Upgrades of EMFAC-HK

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Acknowledgement

- Eastern Research Group, Inc.
- My colleagues,
  - Anson Wong, Casey Lee, Eddie Lo, SW Ng, Eric Kam, Patrick Chung, WH Leung, Catherine Lau, Ruby Wong

Vehicle Classification Chart

HK 1.2 Sub-Model	Vehicle Class Index		Vehicle Class Description		Fuels	
	HK 1.2	HK 2.1	HK 1.2	HK 2.1	HK 1.2	HK 2.1*
MC	1	1	Petrol Private Cars (PC) & Light Goods Vehicles (LGV)	Private Cars (PC)	Petrol	ALL
Taxi	3	3	Taxi		LPG =Petrol	ALL
MC	3	4	Diesel Private Cars & Light Goods Vehicles (<=2.5t)	Light Goods Vehicles (<=2.5t)	Diesel	ALL
MC	4	5	Light Goods Vehicles (2.5-3.5t)		Diesel	ALL
MC	6	6	Light Goods Vehicles (3.5-5.5t)		Diesel	ALL
MC	7	7	Medium & Heavy Goods Vehicles (5.5-15t)		Petrol, Diesel	ALL
MC	8	8	Medium & Heavy Goods Vehicles (>=15t)		Petrol, Diesel	ALL

Vehicle Classification Chart (Con't)

HK 1.2 Sub-Model	Vehicle Class Index		Vehicle Class Description		Fuels	
	HK 1.2	HK 2.1	HK 1.2	HK 2.1	HK 1.2	HK 2.1*
MC	5	11	Public Light Buses		LPG=petrol, Diesel	ALL
Taxi	4	12	Private Light Buses (<=3.5t)		Petrol, Diesel	ALL
Taxi	5	13	Private Light Buses (>3.5t)		LPG=Petrol, Diesel	ALL
Taxi	6	14	Non-franchised Buses (<6.4t)		Petrol, Diesel	ALL
Taxi	7	15	Non-franchised Buses (6.4-15t)		Petrol, Diesel	ALL
Taxi	8	16	Non-franchised Buses (>15t)		Petrol, Diesel	ALL
Taxi	10	17	Single Deck Franchised Buses		Petrol, Diesel	ALL
MC	10	18	Double Deck Franchised Buses		Petrol, Diesel	ALL
MC	11	19	Motor Cycles		Petrol, Diesel	ALL

Comparison of EMFAC-HK V2.1 & V1.2

EMFAC-HK V1.2	**EMFAC-HK V2.1**
Basic Model: EMFAC2002	**Basic Model:** EMFAC2009
Vehicle Emission standards: Up to Euro IV for light duty vehicles, and Euro V for heavy duty vehicles	**Vehicle Emission Standards:** Up to Euro VI
Vehicle Fuel Standards: Euro V up to 2011 and 15 ppm S beyond (using US fuel property)	**Vehicle Fuel Standards:** Euro V
	Bug fixing

EMFAC2007 - *Summary of Changes (California ARB, 2006)*

Change	**Statewide** Changes For **2015** calendar year
0	Baseline - EMFAC2002 ver2.2
1,4,7	●**Fuel Correction Factors –** *Phase 3 and low sulfur*
2	●**I&M Updates –** *Change of ownership, new enhanced areas, etc.,*
4	●**Brakewear**
5	●**Accrual Rates**
8	●**VMT Matching by Fuel Type**
10,23,31	●**Populations Updates -** *Three changes*
11	●**Redistribution** *of heavy heavy-duty diesel vehicle populations*
15,21,24,32	●**VMT Updates**
16,25,33	●**Corresponding** *changes to speed distribution files*
34	●**Growth Rates –** *Revised growth rates*
13,30	●**Ethanol permeation -** *from fuel sold beginning 2004 calendar year*
14,29	●**Updated Heavy-Heavy-Duty Diesel** *exhaust rates, idle (low & high), and speed corrections*
18	●**Temperatures –** *new summer profiles corresponding to the federal 8-hour Ozone standard*
19	●**Relative Humidities –** *new summer relative humidity profiles corresponding to the federal 8-hour Ozone standard*
3,12,22	●**Bug Fixes, Regime** *Specific Evap Calc,* **Corrected HDV Gas Cap**
	●**Other Changes**

EMFAC 2007 (add'l remarks)

- Extensive code restructuring/modifications
  - Reorganized directory structure
  - Use of data types to store and track scenario data
  - Change of input file format
- GUI Updates

EMFAC 2009 Changes

- Algorithmic Changes for Heavy-Duty Diesel Trucks
- Expand Vehicle Classes
- Extended Idle for heavy-duty diesel
  - not use in current version of EMFAC-HK
- Retrofit corrections

Baseline Model Selection
EMFAC2009 Version 2.50.8

- Ensures EMFAC2009 features are incorporated into EMFAC-HK, including
  - latest correction factors;
  - More user-friendly formatting of input files;
  - Updated coding language;
  - Incorporates bug repairs for EMFAC2002 and EMFAC2007

HK Stds & Implementation Dates

<table>
<tr><td>HK Imple. Dates</td><td colspan="3">Pre - Euro</td><td colspan="2">Euro I</td><td colspan="3">Euro II</td></tr>
<tr><td colspan="2">Vehicle Class</td><td>Pre - ULP</td><td>ULP</td><td>Diesel</td><td>Petrol</td><td>Diesel</td><td>LPG</td><td>Petrol</td><td>Diesel</td></tr>
<tr><td colspan="2">Private Car</td><td rowspan="2">< 1.1.92</td><td rowspan="2">1.1.92</td><td rowspan="5">< 1.4.95</td><td rowspan="5" colspan="2">1.4.95</td><td rowspan="5">NA</td><td>1.4.97</td><td>1.4.98</td></tr>
<tr><td rowspan="2">Goods Vehicle</td><td><= 2.5 t</td><td rowspan="3">1.10.98</td></tr>
<tr><td>2.5 t - 3.5 t</td><td rowspan="2">< 1.4.95</td><td rowspan="2">NA</td></tr>
<tr><td rowspan="2">Light Bus</td><td><= 3.5 t</td></tr>
<tr><td>> 3.5 t</td><td colspan="2" rowspan="2">< 1.4.95</td></tr>
<tr><td colspan="2">Goods Vehicle & Other Bus > 3.5 t</td><td colspan="2">1.4.97</td></tr>
<tr><td colspan="2">Taxi</td><td>< 1.1.92</td><td>1.1.92</td><td>< 1.1.96</td><td>1.4.95</td><td>1.1.96</td><td>1.8.01</td><td>1.10.98</td><td>1.7.99</td></tr>
<tr><td colspan="2">Motorcycle</td><td colspan="3">< 1.10.99</td><td colspan="2">1.10.99</td><td colspan="3">NA</td></tr>
</table>

HK Stds & Implementation Dates

HK Imple. Dates		Euro III			Euro IV		
Vehicle Class		**LPG**	**Petrol**	**Diesel**	**LPG**	**Petrol**	**Diesel**
Private Car		NA	1.1.01		NA	1.1.06	
Goods Vehicle	<= 2.5 t		1.1.02			1.1.07	
	> 2.5 t - 3.5 t						
Light Buses	<= 3.5 t	1.8.03	1.1.02		1.1.07		
	> 3.5 t		1.10.01	1.8.03	1.10.06		
Goods Vehicle & Other Bus > 3.5 t		NA	1.10.01		NA	1.10.06	
Taxi		1.8.03	1.1.01	NA (fr. 1.8.01)	1.1.06		NA
Motorcycle		1.1.07			NA		

Proposed HK Stds & Implementation Dates

<table>
<tr><td colspan="2">HK Imple. Dates</td><td colspan="3">Euro V</td><td colspan="3">Euro VI</td></tr>
<tr><td colspan="2">Vehicle Class</td><td>LPG</td><td>Petrol</td><td>Diesel</td><td>LPG</td><td>Petrol</td><td>Diesel</td></tr>
<tr><td colspan="2">Private Car</td><td rowspan="3">NA</td><td colspan="2">1.6.12</td><td rowspan="3">NA</td><td colspan="2" rowspan="2">1.9.15</td></tr>
<tr><td rowspan="2">Goods Veh <=3.5 t</td><td><= 1.305 t</td><td rowspan="2">1.6.12</td><td rowspan="2">31.12.12</td></tr>
<tr><td>> 1.305 t - 3.5 t</td><td colspan="2">1.9.16</td></tr>
<tr><td rowspan="3">Light Bus</td><td><= 1.305 t</td><td colspan="3" rowspan="3">1.6.12</td><td colspan="3">1.9.15</td></tr>
<tr><td>>1.305 t-3.5 t</td><td colspan="3">1.9.16</td></tr>
<tr><td>> 3.5 t</td><td colspan="3">2016</td></tr>
<tr><td colspan="2">Goods Vehicle & Other Bus > 3.5 t</td><td>NA</td><td colspan="2">1.6.12</td><td>NA</td><td colspan="2">2016</td></tr>
<tr><td colspan="2">Taxi</td><td colspan="2">1.6.12</td><td>NA</td><td colspan="2">1.9.15</td><td>NA</td></tr>
<tr><td colspan="2">Motorcycle</td><td colspan="6">NA</td></tr>
</table>

Technology Group Indexes

Diesel Heavy Goods Vehicles with GVW of 5.5-15 t (HGV7)

HK Standard	Version 1.2 Technology Group Index	Version 2.1 Technology Group Index
pre-Euro	123	
pre-Euro with DOC	124	
Euro I	125	
Euro II	126	
Euro III	129	
Euro IV	130	
Euro V	131	
Euro VI	NA	135

Diesel Non-franchised Buses with GVW of 6.4-15 t except Franchised Buses (NFB7)

HK Standard	Version 1.2 Technology Group Index	Version 2.1 Technology Group Index
pre-Euro	123	43
pre-Euro with DOC	124	44
Euro I	125	45
Euro II	126	46
Euro III	129	99
Euro IV	130	100
Euro V	131	101
Euro VI	NA	105

Comparison of EMFAC-HK V2.1 & V1.2 (con't)

EMFAC-HK V1.2	**EMFAC-HK V2.1**
2003 vehicle population distribution	2010 vehicle population distribution
2003 franchised bus fleet from bus companies	2010 franchised bus fleet from bus companies
No government vehicle fleet	2010 government vehicle fleet
Assumed no growth rates for vehicle fleet	- Increase in private & goods vehicles according to Strategic Highway Project Review 2009; - Franchised buses, public light buses and taxis whose maximum numbers are fixed by TD, so assume no growth rates; - Since the average annual growth rates from 2004-08 for non-franchised buses and private light buses are about zero, assume future growth rates to be zero.

Comparison of EMFAC-HK V2.1 & V1.2 (con't)

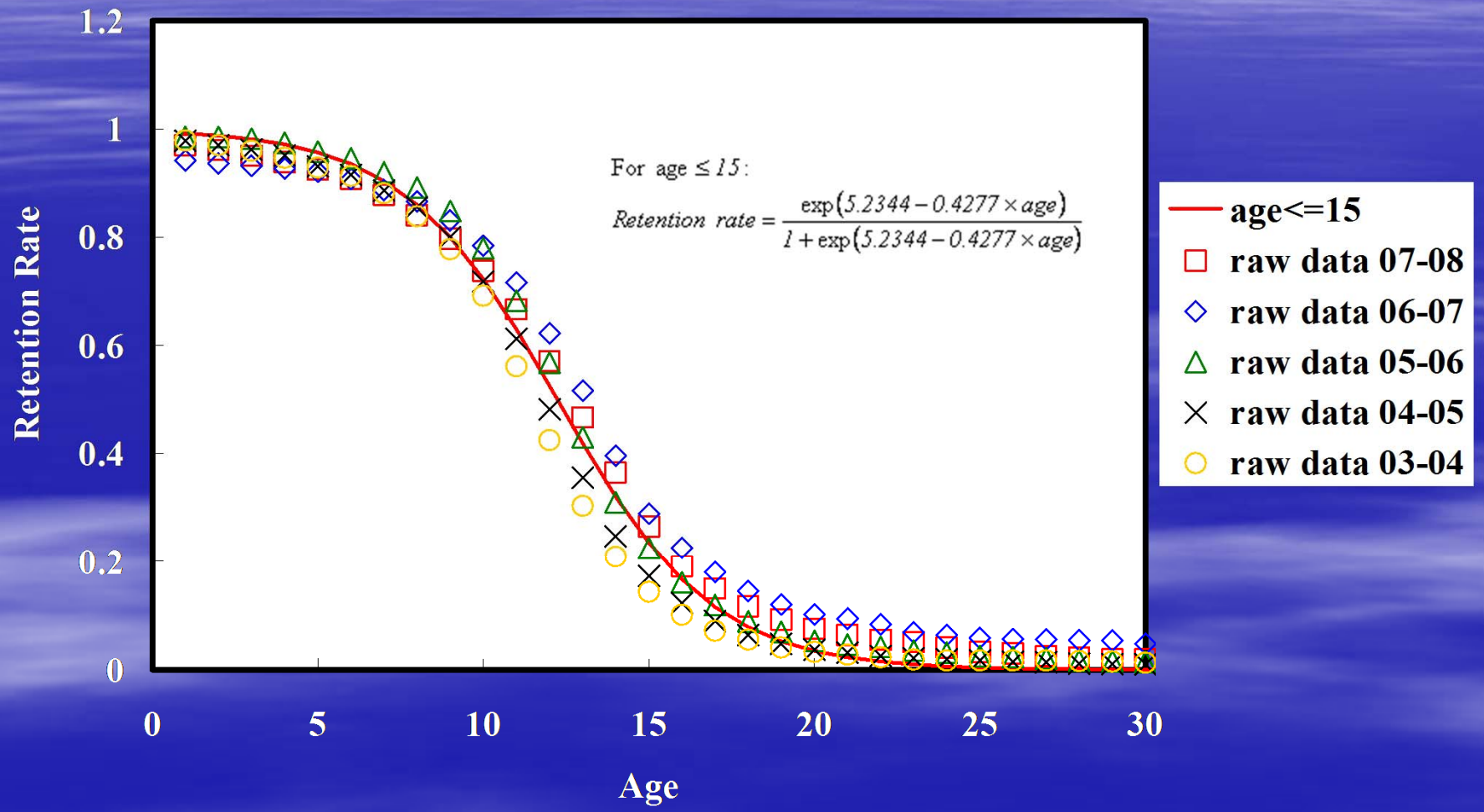
EMFAC-HK V1.2	**EMFAC-HK V2.1**
We discouraged the user to use forecast function in EMFAC. We suggested the user to use the same vehicle population distribution for future scenario years as those provided in EPD's website or to ask TD for inputs.	A forecast function for vehicle population distribution has been included in EMFAC's methodology and 2004-08 vehicle population distributions except LPG taxis and LPG PLB using 2005-08 data.
We discouraged the user to use backcast function in EMFAC.	We have modified the backcast function, which has a much better performance. As such, the user may adopt this function should he/she sees it appropriate.
2003 mileage and age relationship from only one local repair workshop	2010 mileage and age relationship from EPD's own surveys

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

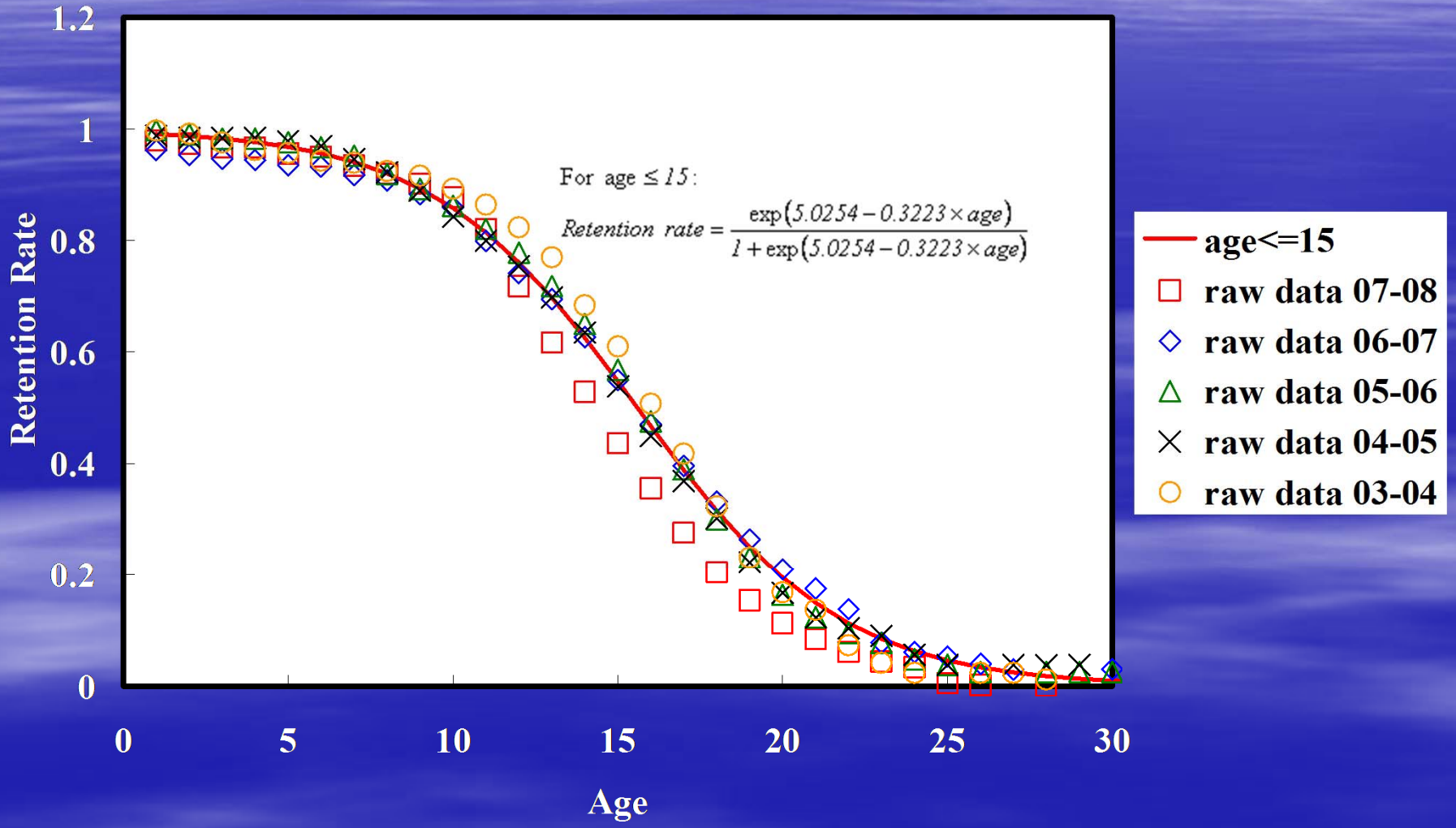
Forecast of Vehicle Population

- 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.

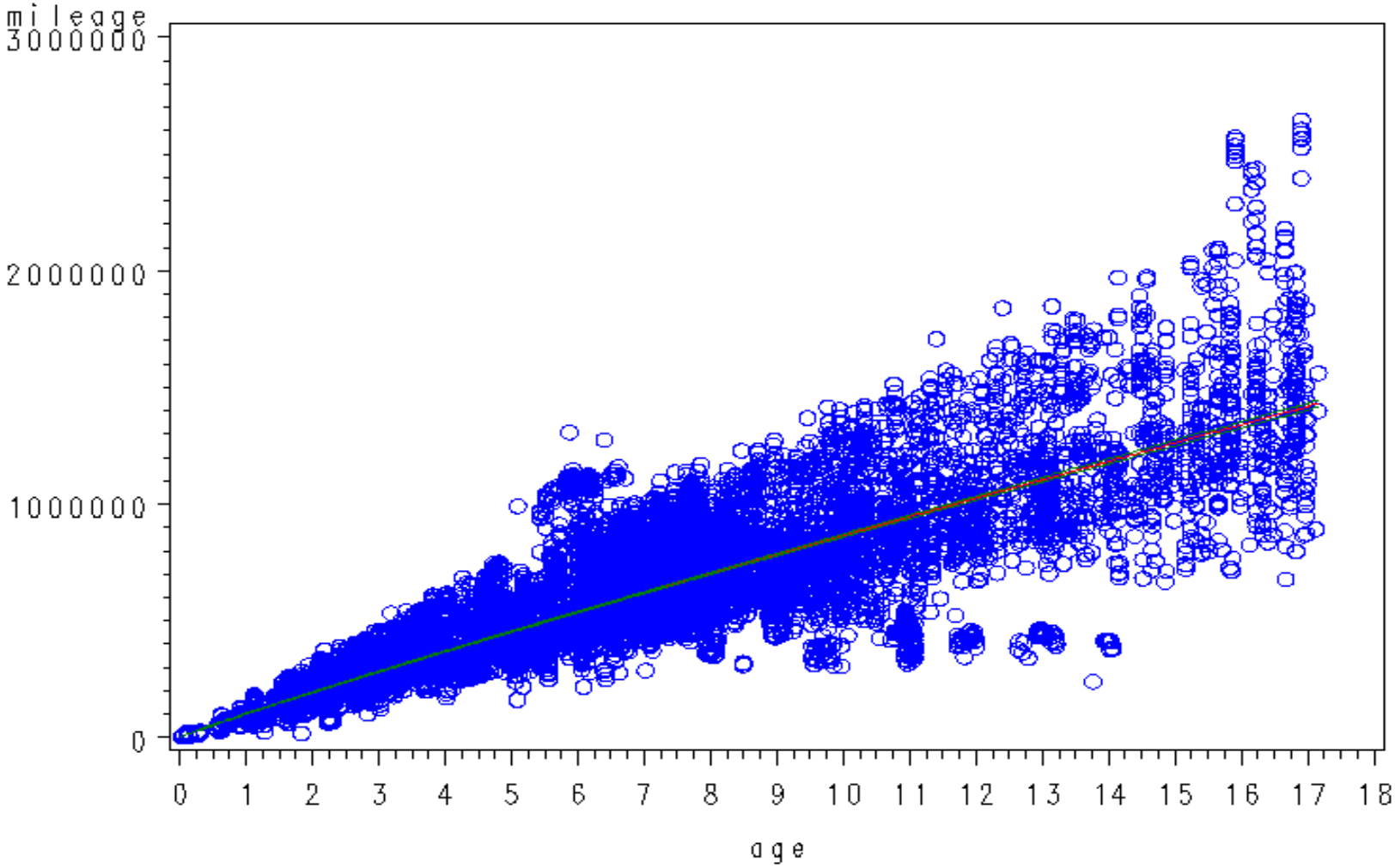
Retention Rates for Private Cars



Retention Rates for Heavy-duty Goods Vehicles



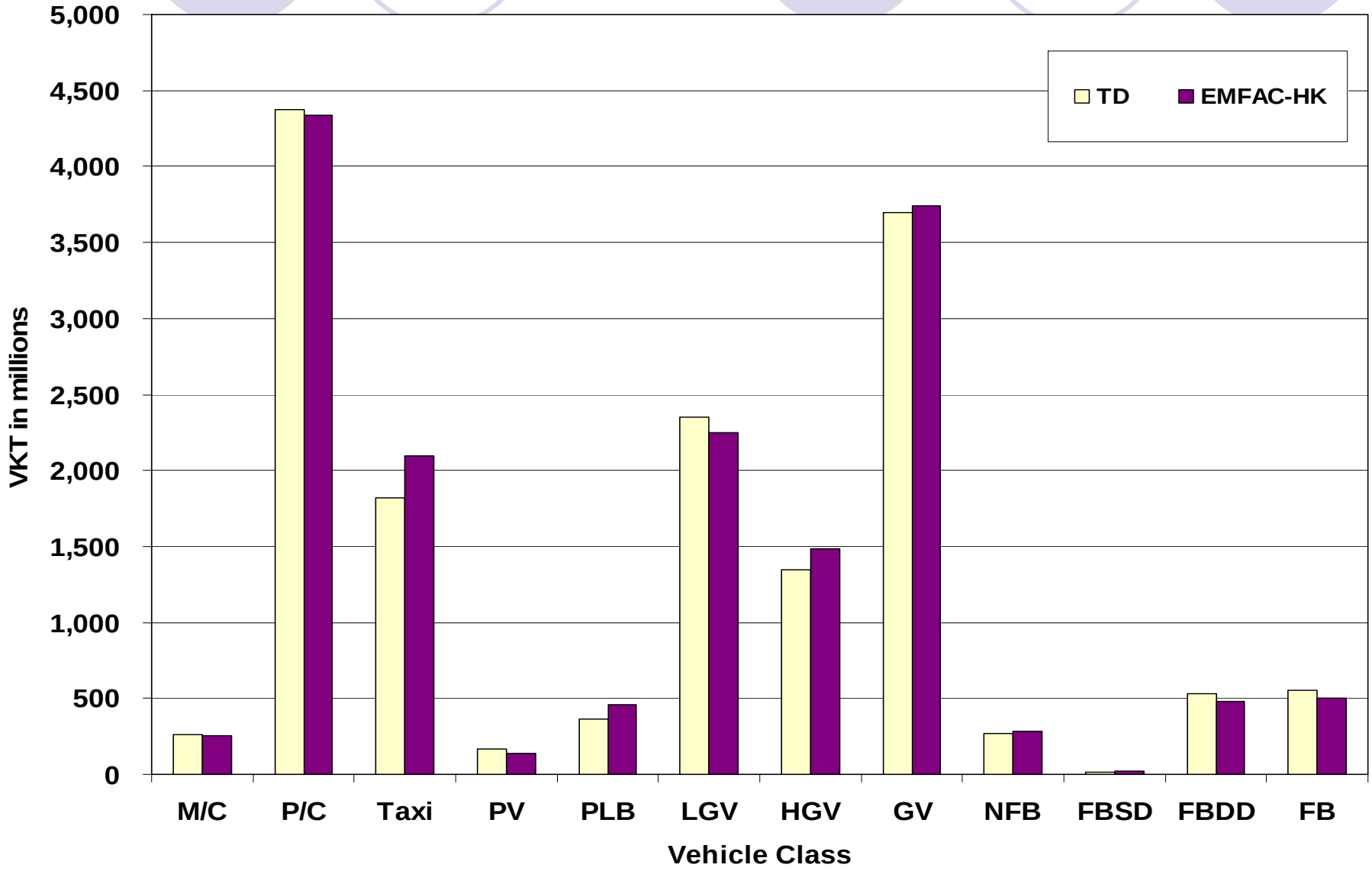
Distribution of Odometer Reading vs. Age for Franchised Buses (2006 Survey)



Comparison of EMFAC-HK V2.1 & V1.2 (con't)

EMFAC-HK V1.2	**EMFAC-HK V2.1**
2003 vehicle kilometer travelled (VKT) from TD	2010 VKT from TD
2003 survey on vehicle classification on about 95 road segments from TD (from 7 a.m. to 11 p.m.; for the remaining hours, it was assumed to be the same as those at 11 p.m.)	2010 survey on vehicle classification on 100 road segments from TD; local surveys conducted in 2004-07 & 2010 on vehicle classifications to supplement TD's data (from 11 p.m. to 7 a.m.) and 65 additional road segments
2003 speed limits from HyD	2010 speed limits from TD
2003 speed surveys from TD	2010 speed surveys from TD

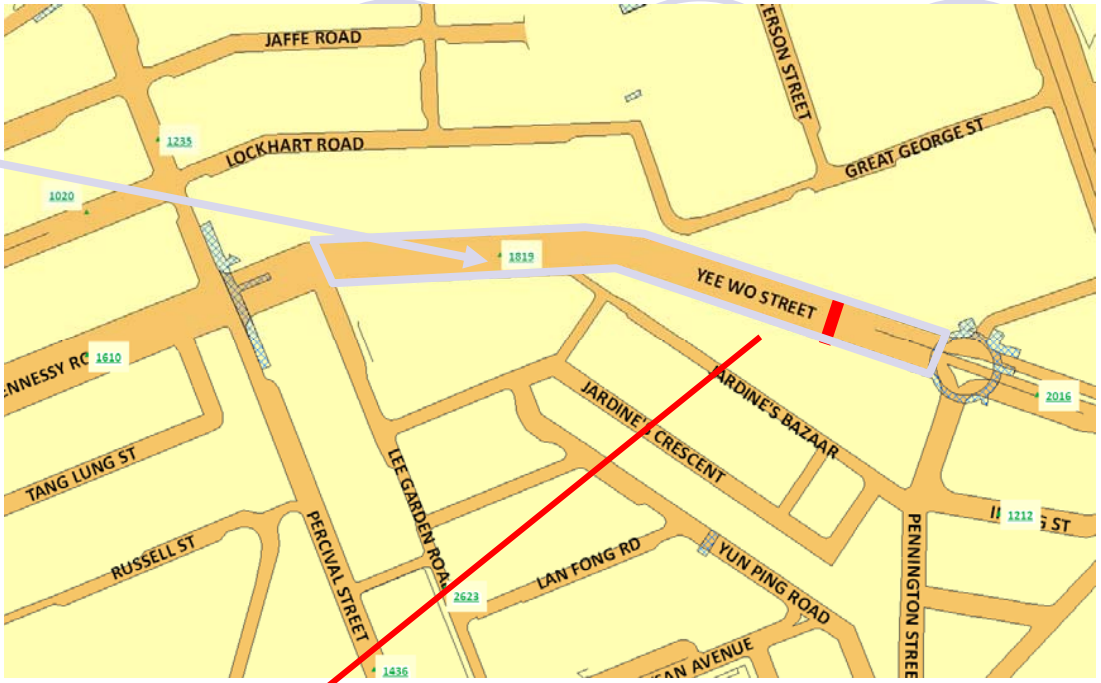
Comparison of VKT in 2001

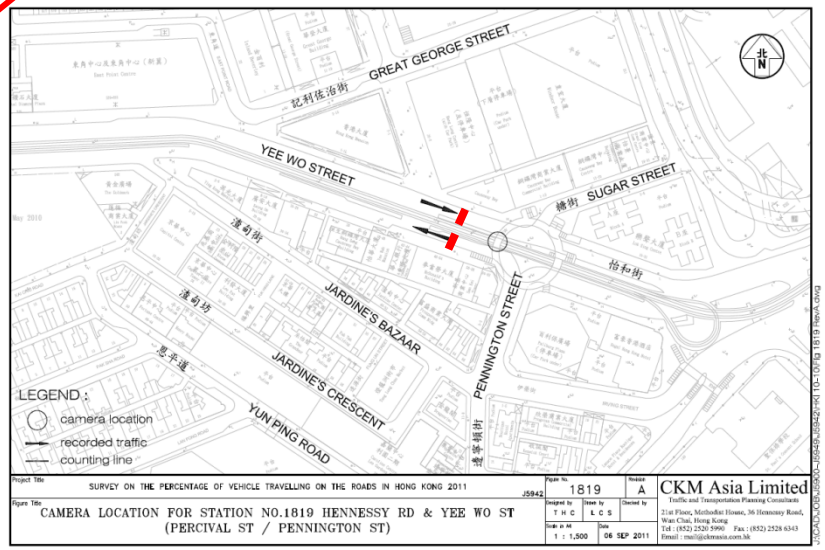


Traffic Counting Station locating on one of our proposed Low Emission Zones

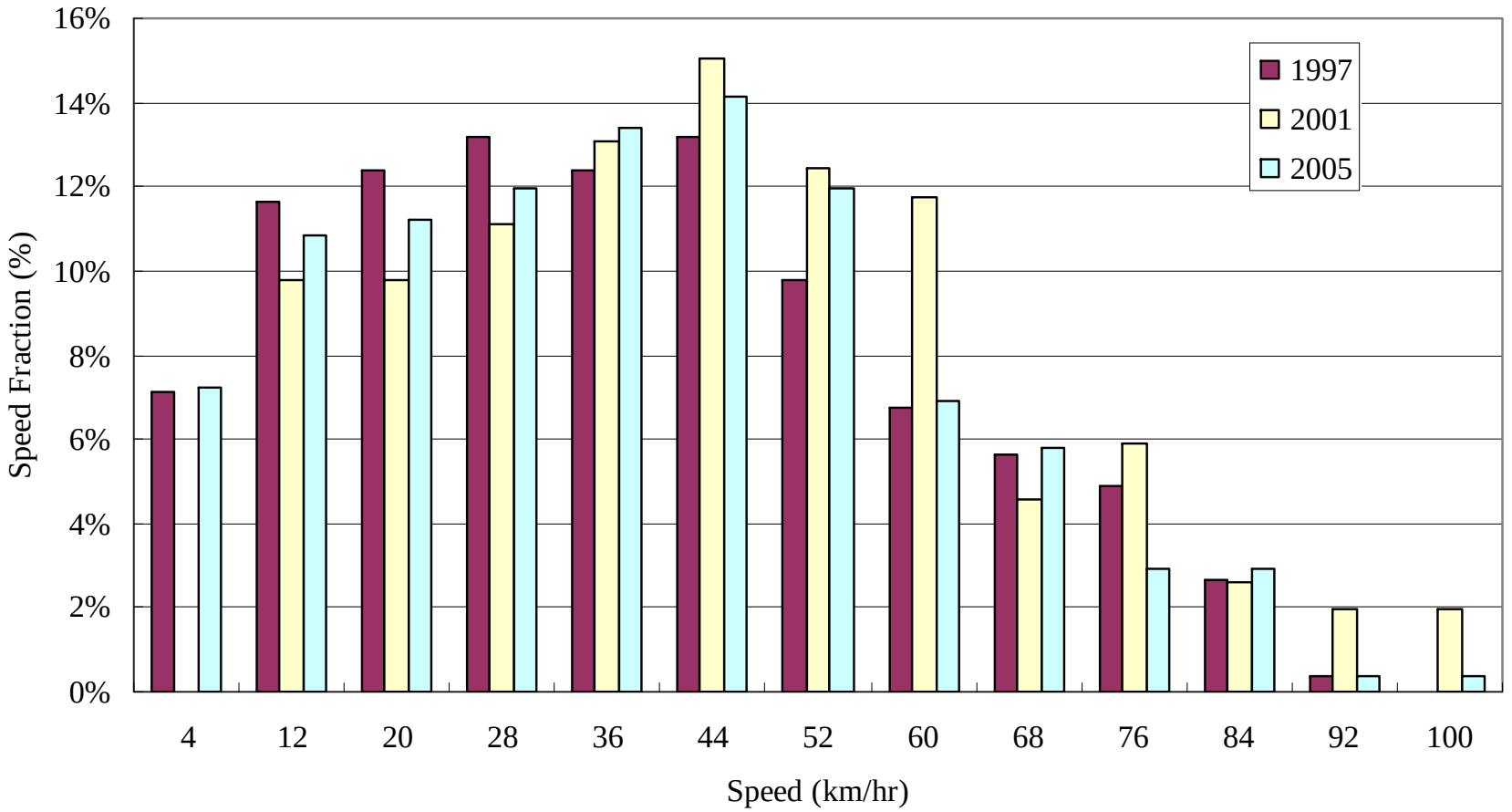
(Yee Wo Street, Causeway Bay)

-Traffic flow before the implementation of low emission zone can then be monitored and evaluated.

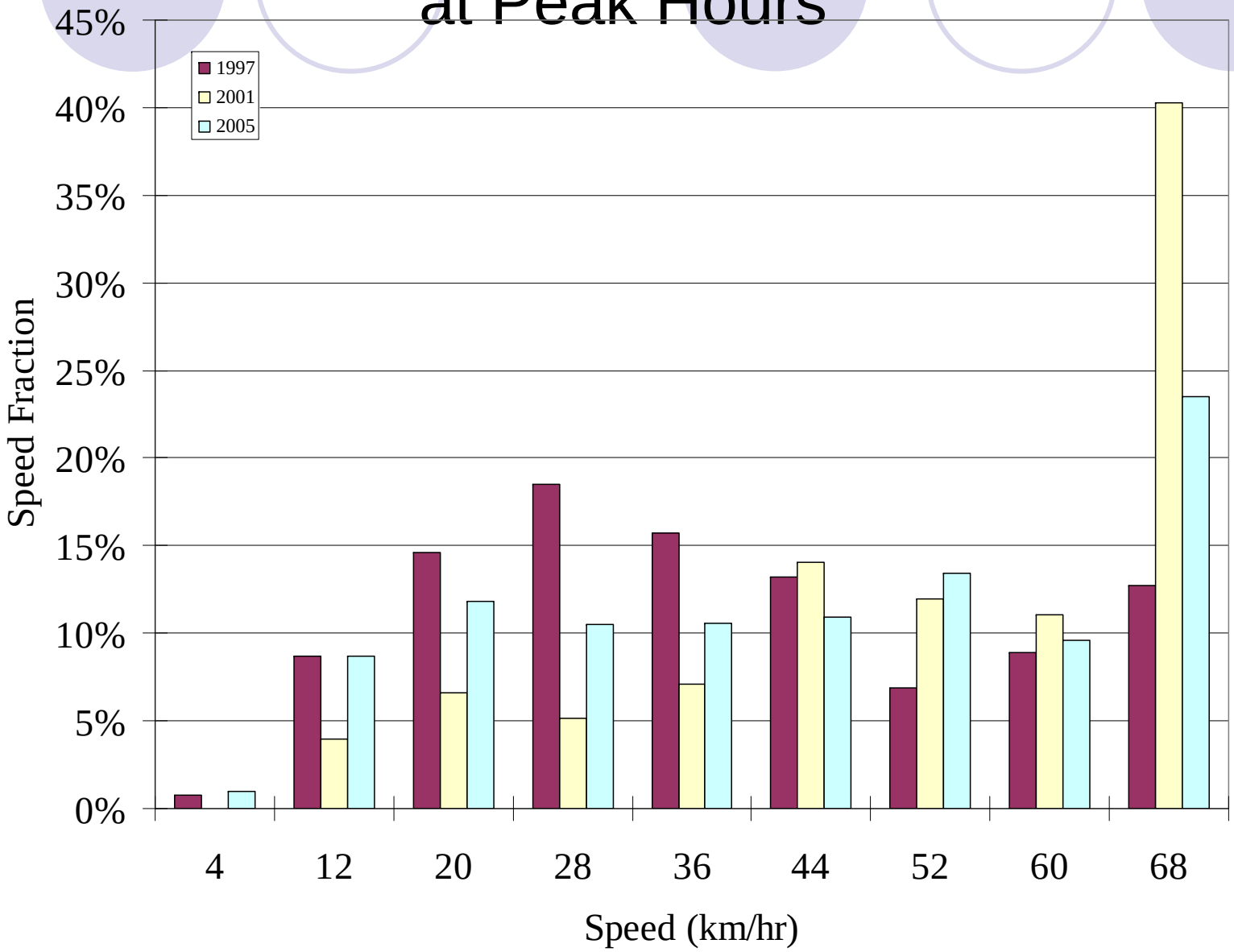




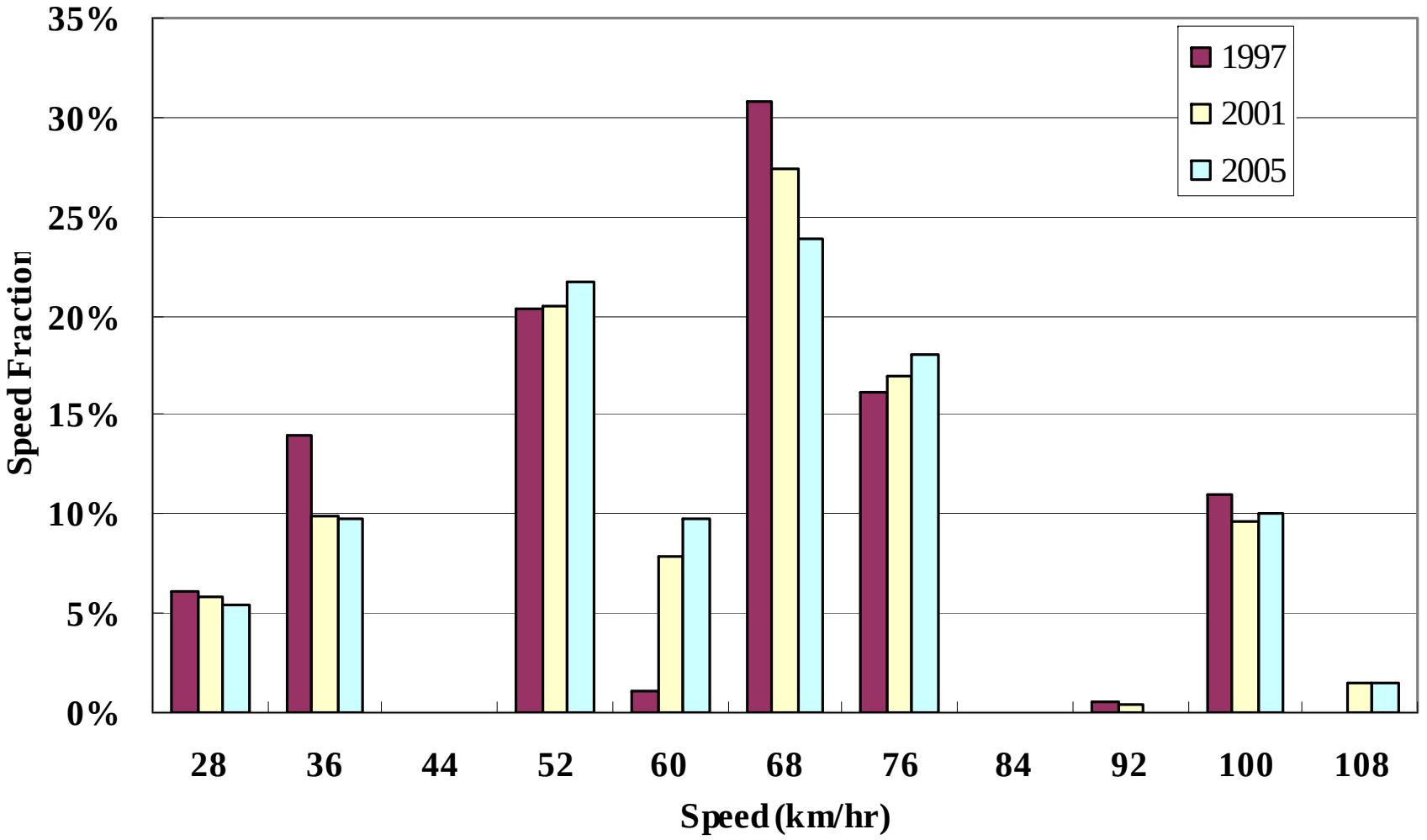
Speed Fractions for Private Cars at Peak Hours



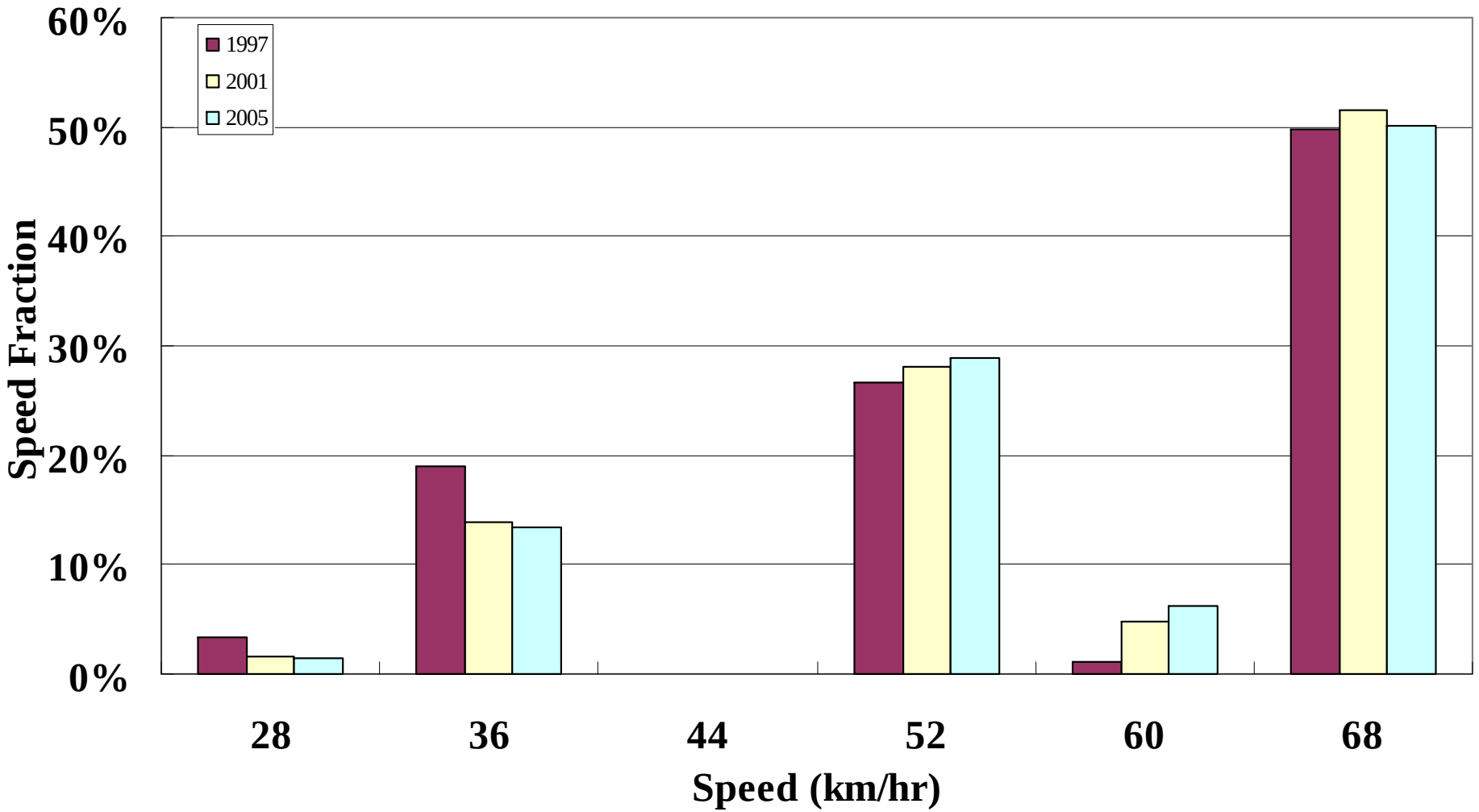
Speed Fractions for Franchised Buses at Peak Hours



Speed Fractions for Petrol Cars at Daytime non-peak Hours



Speed Fractions for Franchised Buses at Daytime non-peak Hours

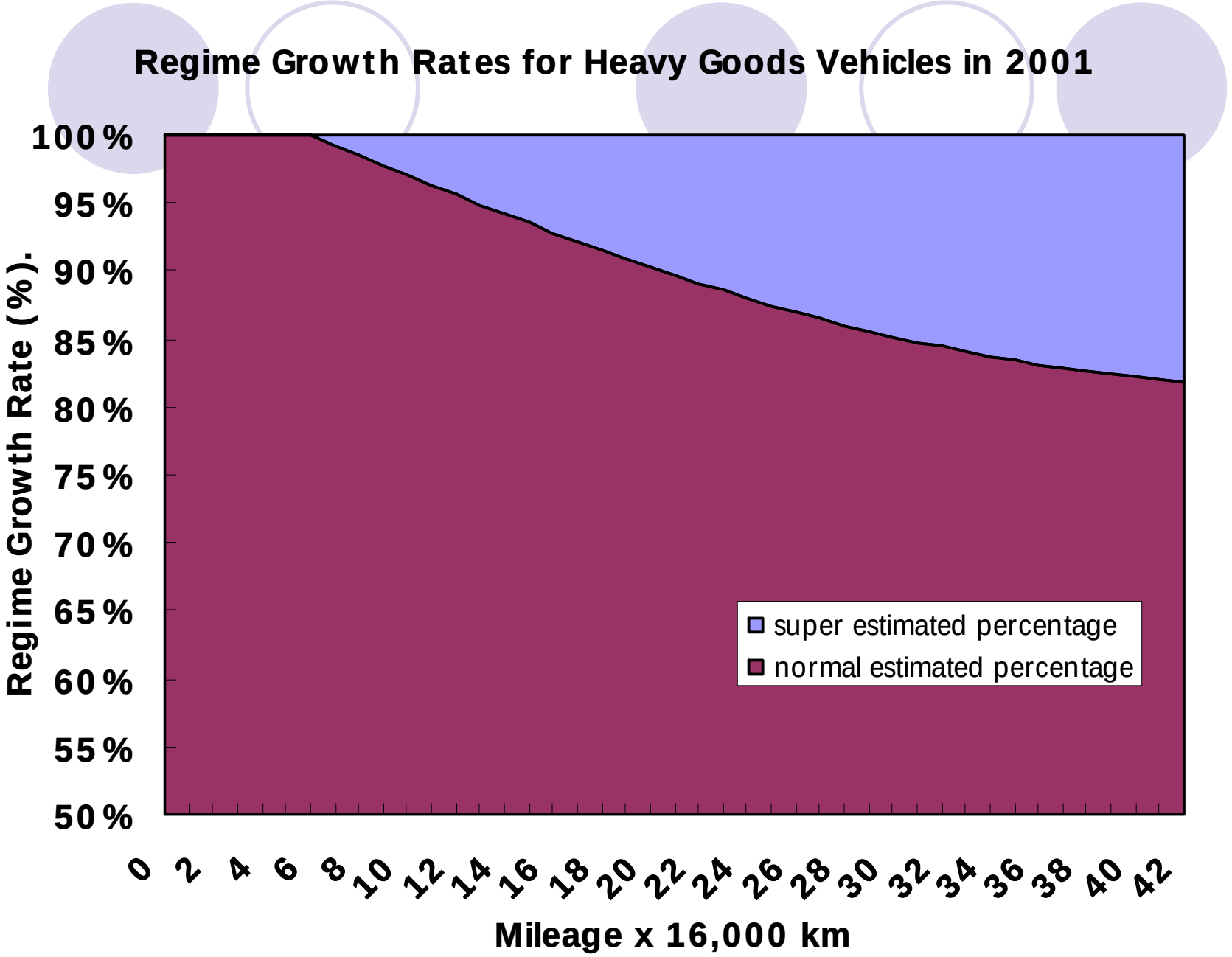


Comparison of EMFAC-HK V2.1 & V1.2 (con't)

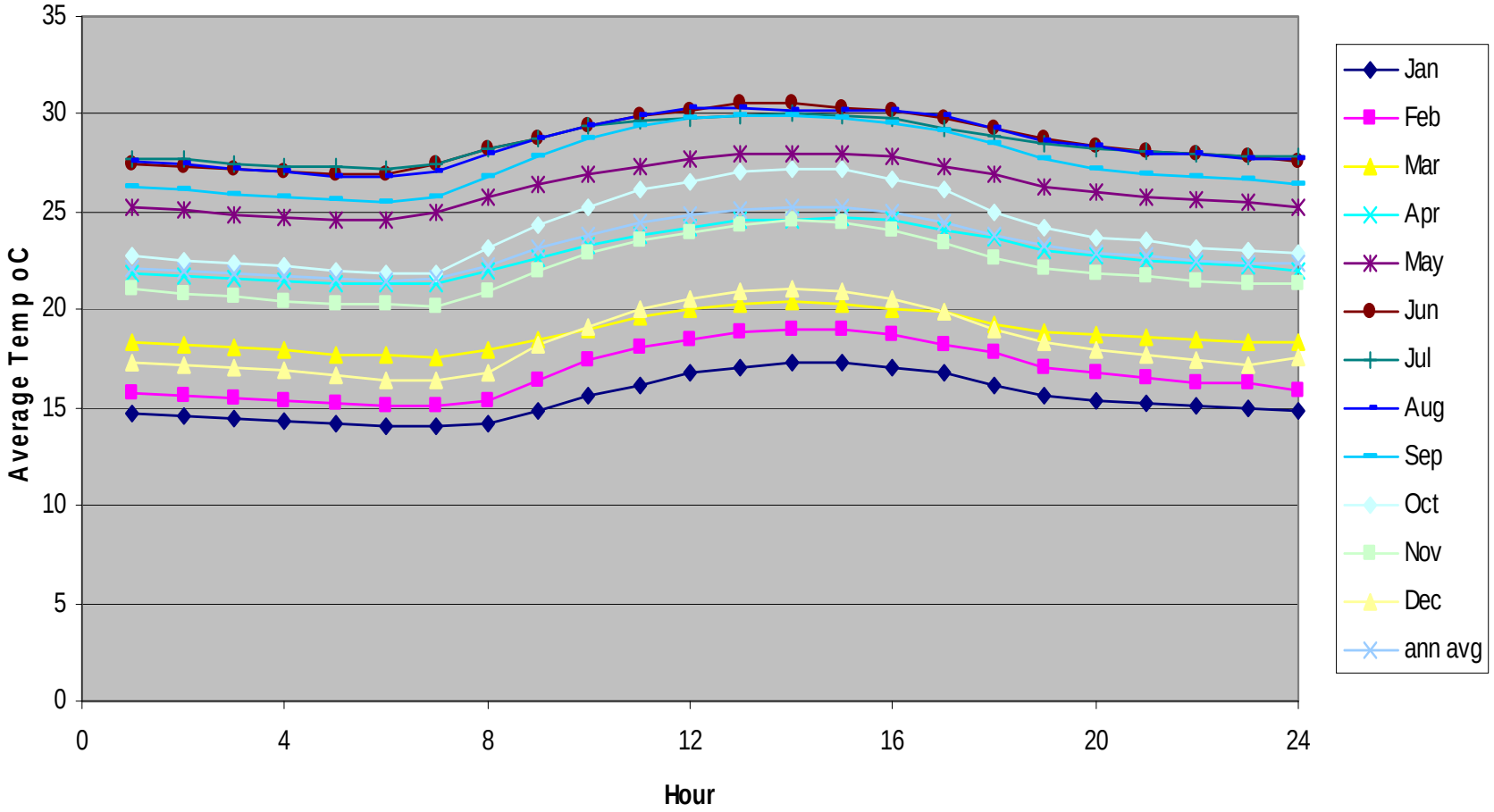
EMFAC-HK V1.2	**EMFAC-HK V2.1**
2003 smoky vehicle data for PM super emitters	2010 smoky vehicle data for PM super emitters except for diesel public light buses where 2004 smoky vehicle data were used
2003 ambient temperature & relative humidity from HKO	2010 ambient temperature & relative humidity from HKO
2001 Reid vapour pressures (RVP) from the oil companies.	2010 Reid vapour pressures (RVP) from the oil companies.
No estimates for evaporative emissions	2010 evaporative emission of petrol vehicles from EPD's own surveys
2001 fuel properties from EPD's fuel analysis	2010 fuel properties (fuel density, lead and sulphur content) from EPD's fuel analysis

Gross Emitter Model for Diesel Vehicles in Hong Kong

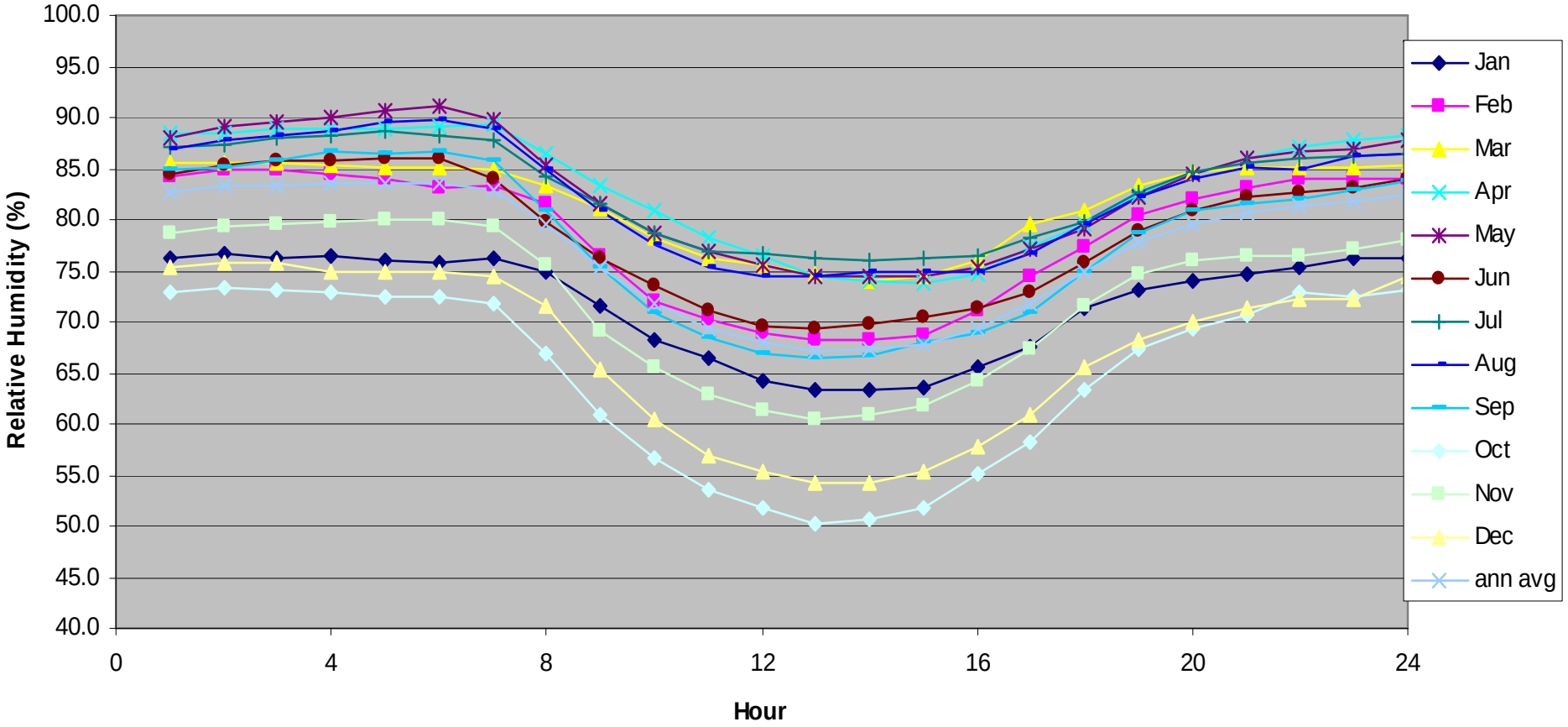
- Diesel vehicles were subdivided into 2 regimes:
  - normal & super
- The percentages of super emitters are estimated from annual smoky vehicle number


Regime Growth Rates for Heavy Goods Vehicles in 2001
Regime Growth Rate (%).
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Mileage x 16,000 km
super estimated percentage
normal estimated percentage

Mthly Avg Temp by Hour in 2004



Mthly Avg Relative Humidity by Hour in 2004



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

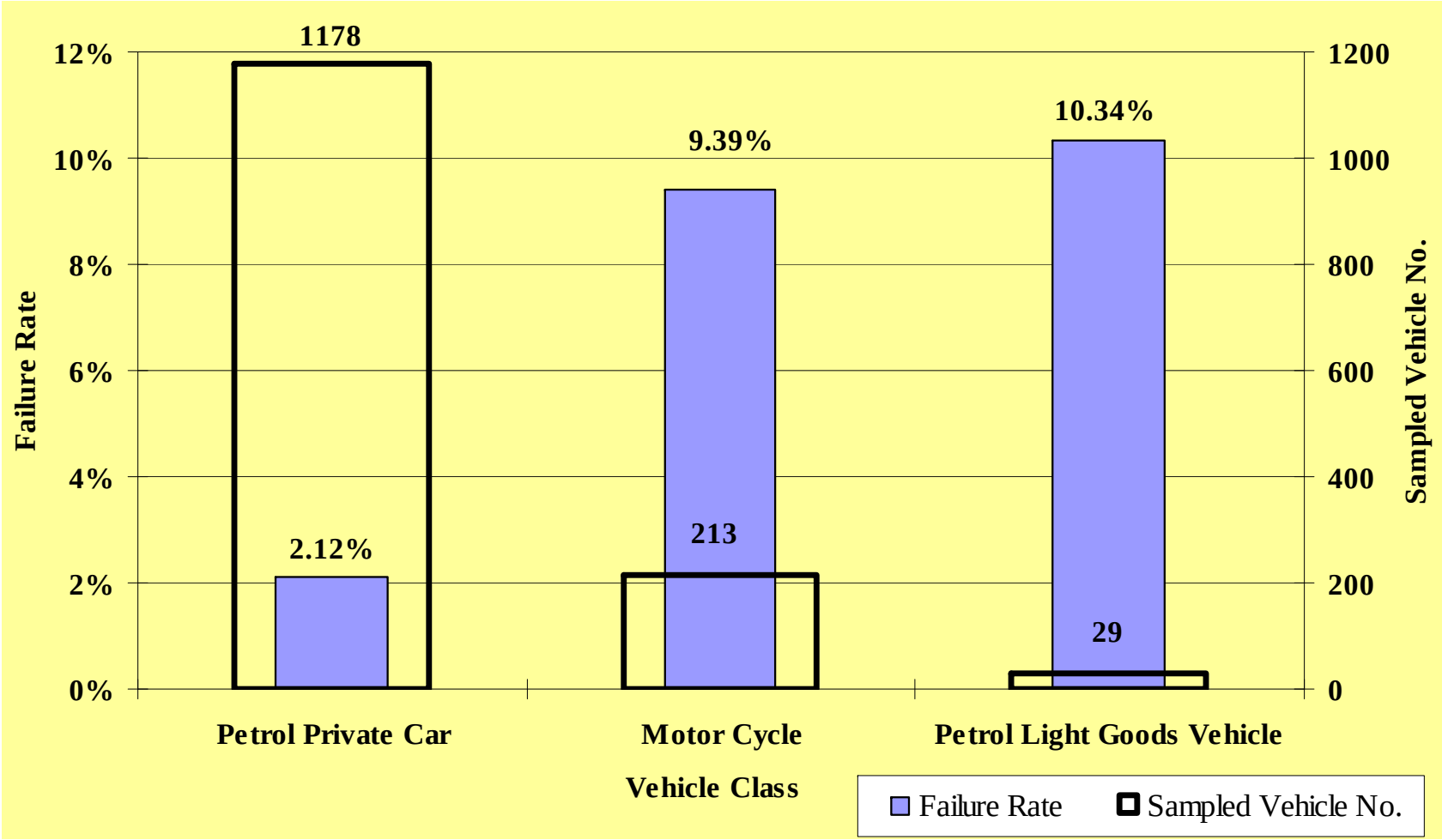
Petrol filling station

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 2006



Comparison of EMFAC-HK V2.1 & V1.2 (con't)

EMFAC-HK V1.2	**EMFAC-HK V2.1**
LPG vehicles were newly introduced. With the absence of measurement and remote sensing data, their deterioration rates and their growth of high and super emitters over age were derived by making reference to petrol vehicles with similar vehicle weight in EMFAC2002.	We have incorporated the excessive emissions of poorly maintained petrol and LPG vehicles, which have been estimated based on our emission measurement data by PEMS equipment and remote sensing equipment.
No inspection and maintenance (I/M) programs	I/M programs for taxis, private cars, light buses and goods vehicles from 2013 (a separate executable from 2013 onwards to reflect that)
Before 2004, TD restricted the gross vehicle weight (GVW) of light buses (LB) up to 4 tonne, therefore, in V1.2 vehicles class <= 3.5 tonne is used.	In 2004, TD had relaxed its restriction on LB's GVW <= 5.5 tonne. The increase in GVW causes the transfer of our data to heavy weighted vehicle class (3.86-6.36 tonnes in EMFAC-HK).

Comparison of EMFAC-HK V2.1 & V1.2 (con't)

EMFAC-HK V1.2	**EMFAC-HK V2.1**
The emission rates were chosen from those in U.S. models including MOBILE5/6, EMFAC2002.	The emission rates and deterioration rates were chosen from those in U.S. models including EMFAC207, MOBILE5/6 and MOVES based on our local vehicle emission data measured by PEMS.

Vehicles Used for Updating the EMFAC Model

Vehicle Class	Fuel Type	Emission Standard					Total
		Pre-Euro	Euro I	Euro II	Euro III	Euro IV	
Cars	**Petrol**			2	8	11	21
Taxis	**LPG**			3	4	4	11
Public light buses	**LPG**				4	3	7
	Diesel			1		1	2
Light goods vehicles <= 5.5t	**Diesel**	4	1	3	11	8 (inc. 1 Euro V)	27
Heavy goods vehicles > 5.5t	**Diesel**	1		3	11	5 (inc. 1 Euro V)	20
Single Deck Coaches	**Diesel**				5	7	12
Franchised Buses (w DPF)	**Diesel**			2	1		3
Total		5	1	14	44	39	103

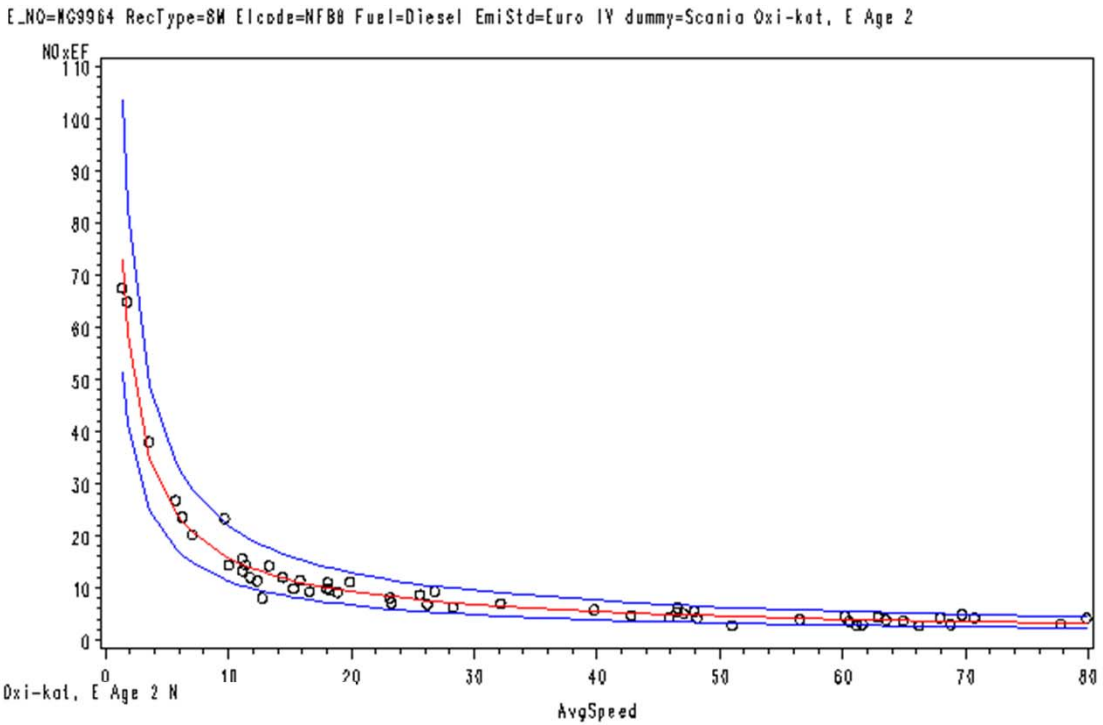
Euro III & IV Diesel Vehicles Used for Updating the EMFAC Model

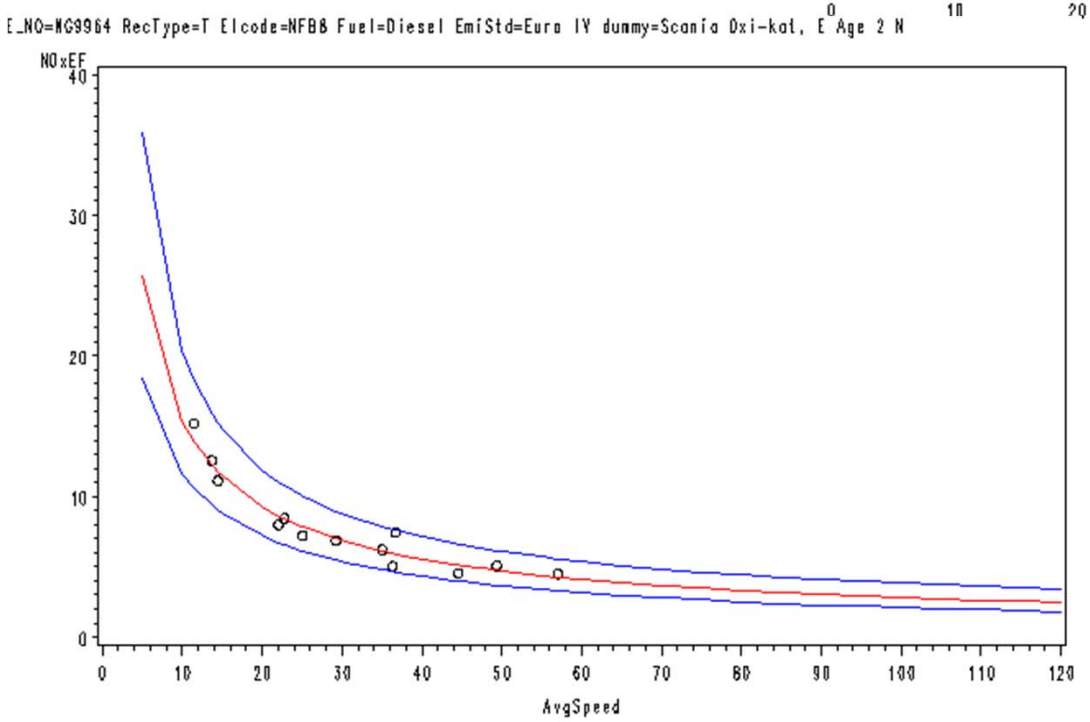
Vehicle Class	Euro III				Euro IV				
	Nil	DOC	DOC & EGR	EGR	DOC & EGR	POC & DOC, EGR	DPF	DPF & EGR	SCR
Public light buses								1	
Light goods vehicles <= 5.5 t		3	8			4		3	
Heavy goods vehicles > 5.5t	5	1	4	1	1	2		1	
Single Deck Coaches	1		3	1	1		1		5
Total	6	4	15	2	2	6	1	5	5

Statistical Analysis

- Calculated emission factors at 1-minute, 8-minute and 1-hour intervals of PEMS data for each vehicle
- Conducted statistical analysis on the emission factors (in g/km) by linear and non-linear models (PROC REG & PROC NLIN)
- Used the estimated trend lines and 95% confidence intervals to estimate the emissions at average speeds of FTP/UC/UDDS cycles
- Selected the estimate with the smallest confidence interval for each test vehicle

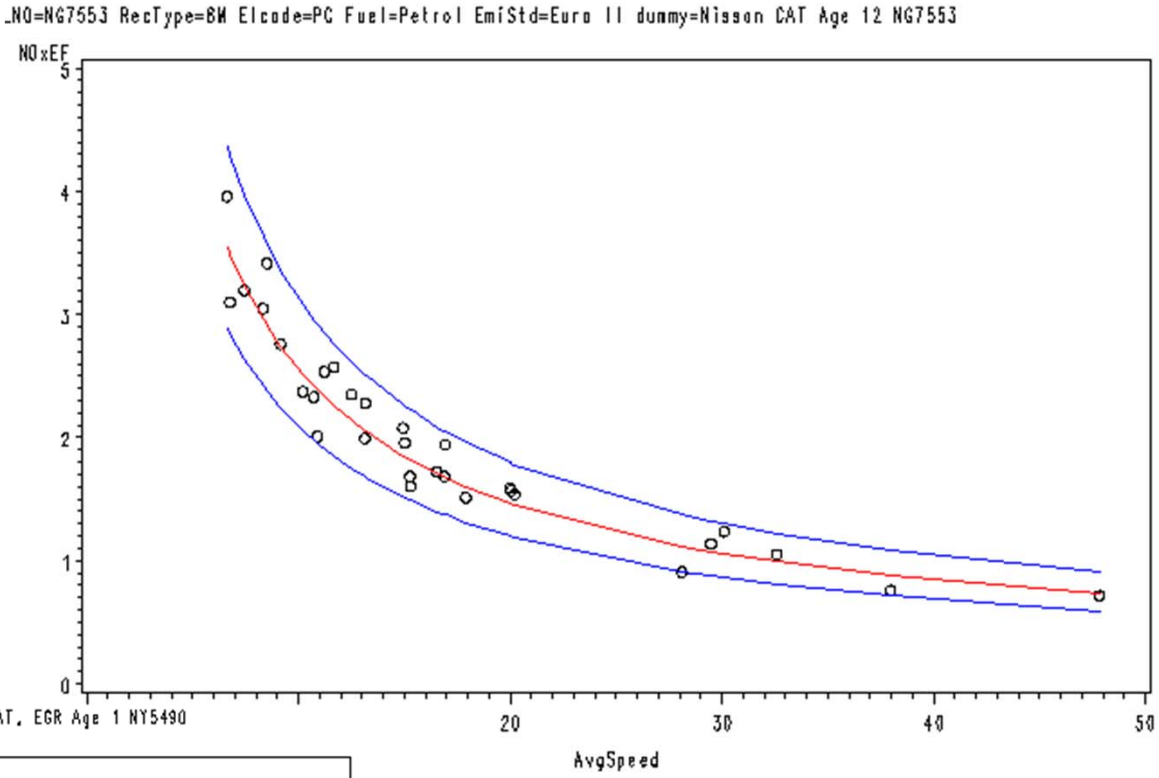
A Euro IV Single deck coach, NOx emission factors averaged over 8-minute intervals

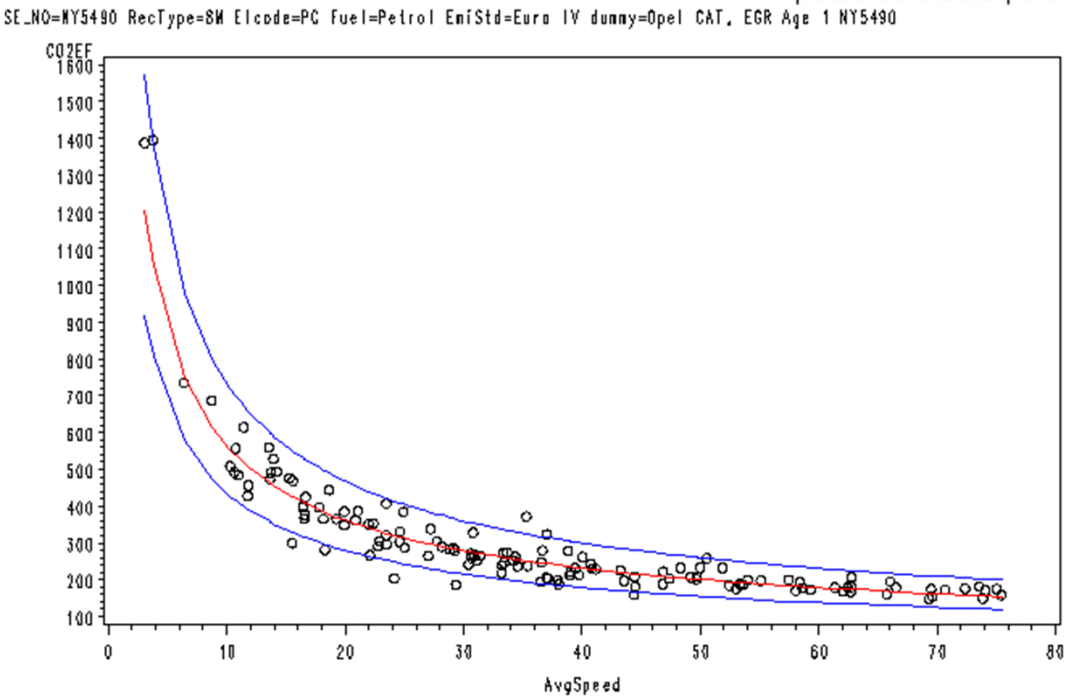




The same Euro IV Single deck coach, NOx emission factors averaged over 1-hour intervals

Petrol Car, Euro II, NOx emission factors averaged over 8-minute intervals





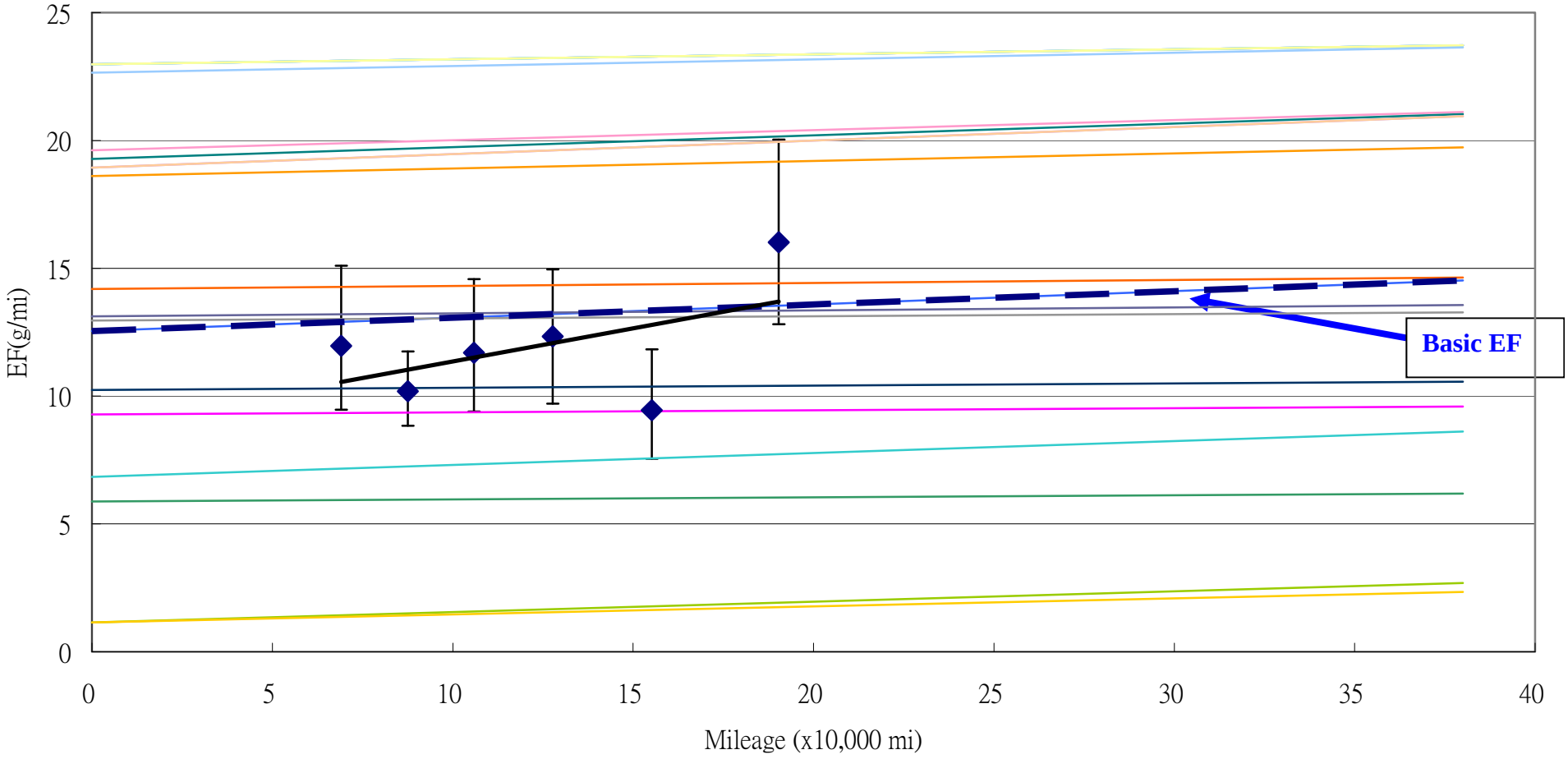
Petrol Car, Euro IV, CO2 emission factors averaged over 8-minute intervals

Matching of Technologies

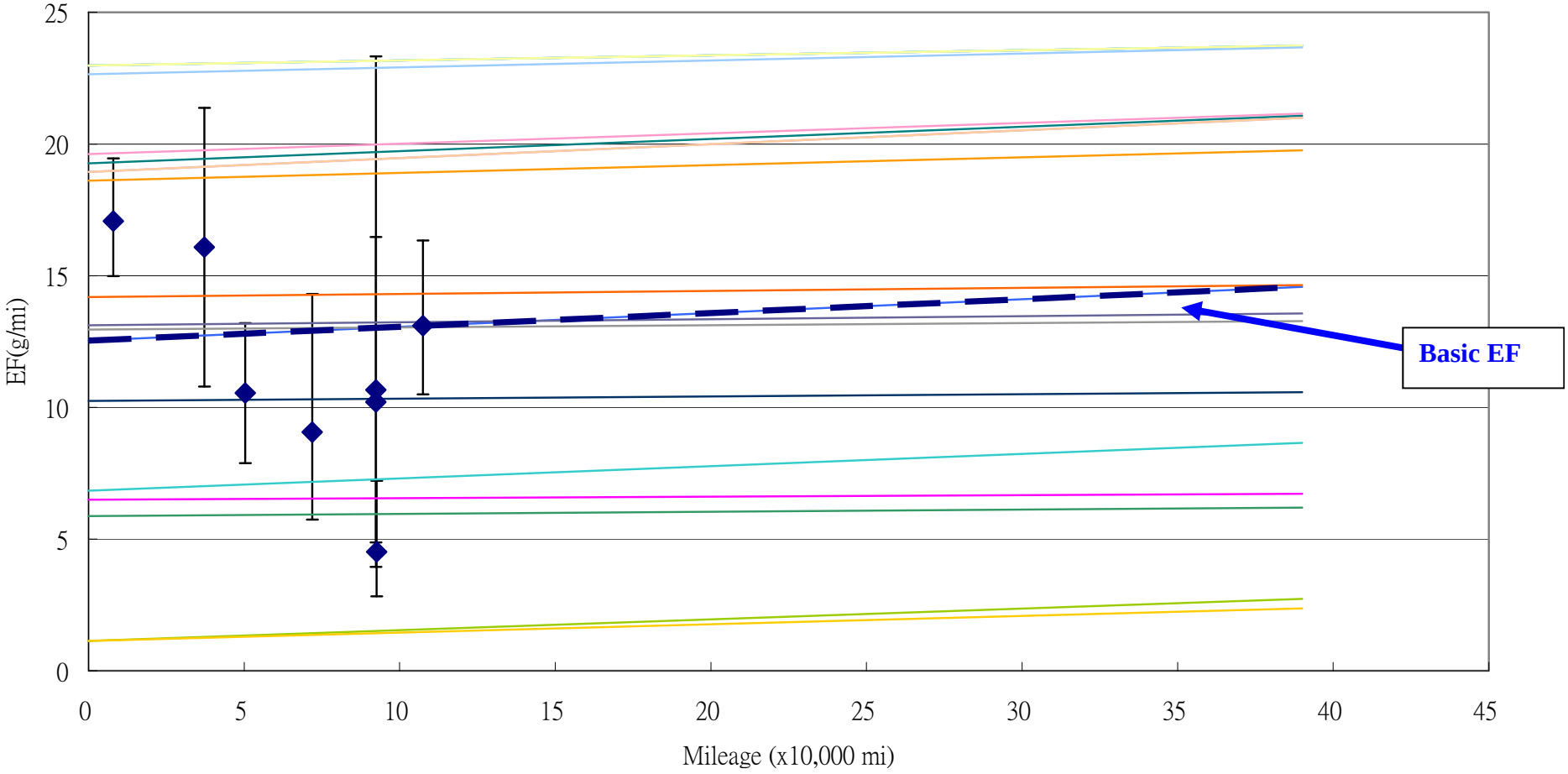
	Euro I	Euro II	Euro III	Euro IV
Petrol cars	1995	1997	2001	2006
Diesel vehicles	1995	1997	2002	2007

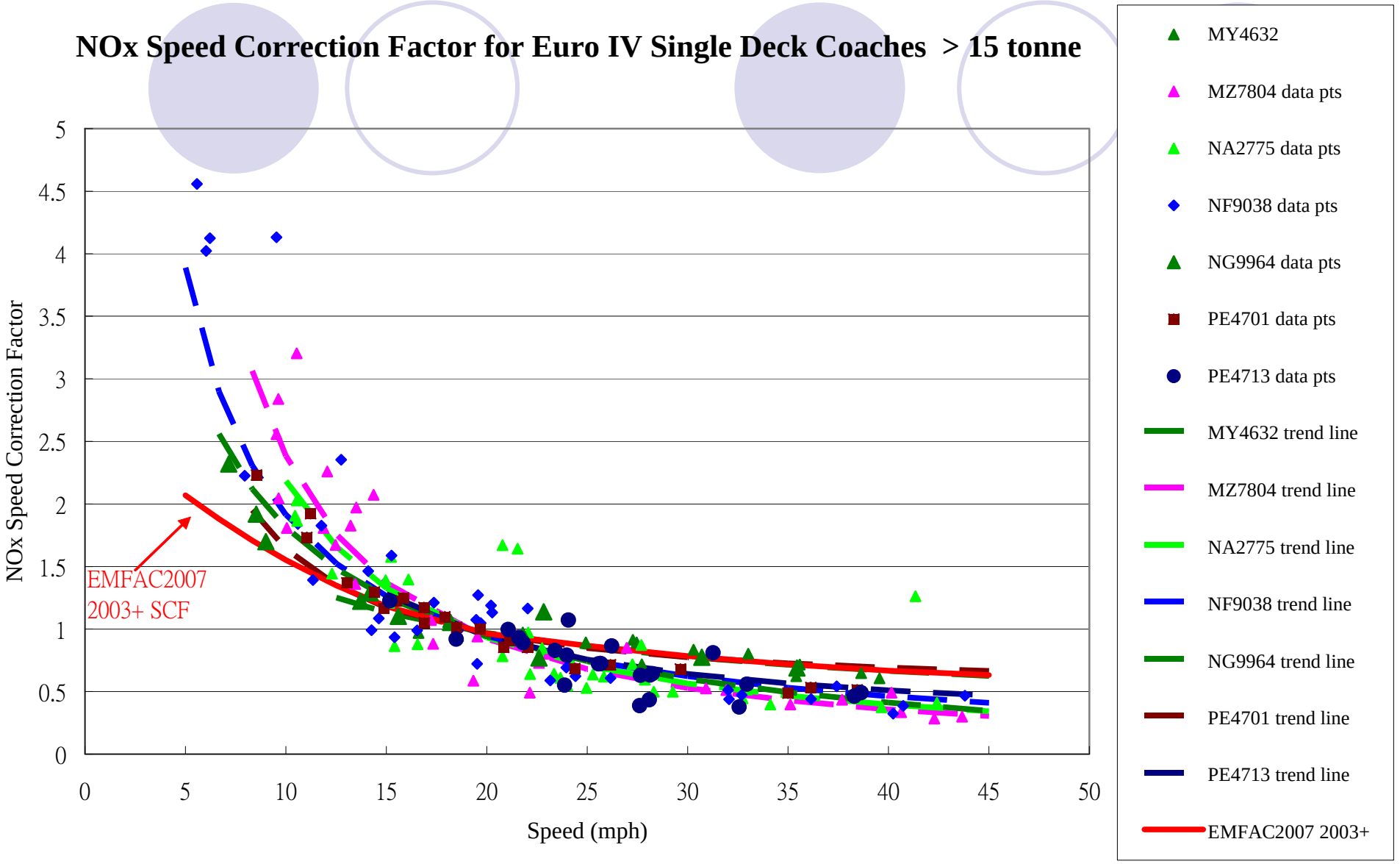
- Referencing to the emission factors just obtained, selected zero mile emission factors and deterioration rates in Mobile 5/6, and EMFAC2009
- CO2 emission factors by class are the average of PEMS emission factors over all Euro stds of that class
- If no emission factors for a particular Euro std or vehicle class, estimates are based on the ratio of emission standards and by U.S. conversion factors.

NOx emission factors for Euro III Heavy Goods Vehicles of 5.5-15t
MOBILE6 Medium-Heavy Duty Trucks 8.85-15t (MHDT) 1998-2003



NOx emission factors for Euro IV Single Deck Coaches = >15 tonne; 2003-2006, Heavy-Heavy Duty Trucks (HHDV-LHV), diesel, 2003-06, CA 2g NOx Stds





Each data pt is NOx emission factor averaged over 1-hour interval in this case


Thank you.
MARKS & SPENCER
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703
Central
6X
TAXI
TAXI