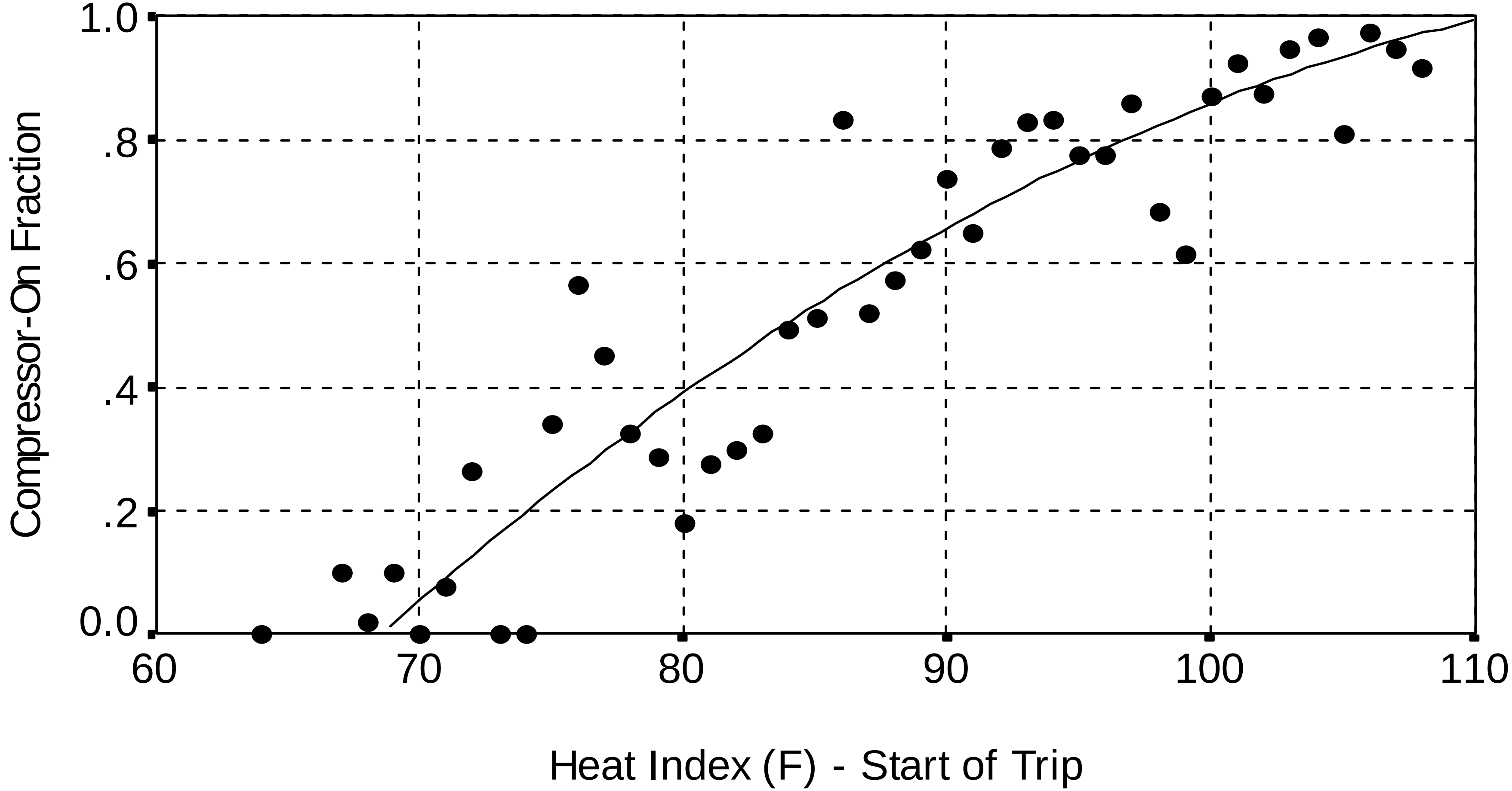
COMPon = Factor representing compressor activity as a function of temperature and humidity.

Temperature, Humidity, and Heat Index



Note: Heat Index values based on shady conditions

Compressor-On vs. Heat Index



Non-idle trips (weighted by number of trips)

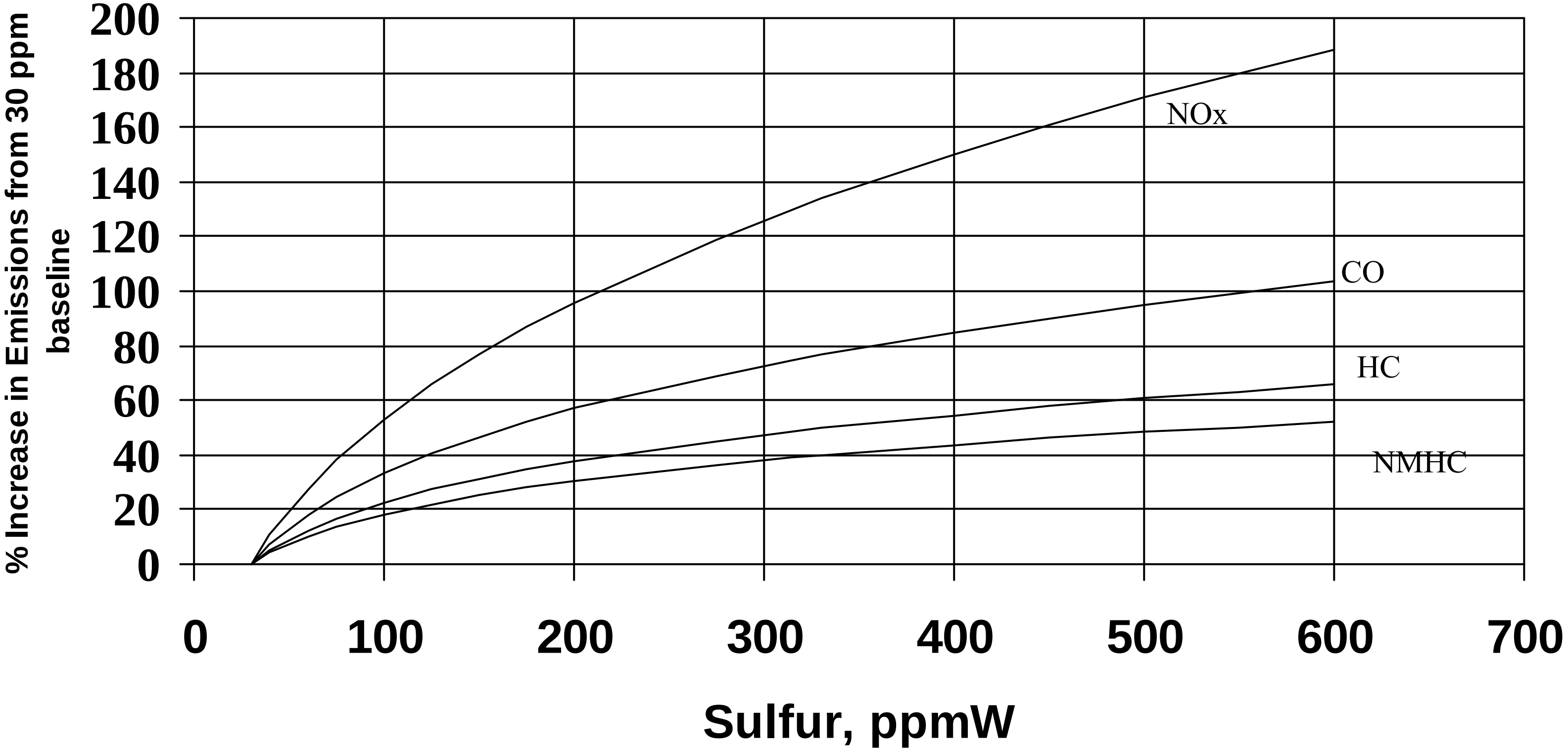
Fuel Correction Factors

- Petrol correction factors are
  - Driving mode, pollutant, season, fuel reg, and tech group
- Diesel correction factors are
  - Driving mode, pollutant, season, fuel reg, and tech group
- Stored in FCF_Data.for

Effects of Fuel Composition

- Updated effects of oxygenated fuels on CO emissions
- Explicit effects of sulfur on exhaust emissions
  - including long-term and irreversibility effects.
- Explicit modeling of LPG vehicles

LEV Normal Emitter Composite Emission Effects Based on Regression Coefficients



Fuel overview

- Most modern gasoline-fueled vehicles use catalysts to reduce HC, CO, and NO_x emissions
- Sulfur is a catalyst poison. Increased sulfur levels in fuels thereby increase emissions through catalyst deactivation

Modeling Objectives

- Identify valid data for sulfur's effect on exhaust emissions
- Develop correlations between sulfur and exhaust emissions as a function of:
  - Pollutant
  - Emitter class
  - Vehicle technology
  - Emission mode (composite, running, start)

Combined Correction Factor

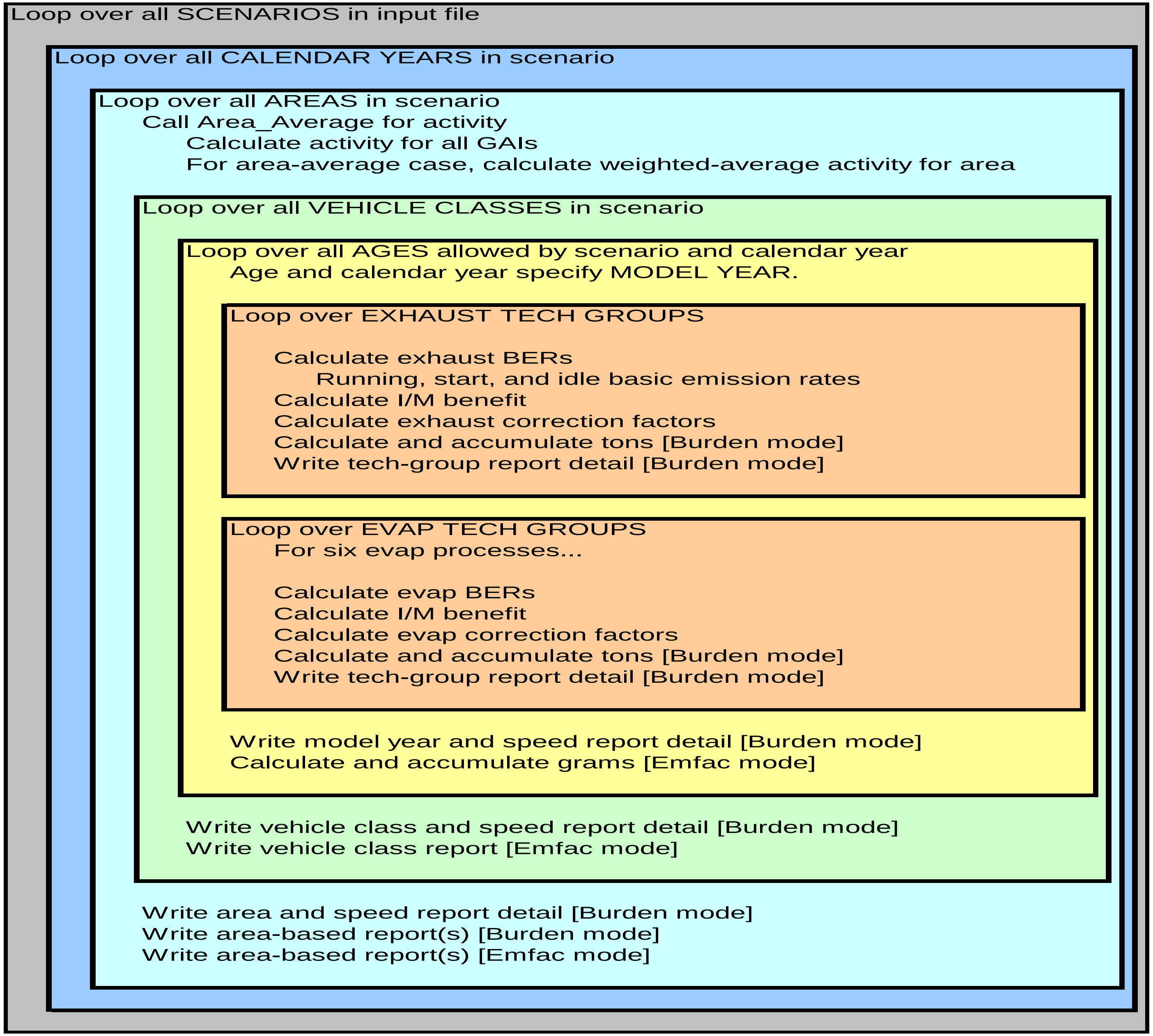
Example for normal regime:

```
CF = CF
   &       + ALTCF
   &       * LOADCF
   &       * SCFACTOR(iPer, iReg)
   &       * EX_TCF(iMode,iAge,iPer,iMon,iReg)
   &       * RH_CF(iPer,iMon,iReg)
   &       * AC_CF(iPer,iAge,iMon)
   &       * FCF(iMode,iAge,iMon)
   &       * HI_CF
```

Burden Calculations

- Emission Rate E_{model_year}, for pollutant
- Correction Factors (CF)
- Activity (Population, VMT, Starts)
- By Area
- Calculate for both No_I/M and Post I/M
- Estimate Tons/year :

E_{model_year} * ALL_CF * Activity


Loop over all SCENARIOS in input file
Loop over all CALENDAR YEARS in scenario
Loop over all AREAS in scenario
Call Area_Average for activity
Calculate activity for all GAIs
For area-average case, calculate weighted-average activity for area
Loop over all VEHICLE CLASSES in scenario
Loop over all AGES allowed by scenario and calendar year
Age and calendar year specify MODEL YEAR.
Loop over EXHAUST TECH GROUPS
Calculate exhaust BERs
Running, start, and idle basic emission rates
Calculate I/M benefit
Calculate exhaust correction factors
Calculate and accumulate tons [Burden mode]
Write tech-group report detail [Burden mode]
Loop over EVAP TECH GROUPS
For six evap processes...
Calculate evap BERs
Calculate I/M benefit
Calculate evap correction factors
Calculate and accumulate tons [Burden mode]
Write tech-group report detail [Burden mode]
Write model year and speed report detail [Burden mode]
Calculate and accumulate grams [Emfac mode]
Write vehicle class and speed report detail [Burden mode]
Write vehicle class report [Emfac mode]
Write area and speed report detail [Burden mode]
Write area-based report(s) [Burden mode]
Write area-based report(s) [Emfac mode]

Evaporative Emissions

- Evap calculations are done for a specific combination of:
  - Calendar year,
  - Area,
  - Vehicle class,
  - Vehicle age, and
  - Evap technology group.
- Evap emissions are calculated for six distinct emissions processes:
  - Hot soak
  - Running losses
  - Partial-day resting losses
  - Multi-day resting losses
  - Partial-day diurnal losses
  - Multi-day diurnal losses
- There are three emitter class regimes defined in the model:
  - Normal
  - Moderate
  - High

Hot Soak Emissions

Basic Emission Rates are calculated for each emitter regime as:

Type of Equation Based on Tech Group		Age	Odometer
	Linear	1	2
	Exponential	3	4

Emissions Calculations:

$$EF_{N,M,H} = EF_o + Det * \begin{bmatrix} Age \\ or \\ Odo \end{bmatrix}$$

or

$$= \exp\left(EF_o + Det \begin{bmatrix} Age \\ or \\ Odo \end{bmatrix} \right)$$

Running Loss Emissions

Emission rates for running loss emissions are calculated by the use of the following equation:

$$EF_{(N,M,H)} = Zm + DR * Odo + RL\_Age * Age$$

A correction factor is calculated for use later which accounts for increased running loss due to longer trips. This factor is calculated as:

RL_TOF = RL_TIME * TIME_ON[a1]
Evap_EF = $EF_{(N,M,H)}$ + RL_TOF

Partial Day Resting Losses

Stored in :

Partial day results:	Rest_BER(1,:,:,:)
Single day results:	Rest_BER(2,:,:,:)
Multiple day results:	Rest_BER(3,:,:,:)

Next, the BER is calculated as a function of temperature T. For normal and moderate emitters, between 55F and 65F the emissions relationship is linear:

$$Rest\_BER\_All = (T-55) * EF_4 * RVP\_CF$$

Beyond 65°F, the equation form used is a polynomial in temperature:

$$Rest\_BER\_All = [EF_0 + EF_1 * T + EF_2 * T^2 + EF_3 * T^3] * RVP\_CF$$

Where:

$$Numerator = A + B * (T+15) + C * RVP + D * (T+15) * RVP$$

$$Denominator = A + B * (T+15) + C * 9.0 + D * (T+15) * 9.0$$

$$RVP\_CF = Numerator/Denominator$$

The Coefficients A,B, C, and D are stored in Array EVAP_TCF, which is the file TCF_Data.for

Multiple Day Resting Losses

Multiple day resting losses are calculated by scaling the partial day BERs with a multi-day factor selected based on the tech group:

$Rest\_BER\_All_2 = Rest\_BER\_All_1 * MD\_Factor_2$
$Rest\_BER\_All_3 = Rest\_BER\_All_1 * MD\_Factor_3$

Partial Day Diurnal Emissions

Stored in :

Partial day results:	Drnl_BER(1,:,:,:)
Single day results:	Drnl_BER(2,:,:,:)
Multiple day results:	Drnl_BER(3,:,:,:)

Diurnal emission factors are a function of primary temperature and RVP. In the EVAP subroutine an additive emission factor is estimated as follows and another multiplicative emission factor is applied in Burden.

Drnl_BER = F (T)
= Additive in Evap Subroutine
= Multiplicative in Burden

$$Drnl\_CF = CF_0 + CF_1 * (T + 15) + CF_2 * RVP + CF_3 * (Temp + 15) * RVP$$

$$Drnl\_BER(1) = A + B * Temp + C * Temp^2 + D * Temp^3 + Dirnl\_CF$$

Diurnal losses only occur when temperature is rising.
Diurnal emission factors are stored for each vehicle age, emitter category, and tech group.

Multiple Day Diurnal Emissions

Multiple day diurnal losses are calculated by scaling the partial day BERs with a multi-day factor selected based on the tech group:

$Drnl\_BER\_All_2 = Drnl\_BER\_All_1 * MD\_Factor_2$
$Drnl\_BER\_All_3 = Drnl\_BER\_All_1 * MD\_Factor_3$

Evap I/M

- Not in current version of EMFAC HK – may be added later
- I/M only causes the regime size fractions to change- Similar to Exhaust Calculations
- Emissions changes are caused as vehicles “MOVE” from higher emitting regimes to lower emitting regimes
- The emissions levels of emissions regimes doesn’t change
- After I/M the fraction of high emitters is lower

Evap Correction Factors

Hot Soak Correction

Temperature and RVP correction: The hot soak corrections for temperature and RVP are based on “correcting” temperature from 75F to actual and “correcting” RVP from 9.0psi to actual, using the following equation form:

$$\text{HS\_RVP\_TEMP\_CF} = \frac{\exp\left(A + B * (T - 75) + C * (Rvp - 9)\right)}{\exp\left(A + B * (75 - 75) + C * (9 - 9)\right)}$$

Estimate the number of soak events in time periods that are below 40 minutes (5 periods, periods are 0-5, 6-10, 11-20, 21-30, 31-40 (with mean of 35), 41-50, 51-60, 61-120 etc.)

Run_Frac allows us to discount the hot soak emissions which follow very short trips (4 minutes or less).

$$\text{Run Frac} = \left[\frac{\text{Sum of Trips which are greather than 5 minutes}}{\text{Sum of all trips}}\right]$$

$P = [C_1 * [C_2 t + C_3 t^2 + C_4 t^3 + C_5 t^4]/C_6/100]$

F = frequency of trips with this time-off period at this hour

Where t is the length of the time-off period from TIME_OFF, C_1 to C_6 are constants specific to the emitter regime, and F is evaluated from array TIME_OFF_FREQ.

Partial _Soak factor = Sum(P*F) / Sum(F)

The function result is the combination of the two corrections:

HS_BER_TO_GM_PER_HR = Run_Frac * **Partial_Soak**

The final hot soak correction factor is the combination of temperature and RVP correction and basis conversion:

CF = HS_RVP_TEMP_CF * HS_BER_TO_GM_PER_HR

Running Loss Correction

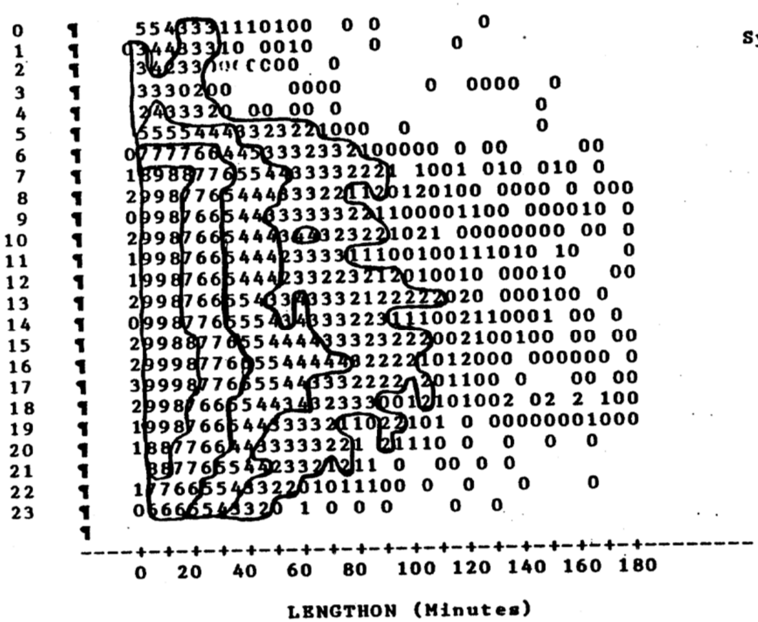
$$RL_{CF} = \frac{A + Time\_On * (B * RVP * Temp + C + RVP + D * Temp)}{E + F * TIME\_ON}$$

RL_{CF} are only valid for Time_On values < 60 minutes

Evap EF ( ) =

$$\sum_{TIMEON} RL\_TOF * RL_{cf} * TIME\_ON\_FREQ$$

Time ON Matrix



Symbol	Number of Timeon Periods
0	1-2
1	3-4
2	5-8
3	9-18
4	19-37
5	38-77
6	78-159
7	160-329
8	330-680
9	681-1400

Figure 6-11. Frequency Distributions of Timeon Periods (Monday-Friday)

Diurnal and Resting Loss Corrections

The four resting and diurnal loss processes are not corrected any further for RVP and Temperature, the corrections are include in the raw BER:

Partial day resting loss CF	=	1.0
Multi-Day Resting Loss CF	=	1.0
Partial Day Diurnal CF	=	1.0
Multi-Day Diurnal CF	=	1.0

Evap EF = Rest_BER (1,2,3) * Activity (AT_Rest(1,2,3)

Evap EF = Diurnal_BER (1,2,3) * Activity (AT_Rest(1,2,3)

Partial – Index 1
Multiple – Sum of 2 and 3

Time OFF (AT_Rest) Matrix

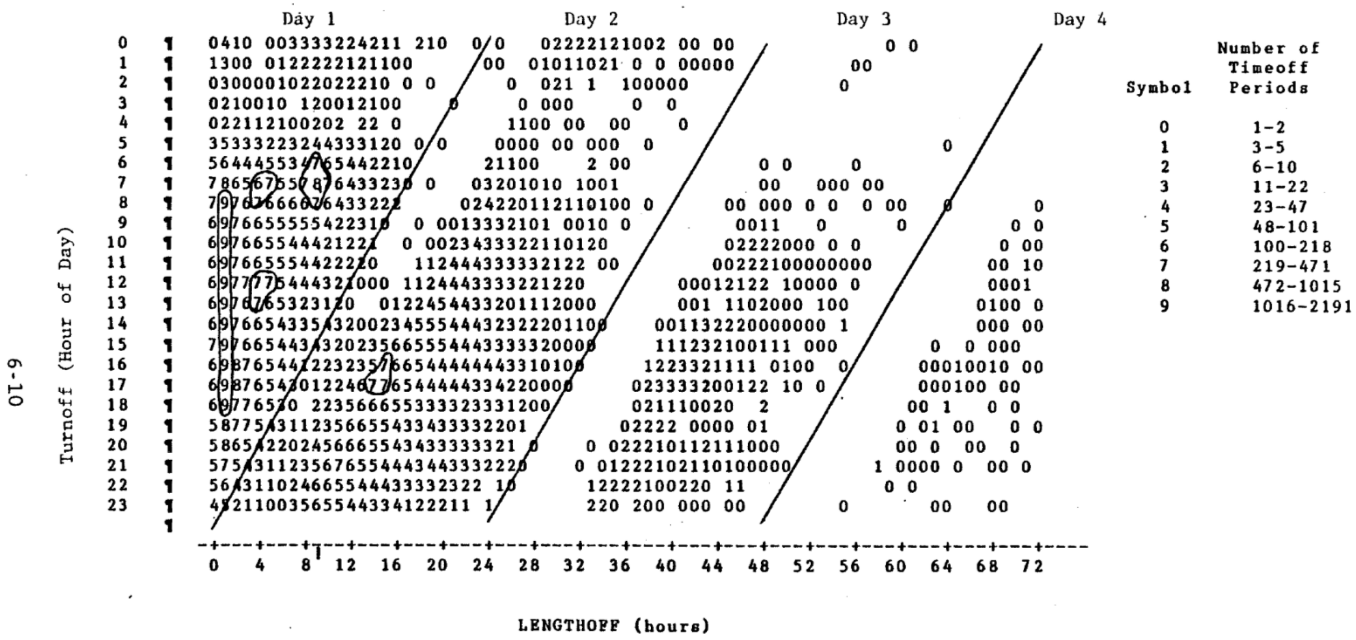


Figure 6-3. Frequency Distribution of Timeoff Periods (Monday-Friday)

Evaporative Emissions –

Fuel Cap Survey

- Sampled at random a certain proportion of vehicles of different vehicle ages from the relevant vehicle classes for a fuel cap pressure test.
- Conducted a survey on the general maintenance condition of the vehicle and a visual assessment.

Sampling Locations

Motor cycle repair shop

Petrol filling station

Wash & Wax Shop

Private car repair shop

To ensure randomness, surveys were mainly conducted at petrol filling stations over strategic locations.

Fuel Cap Failure Rates of Petrol Vehicles in Evaporative Survey in 2012