



# Upgrades of EMFAC-HK

*Dr. Carol Wong  
Senior Environmental Protection Officer  
Environmental Protection Department  
Hong Kong SAR Government, China  
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# Vehicle Classification Chart

V3.1 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

# HK Stds & Implementation Dates

HK Imple. Dates		Pre - Euro			Euro I		Euro II		
Vehicle Class		Pre - ULP	ULP	Diesel	Petrol	Diesel	LPG	Petrol	Diesel
<b>Private Car</b>		< 1.1.92	1.1.92					1.4.97	1.4.98
<b>Goods Vehicle</b>	<= 2.5 t	1.1.92		< 1.4.95	1.4.95	NA	NA	1.10.98	
	2.5 t - 3.5 t	< 1.4.95	NA						
<b>Light Bus</b>	<= 3.5 t								
	> 3.5 t								
<b>Goods Vehicle &amp; Other Bus &gt; 3.5 t</b>		< 1.4.95					1.4.97		
<b>Taxi</b>		< 1.1.92	1.1.92	< 1.1.96	1.4.95	1.1.96	1.8.01	1.10.98	1.7.99
<b>Motorcycle</b>		< 1.10.99			1.10.99		NA		

# HK Stds & Implementation Dates

HK Imple. Dates		Euro III			Euro IV			Euro V		
Vehicle Class		LPG	Petrol	Diesel	LPG	Petrol	Diesel	LPG	Petrol	Diesel
<b>Private Car</b>		NA	1.1.01		NA	1.1.06		NA	1.6.12	
<b>Goods Vehicle</b>	<= 2.5t		1.1.02			1.1.07			1.6.12	
	> 2.5t - 3.5t									
<b>Light Buses</b>	<= 3.5t	1.8.03	1.1.02		1.1.07			1.6.12		
	> 3.5t		1.10.01	1.8.03	1.10.06					
<b>Goods Vehicle &amp; Other Bus &gt; 3.5t</b>		NA	1.10.01		NA	1.10.06		NA	1.6.12	
<b>Taxi</b>		1.8.03	1.1.01	NA (fr. 1.8.01)	1.1.06	NA		1.6.12		NA
<b>Motorcycle</b>		1.1.07 <sup>^</sup>								

*Notes: ^ All new motorcycle models are required to comply with Euro III emission standards on this date. From 1 January 2009, all motorcycles are required to meet Euro III emission standards.*

# HK Stds & Implementation Dates

Not Applied  
to Beta Yet!

HK Imple. Dates		Euro VI*		
Vehicle Class		LPG	Petrol	Diesel
Private Car			1.9.16	1.9.16
Goods Veh	<= 3.5t	NA	1.1.17	1.1.17
	>3.5 t			
Bus	<= 7 t	NA	1.1.18	1.1.18
	>7 t		1.1.17	1.1.17
	> 3.5 t			
Light Bus	<= 3.5t	1.1.17		
	>3.5 t	1.1.18		
Taxi		1.9.16		NA

*Notes: \* The implementation dates are for the purpose of assessment only.*

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## Exhaust technology groups (Tech Group)

- 23 New Tech Groups
- 2 Tech Groups Removed
- 45 Tech Group Descriptions Revised  
(Some with definition changes)

## 23 New Tech Groups

## Exhaust Tech Group Indexes

Fuel Type	Vehicle Class	Vehicle Emission Standards	EPD Version 3.1	TG_FracMYr
Diesel	HGV7	Euro IV - POC	136	2006-2012
Diesel	HGV7	Euro V - DPF & SCR	138	2012-2016
Diesel	HGV7	Euro V - SCR	137	2012-2016
Diesel	HGV8	Euro IV - DPF	163	2006-2012
Diesel	HGV8	Euro IV - SCR	164	2006-2012
Diesel	HGV8	Euro V - DPF	165	2012-2016
Diesel	HGV8	Euro V - SCR	166	2012-2016
Diesel	LGV3/LGV4	Euro V - DPF	196	2013-2017
Diesel	LGV6	Euro IV - POC	119	2006-2012
Diesel	LGV6	Euro V - DPF & SCR	139	2012-2016
Diesel	NFB7	Euro IV - SCR	93	2006-2012
Diesel	NFB8	Euro IV - DPF	63	2006-2012
Diesel	NFB8	Euro IV - SCR	64	2006-2012
Diesel	NFB8	Euro V - DPF	65	2012-2016
Diesel	NFB8	Euro V - SCR	66	2012-2016
Diesel	PC	Euro V - DPF & SCR	174	2012-2015
Diesel	PC	Euro VI	177	2016-09+
LPG	PLB	Euro III CAT Replaced	56	pre-2006
LPG	PLB	Euro IV & V CAT Replaced	58	2006-2012
LPG	PV5	Euro V CAT Replaced	142	2012-2015
LPG	TAXI	Euro III CAT Replaced	19	2003-2005
LPG	TAXI	Euro IV CAT Replaced	20	2006-2011
LPG	TAXI	Euro V & VI CAT Replaced	21	2012+

Not Applied to Beta Yet!

## 2 Tech Groups are Removed

Fuel Type	Vehicle Class	Vehicle Emission Standards	EPD Version 3.1	TG_FracMYr
LPG	PLB	Euro V	51	2012-2017
LPG	TAXI	Euro II	14	pre-2003

45 New Tech Groups with Descriptions Revised

Fuel Type	Vehicle Class	Vehicle Emission Standards	EPD Version 3.1	TG_FracMYr
Diesel	FBDD	pre-Euro DOC Retrofitted	217	pre-1995
Diesel	FBDD	Euro I DOC Retrofitted	219	1995-1997
Diesel	FBDD	Euro I DPF Retrofitted	225	1995-1997
Diesel	FBDD	Euro II DPF & SCR Retrofitted	228	1997-2001
Diesel	FBDD	Euro II DPF Retrofitted	221	1997-2001
Diesel	FBDD	Euro II VEC Retrofitted	227	1997-2001
Diesel	FBDD	Euro III DPF & SCR Retrofitted	229	2001-2006
Diesel	FBDD	Euro III DPF Retrofitted	223	2001-2006
Diesel	FBSD	pre-Euro DOC Retrofitted	107	pre-1995
Diesel	FBSD	Euro I DOC Retrofitted	109	1995-1997
Diesel	FBSD	Euro I DPF Retrofitted	115	1995-1997
Diesel	FBSD	Euro II DPF & SCR Retrofitted	230	1997-2001
Diesel	FBSD	Euro II DPF Retrofitted	111	1997-2001
Diesel	FBSD	Euro II VEC Retrofitted	117	1997-2001
Diesel	FBSD	Euro III DPF & SCR Retrofitted	231	2001-2006
Diesel	FBSD	Euro III DPF Retrofitted	113	2001-2006
Diesel	HGV7	pre-Euro DOC Retrofitted	124	pre-1995
Diesel	HGV7	Euro IV - DPF	130	2006-2012
Diesel	HGV7	Euro V - DPF	131	2012-2016
Diesel	HGV8	pre-Euro DOC Retrofitted	155	pre-1995
Diesel	LGV3	pre-Euro DOC Retrofitted	180	pre-1995
Diesel	LGV3	pre-Euro Traps Retrofitted	179	pre-1995



45 New Tech Groups with Descriptions Revised (Con't)

Fuel Type	Vehicle Class	Vehicle Emission Standards	EPD Version 3.1	TG_FracMYr
Diesel	LGV4	pre-Euro Traps Retrofitted	179	pre-1995
Diesel	LGV6	pre-Euro DOC Retrofitted	121	pre-1995
Diesel	LGV6	Euro IV - DPF	132	2006-2012
Diesel	LGV6	Euro V - DPF	133	2012-2016
Diesel	NFB6	pre-Euro DOC Retrofitted	91	pre-1995
Diesel	NFB7	pre-Euro DOC Retrofitted	44	pre-1995
Diesel	NFB7	Euro IV - DPF	100	2006-2012
Diesel	NFB8	pre-Euro DOC Retrofitted	55	pre-1995
Diesel	PC	pre-Euro DOC Retrofitted	172	pre-1995
Diesel	PC	pre-Euro Traps Retrofitted	171	pre-1995
Diesel	PC	Euro V - SCR	175	2012-2015
Diesel	PLB	pre-Euro DOC Retrofitted	188	pre-1995
Diesel	PLB	pre-Euro Traps Retrofitted	187	pre-1995
Diesel	PV4	pre-Euro DOC Retrofitted	80	pre-1995
Diesel	PV4	pre-Euro Traps Retrofitted	79	pre-1995
Diesel	PV5	pre-Euro DOC Retrofitted	88	pre-1995
Diesel	PV5	pre-Euro Traps Retrofitted	87	pre-1995
Diesel	TAXI	pre-Euro DOC Retrofitted	72	pre-1996
Diesel	TAXI	pre-Euro Traps Retrofitted	71	pre-1996
LPG	PLB	Euro IV & V	50	2006-2012
LPG	PV5	Euro III CAT Replaced	140	pre-2006
LPG	PV5	Euro IV CAT Replaced	141	2006-2012

# 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
<b>Total</b>		9	6	26	89	73	32	7	<sup>10</sup> 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						
<b>Total</b>	<b>7</b>	<b>13</b>	<b>31</b>	<b>2</b>	<b>3</b>	<b>13</b>	<b>6</b>	<b>13</b>	<b>10</b>	<b>4</b>

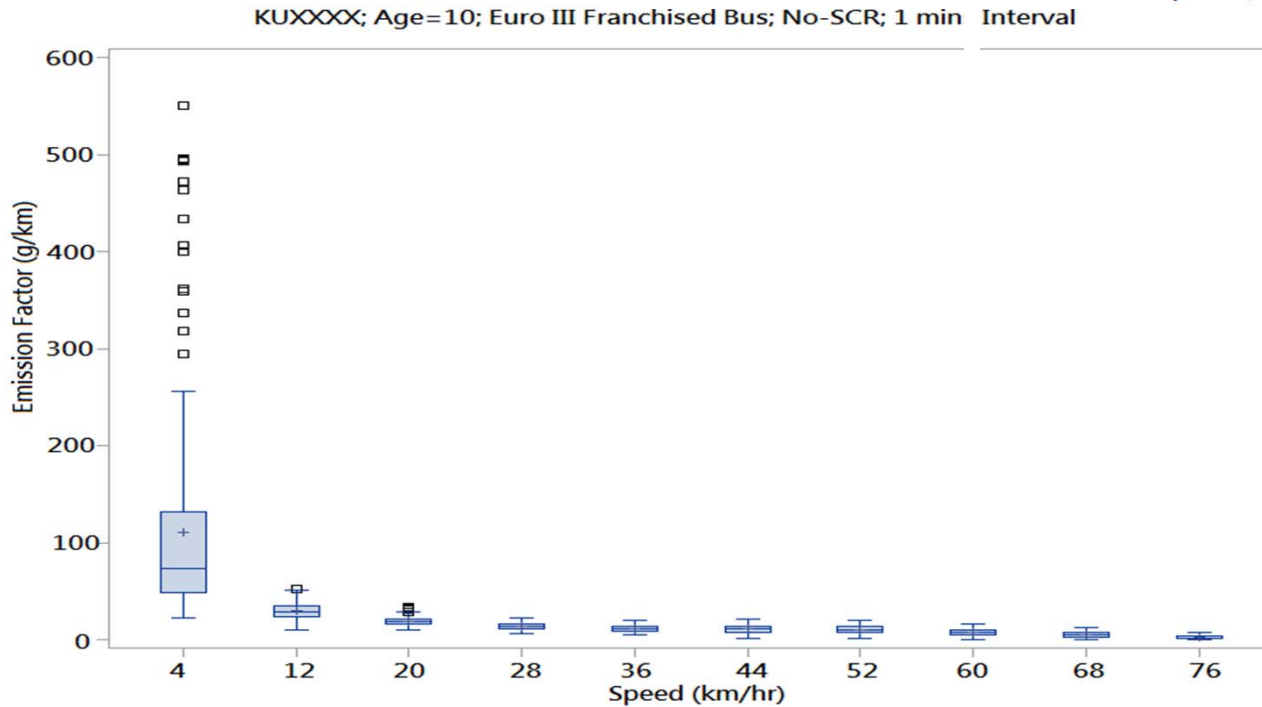
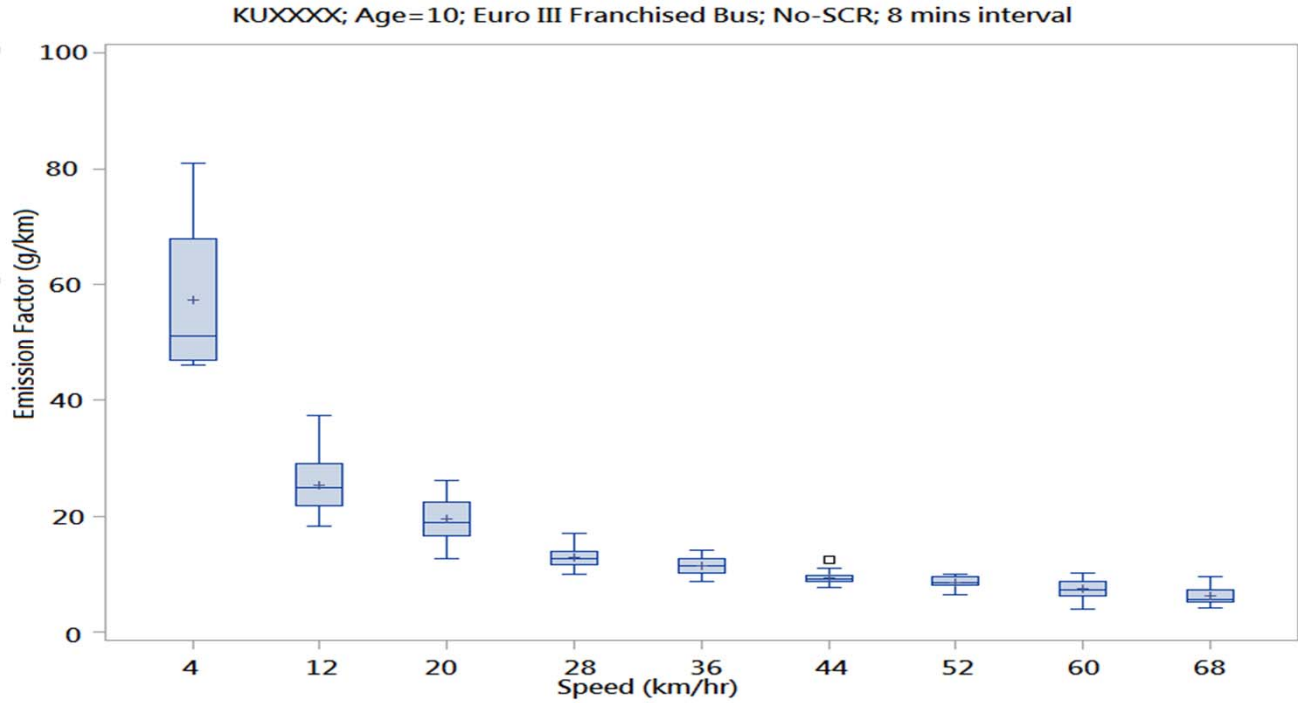
# Euro V & VI Diesel Vehicles Used for Updating the EMFAC-HK Model

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
<b>Total</b>	<b>1</b>	<b>1</b>	<b>14</b>	<b>3</b>	<b>3</b>	<b>1</b>	<b>6</b> <sub>12</sub>

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

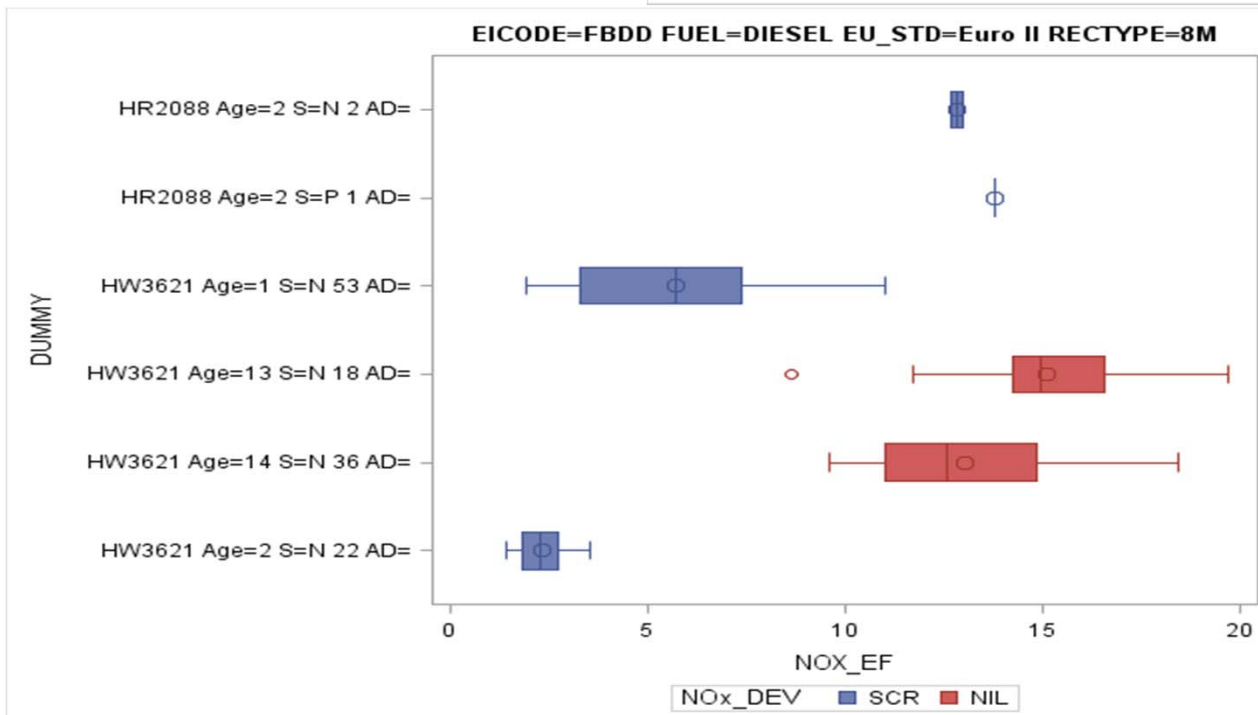
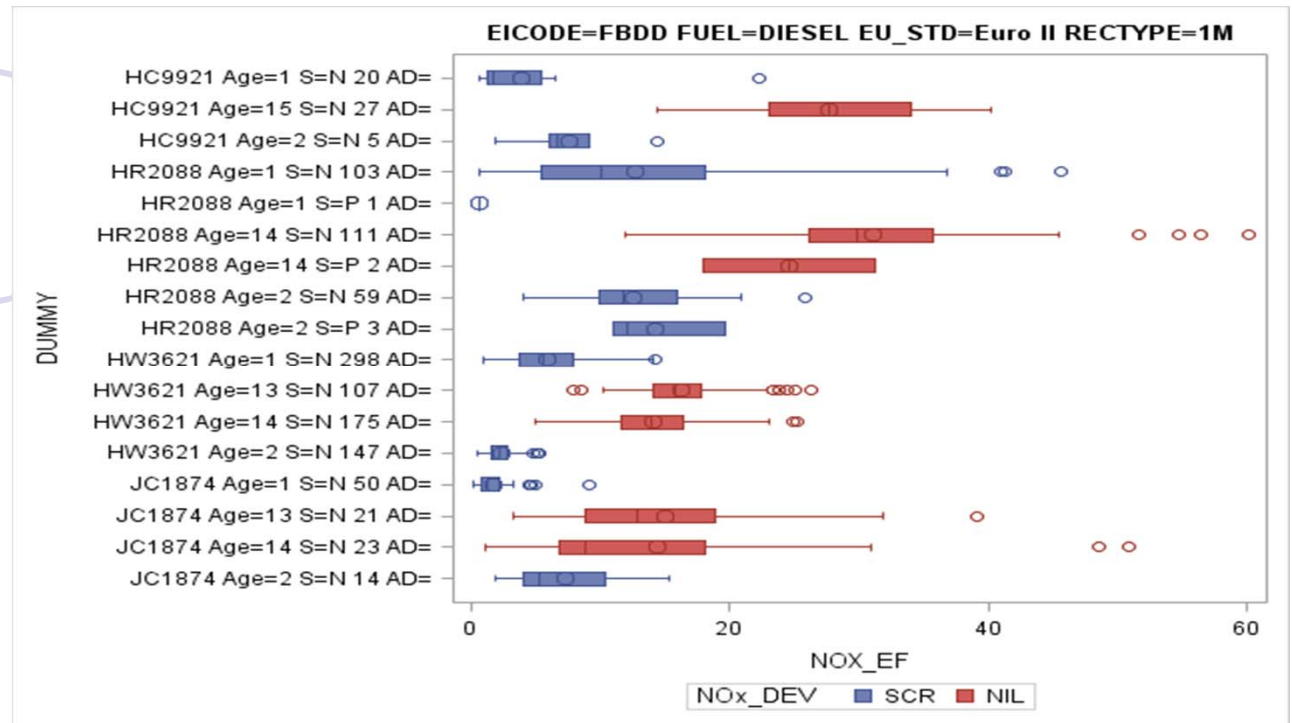
- Calculated emission factors (EF) at 1-minute, 8-minute and 1-hour averages of PEMS data of each vehicle;
- For each Tech Group, estimated the ZMEF and DR by median of EFs of vehicles at average speed between 25 km/hr and 35 km/hr.
- For Speed Correction Factors, conducted statistical analysis on the 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.

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



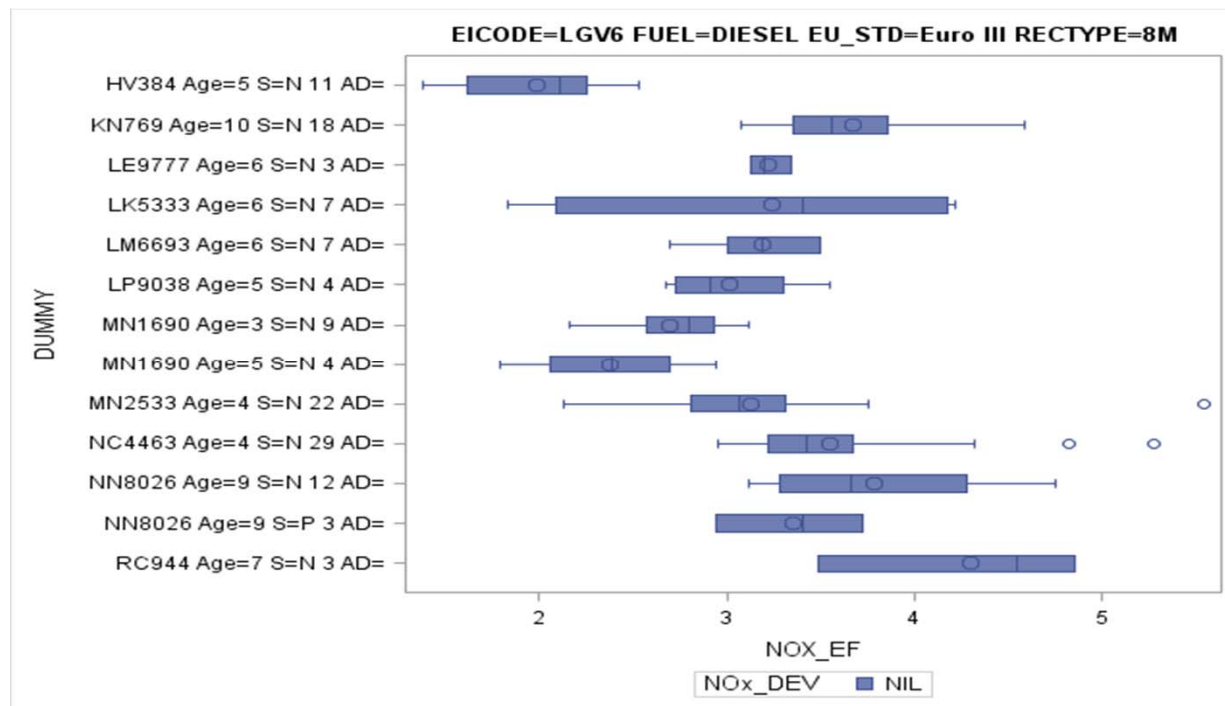
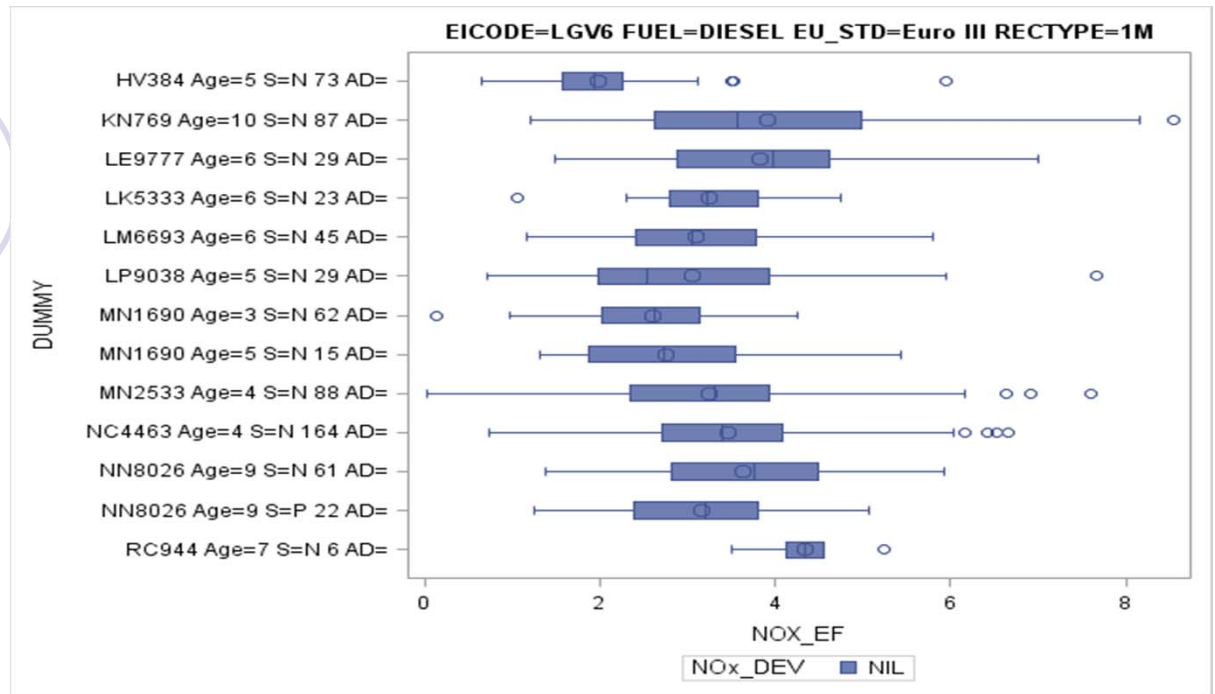
The same Euro III Franchised Bus: 1-minute average NOx emission factors

Euro II Franchised Bus:  
1-minute average NOx  
emission factors at  
average speed  
between 25 and 35  
km/hr.



Euro II Franchised Bus:  
8-minute average NOx  
emission factors at  
average speed between  
25 and 35 km/hr.

Light Goods Vehicles  
>3.5t, Euro III: 1-minute  
average NOx emission  
factors at average speed  
between 25 and 35  
km/hr.



Light Goods Vehicles  
>3.5t, Euro III: 8-minute  
average NOx emission  
factors at average speed  
between 25 and 35  
km/hr.



# Matching of Technologies

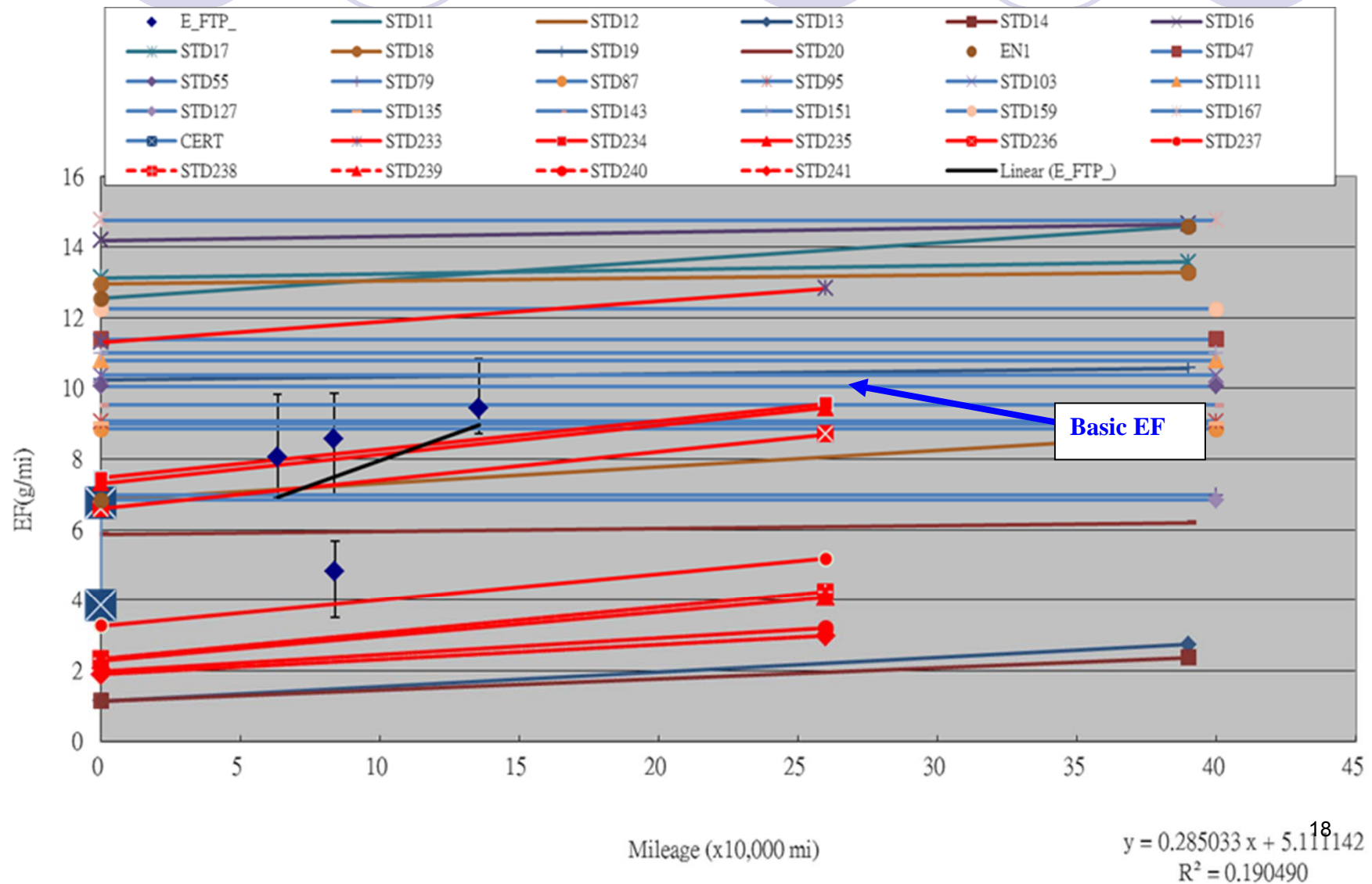
	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
Petrol cars	1995	1997	2001	2006	2012	2017
Goods vehicles	1995	1997	2002	2007	2012	2017
Buses	1995	1997	2002	2007	2012	2017/18

Not Applied to Beta Yet!

- Referencing to the emission factors just obtained, selected zero mile emission factors and deterioration rates in EU's COPERT, USEPA's MOBILE5/6, and CARB's EMFAC2007/2014
- CO2 emission factor for each vehicle class is estimated by first taking the median for sub-group of vehicles having similar GVWs, and then weighted average according to their populations
- If no emission factors for a particular Euro standard or vehicle class, estimates are based on the ratio of emission standards and by U.S. conversion factors.

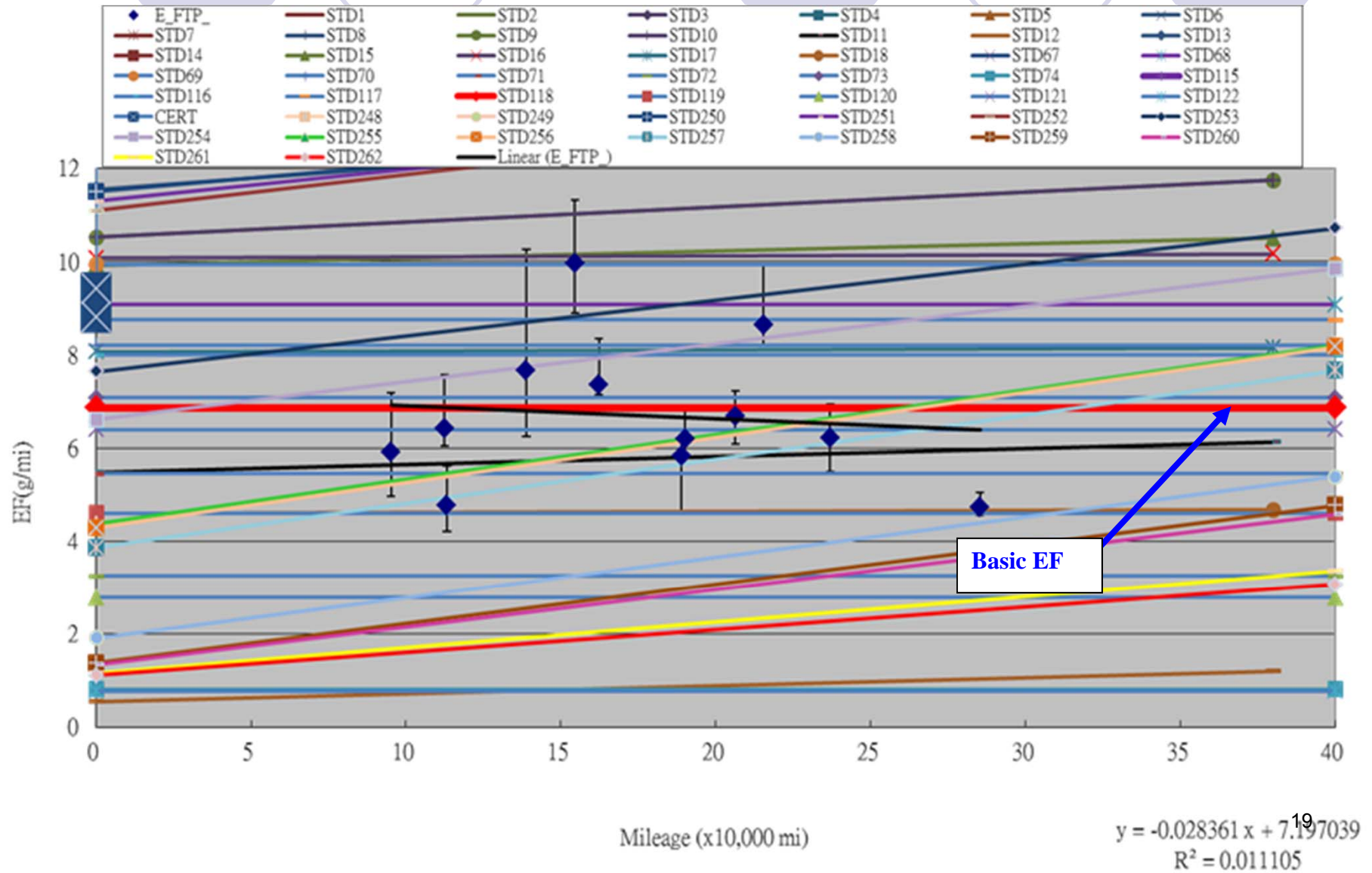
# NOx emission factors for Euro IV SCR Heavy Goods Vehicles > 15t and Non-Franchised Bus > 15t

EMFAC2014 Diesel HHDT 2008 for these vehicle classes is used.

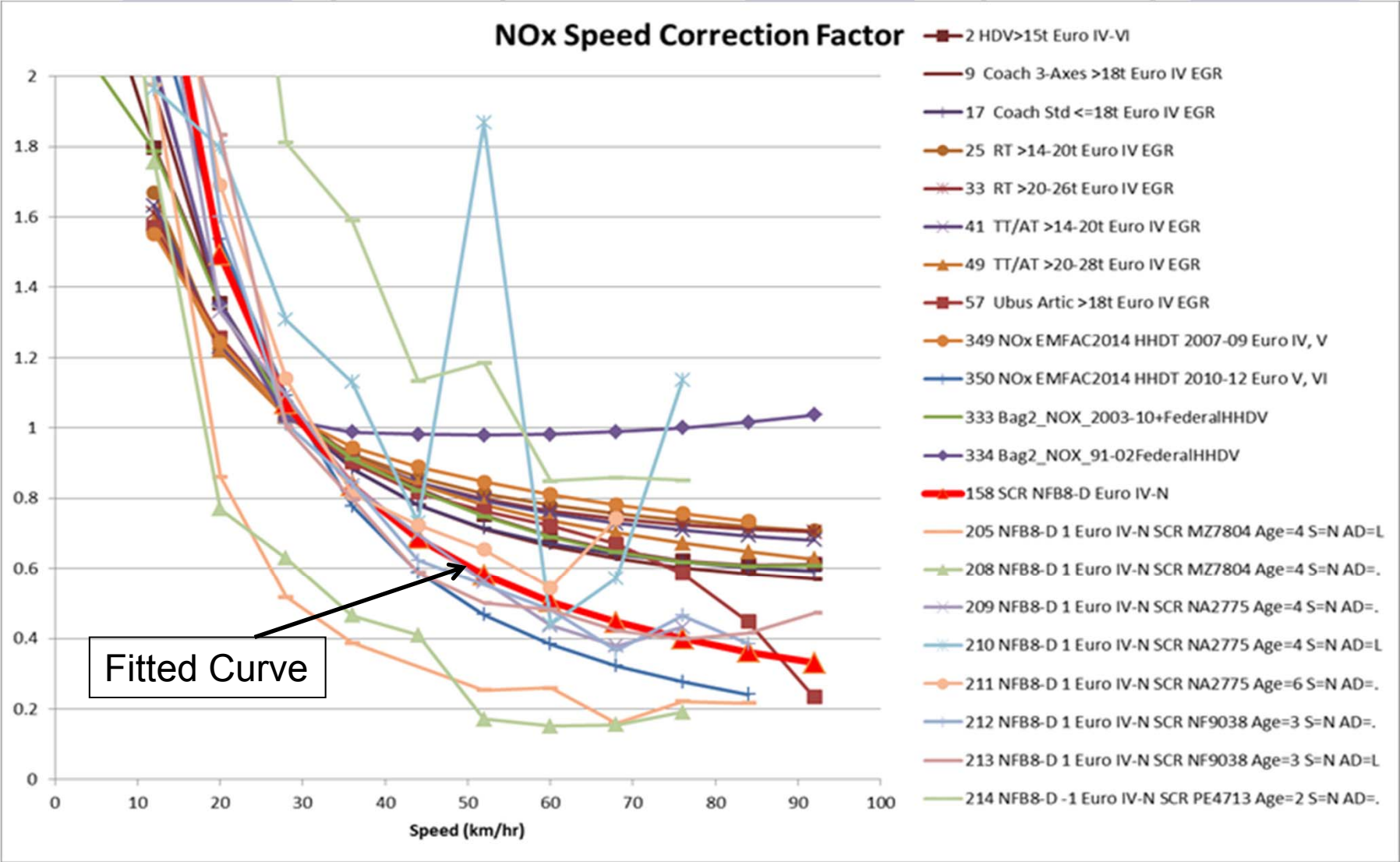


# NOx emission factors for Euro II & III Goods Vehicles 5.5-15t

COPERT RT > 7.5 – 12t Euro-III for this vehicle class is used.



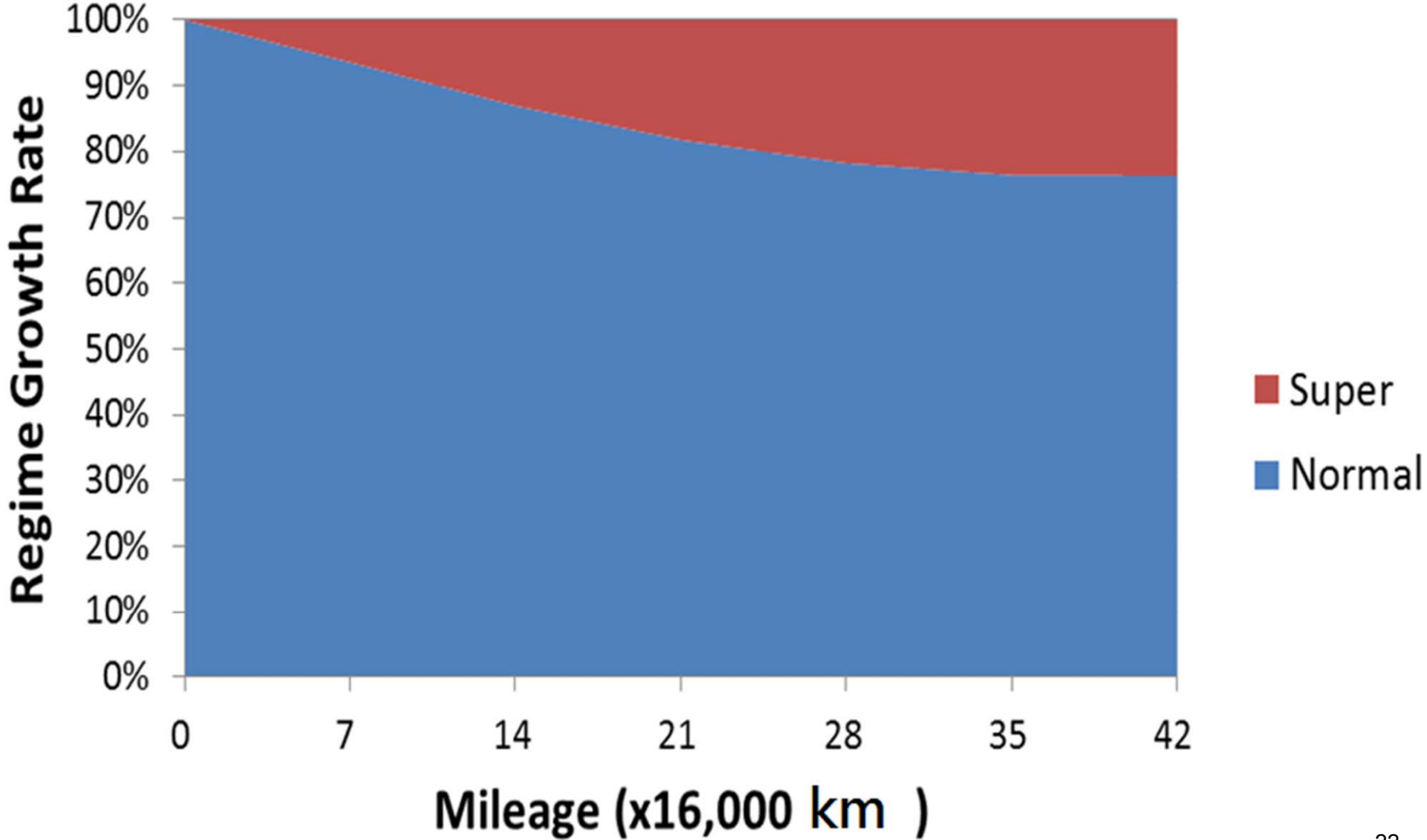
# NOx Speed Correction Factor: Euro IV Heavy Goods Vehicles and Non-Franchised Bus >15t with SCR



# Gross Emitter Model for Diesel Vehicles in Hong Kong

- Diesel vehicles were subdivided into 2 regimes:
  - normal & super
- For Pre-Euro IV diesel vehicles, the occurrences of super emitters are estimated from data from smoky vehicle program;
- For Euro IV+ diesel, references have been made to
  - USEPA's MOVES and CARB's EMFAC2007 update on tampering and malfunction
  - Euro VI's requirement on in-use compliance.

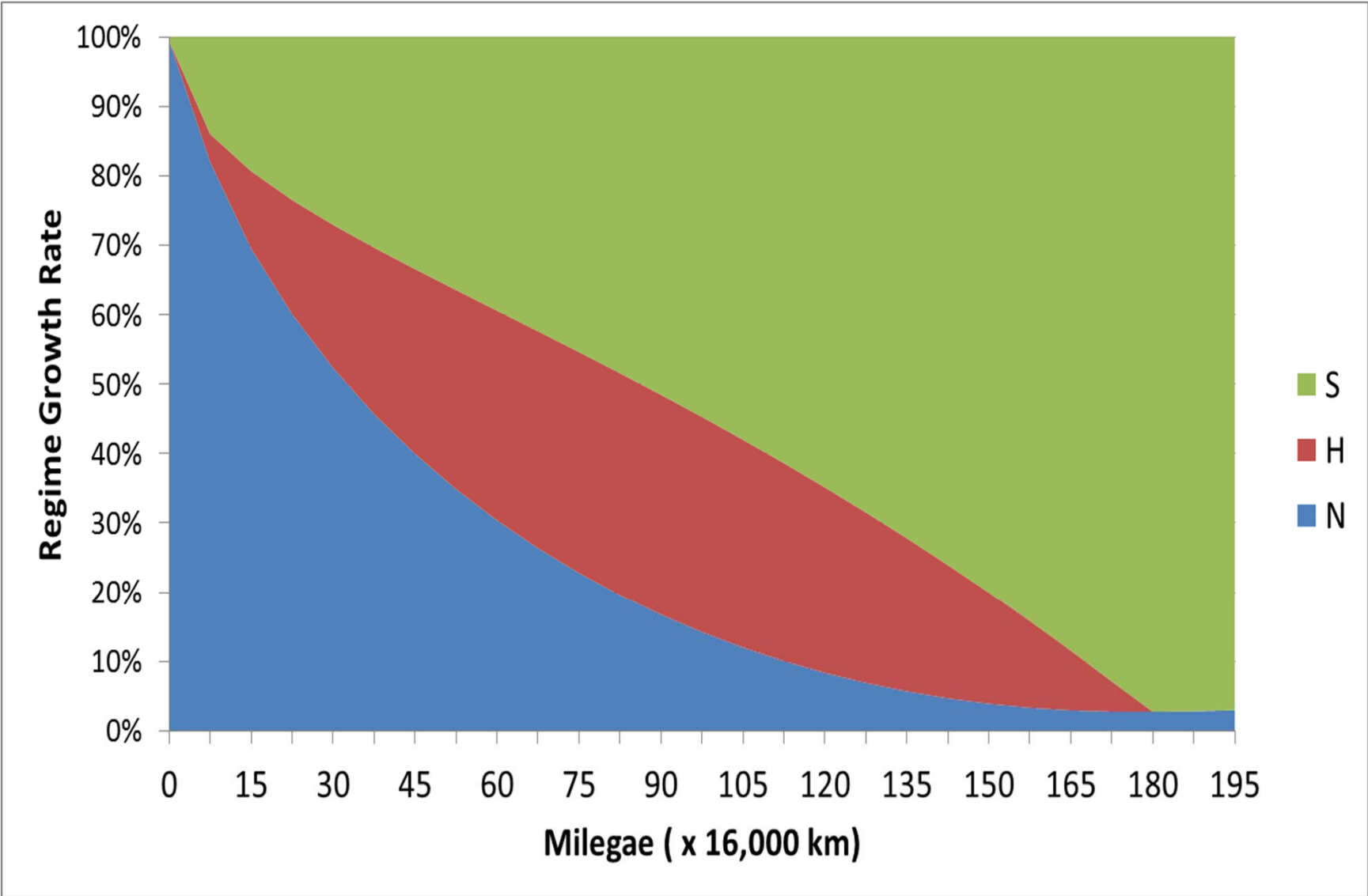
# NOx Regime Growth Rate for Euro IV, V Non-SCR - Heavy Goods Vehicle



# Gross Emitter Model for LPG/Petrol Vehicles in Hong Kong

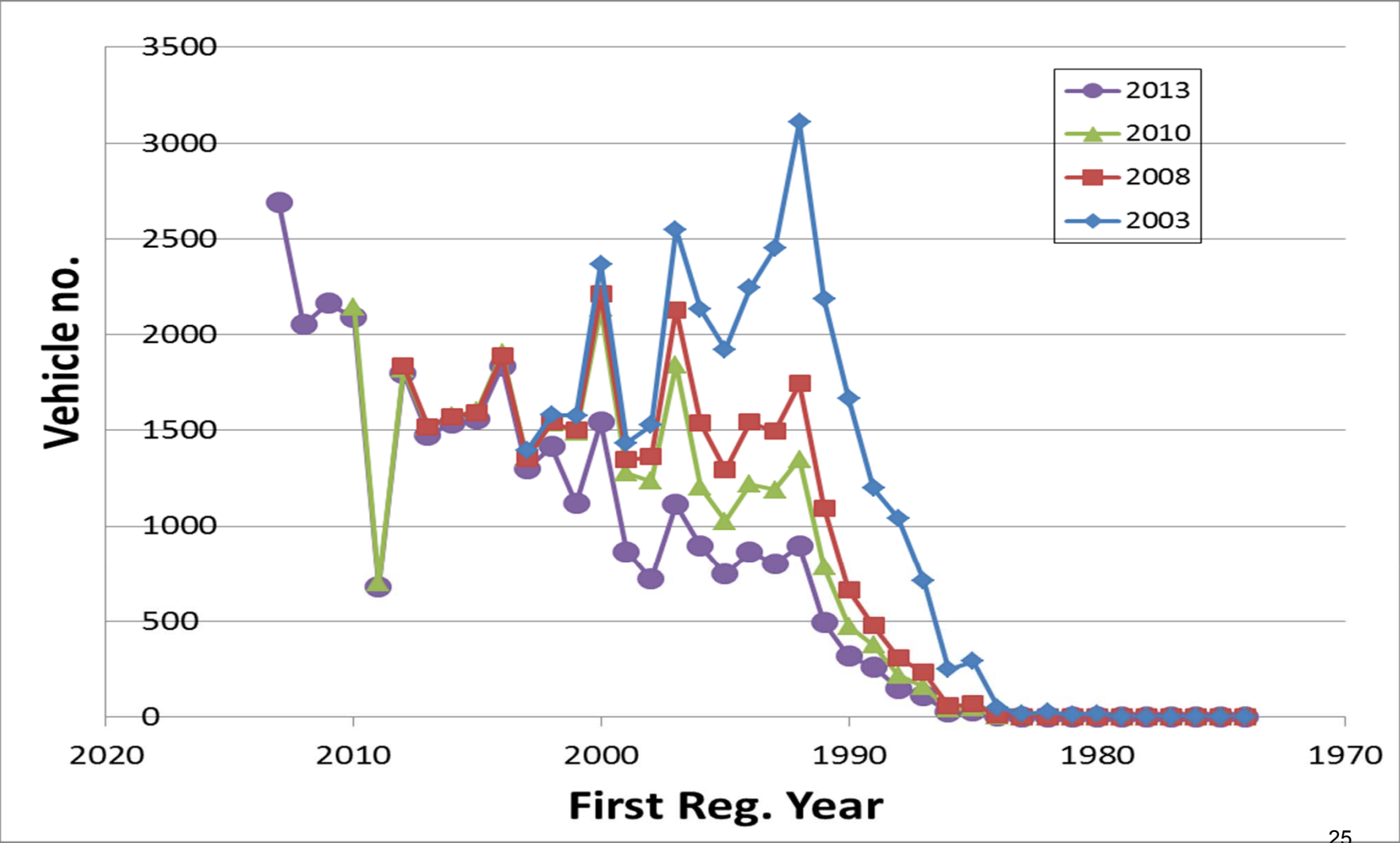
- LPG/Petrol vehicles were subdivided into 3 regimes:
  - normal, high & super
- The occurrences of high and super emitters are estimated from remote sensing data for LPG/petrol vehicles.

# LPG Taxi Regime Growth Rates





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



# Forecast of Vehicle Population

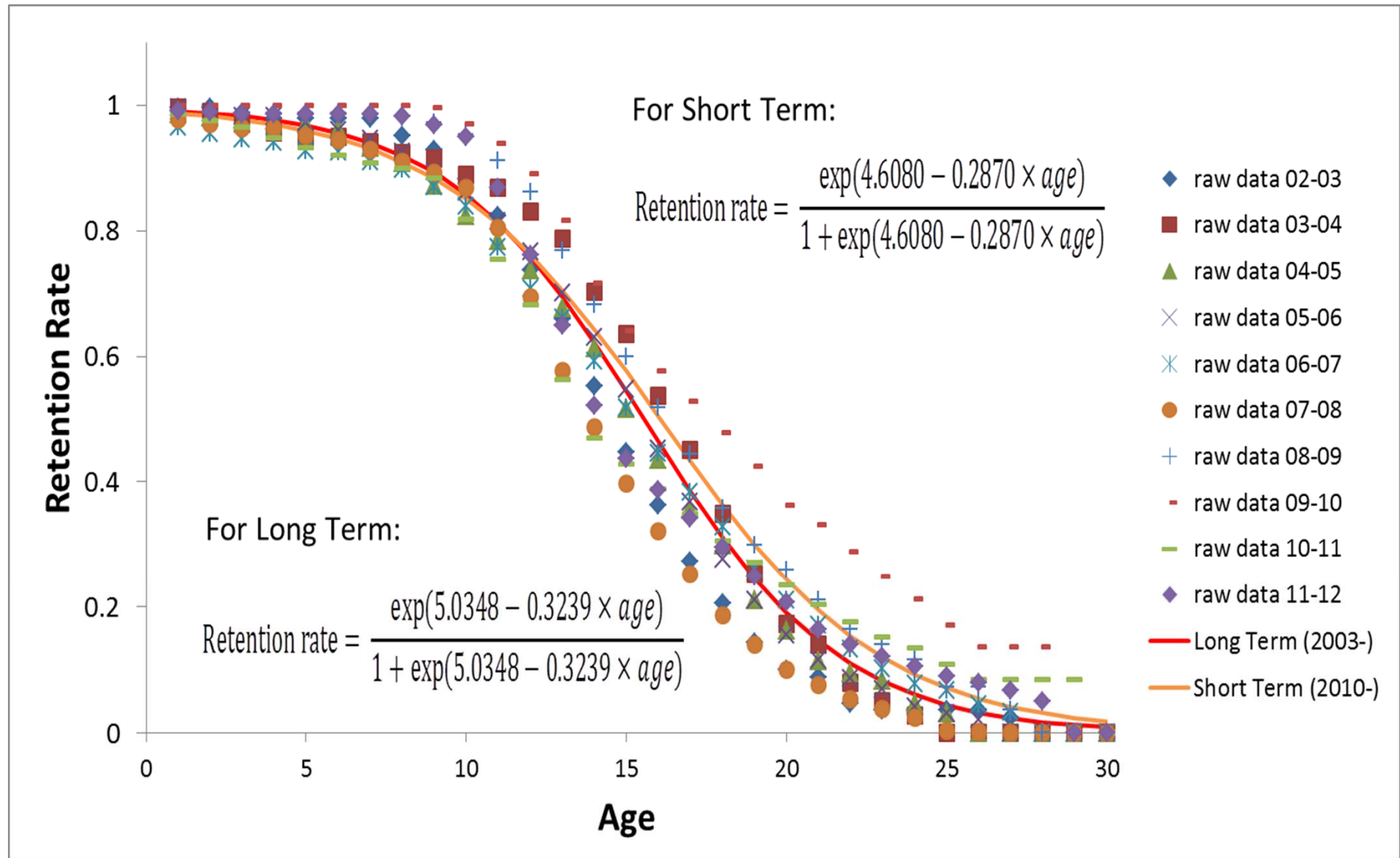
- EMFAC-HK uses the population of a specific model of vehicles for consecutive calendar years to derive a curve of the percentage of vehicles still remain in the fleet after a specified amount of time has elapsed – retention rate.
- Retention rates are then used to forecast vehicle population.
- Retention rates are used in EMFAC-HK for both forecasting to future calendar years and back-casting for those years where vehicle registration information is unavailable.

# Forecast of Vehicle Population (con't)

- Since EMFAC-HK V2.6, short-term and long-term retention rates are fitted from recent data (about 2009-2012) and all available data respectively.
- Short-term and long-term retention rates are used in forecasting for  $\leq 5$  years in the future and  $\geq 5$  years in the future, from the default base year, respectively.



# Retention Rates for Heavy-duty Goods Vehicles



# EMFAC-HK Population Growth Rates from TD

## EMFAC-HK V2.6

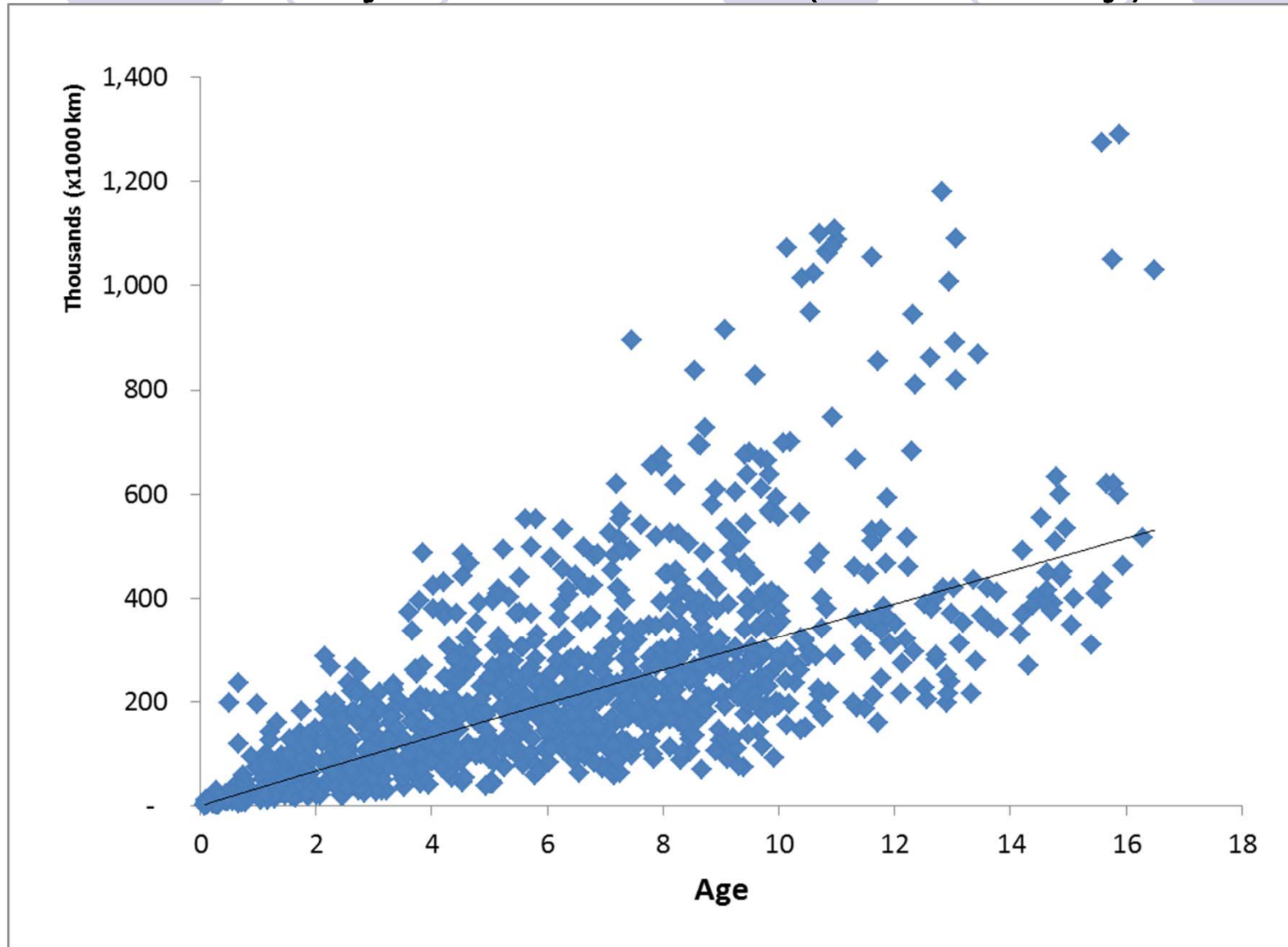
Year	Private Vehicles (private cars and motor cycles)	Goods Vehicles
	Average annual growth rates (up to the Year)	
2011	2.5%	0.0%
2016	2.0%	0.5%
2021	1.5%	0.5%
2026	1.5%	0.5%
2031	1.5%	0.5%

## EMFAC-HK V3.1

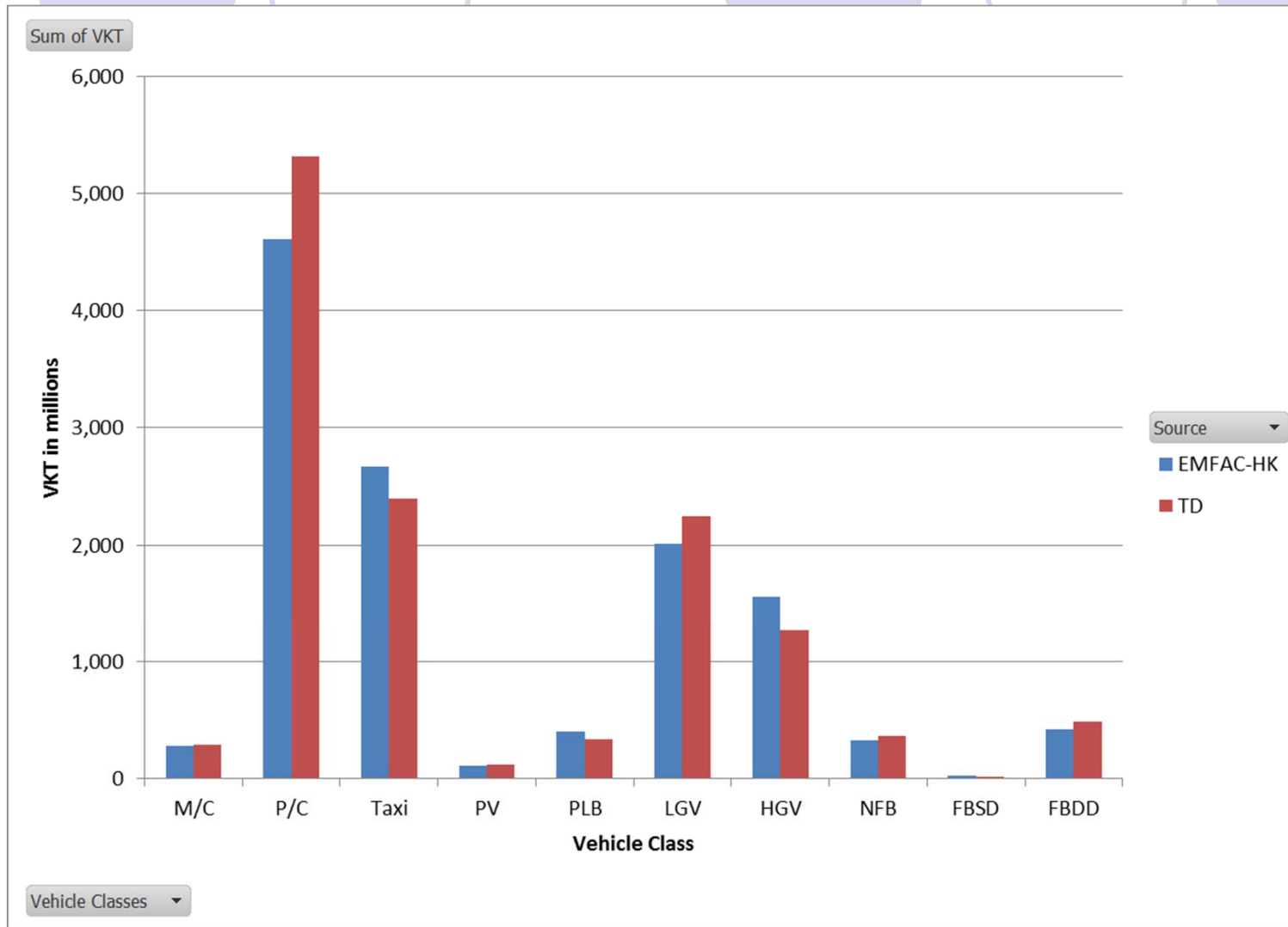
Year	Private Vehicles (private cars and motor cycles)	Goods Vehicles
	Average annual growth rates (up to the Year)	
2011	2.5%	0.0%
2015	3.5% <sup>#</sup>	0.5%
2016	4.0% <sup>#</sup>	0.5%
2021	3.0%	0.5%
2026	3.0%	0.5%
2031	3.0%	0.5%

#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.

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



# Comparison of VKT in 2013

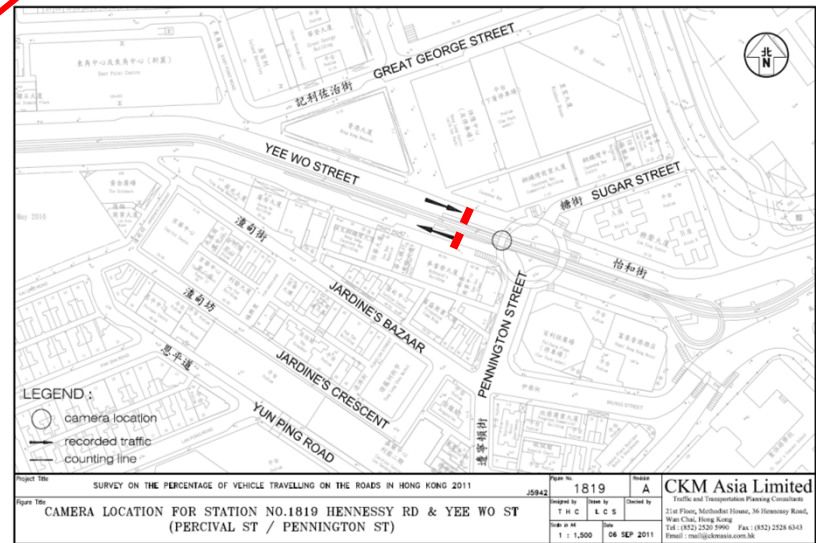




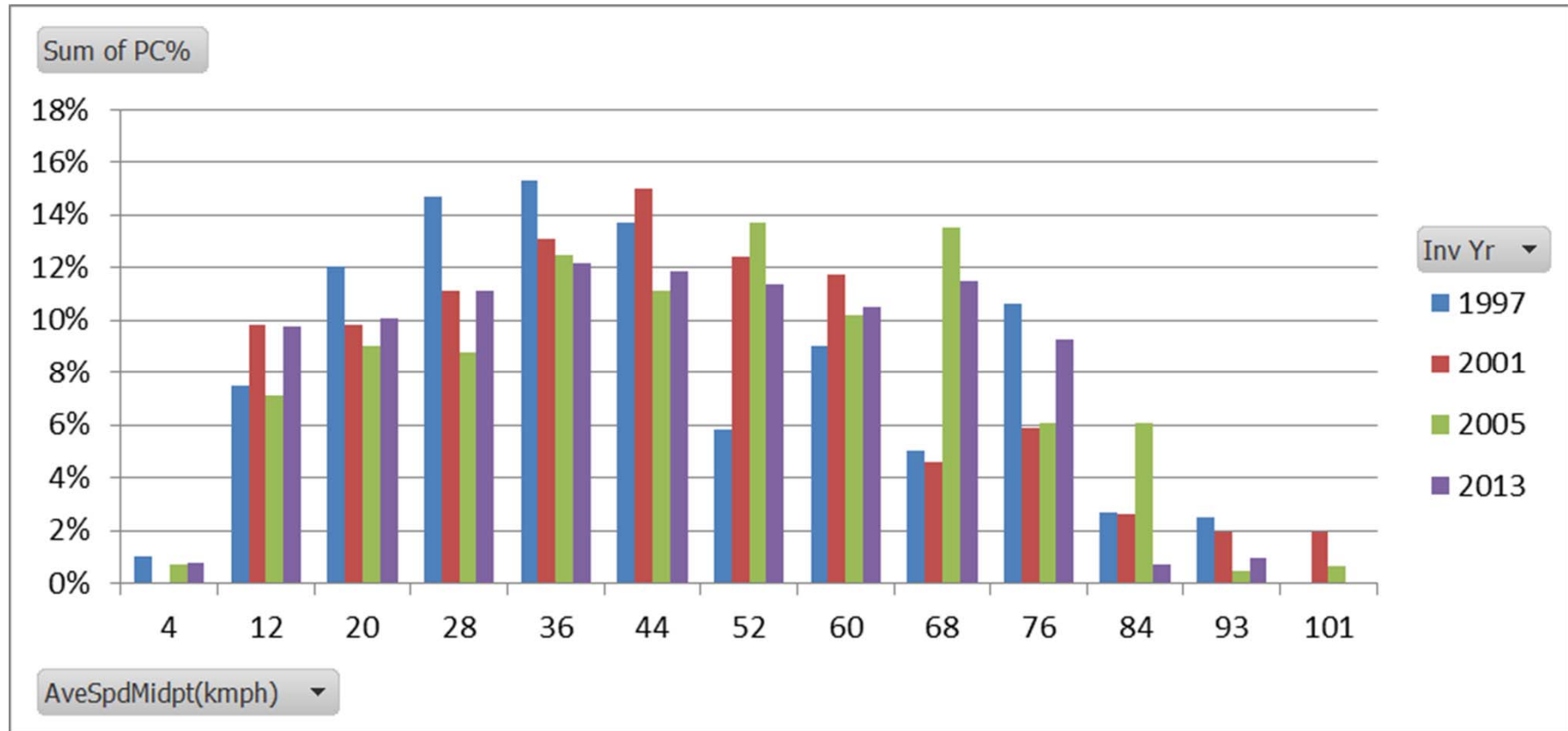
# TD Count Station

(Yee Wo Street, Causeway Bay)

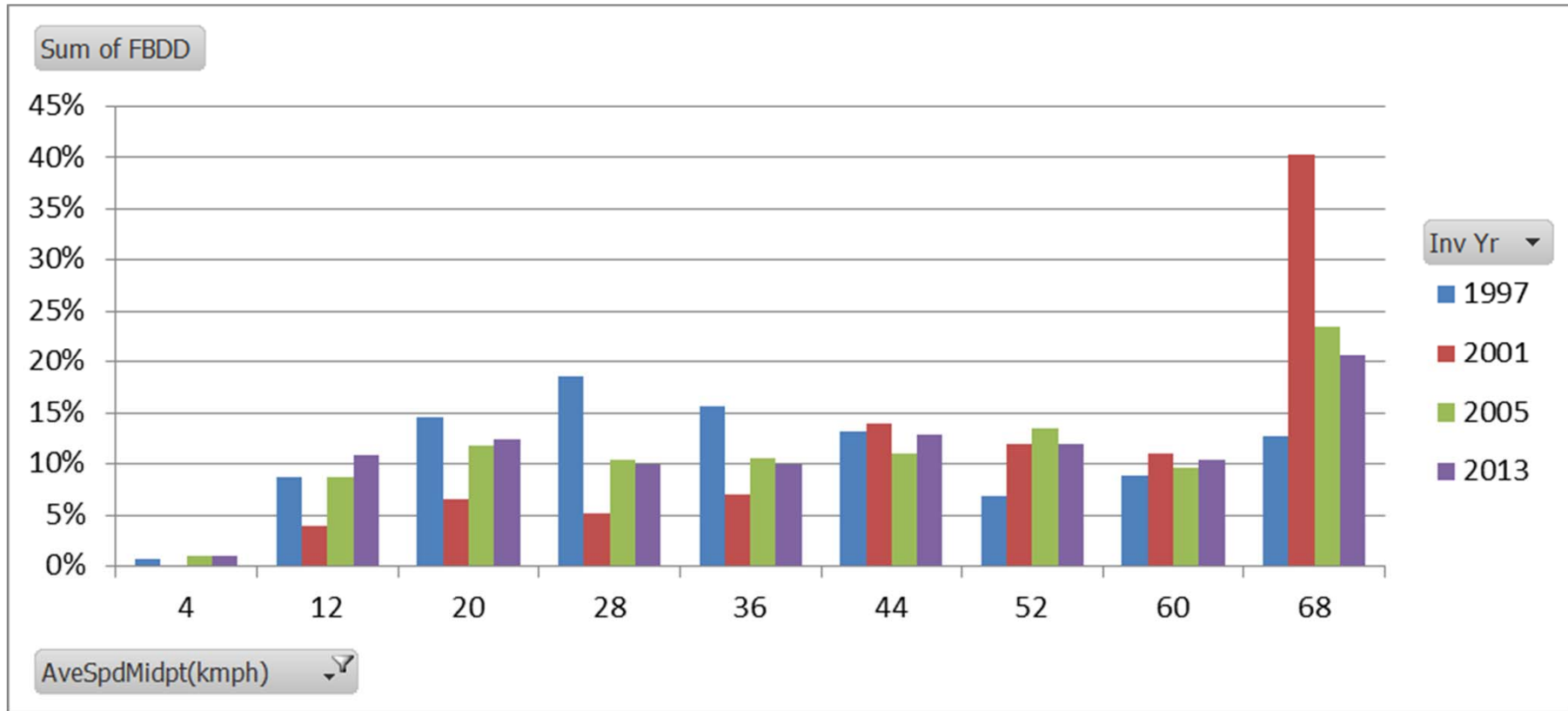
-Traffic flow can be monitored and evaluated.



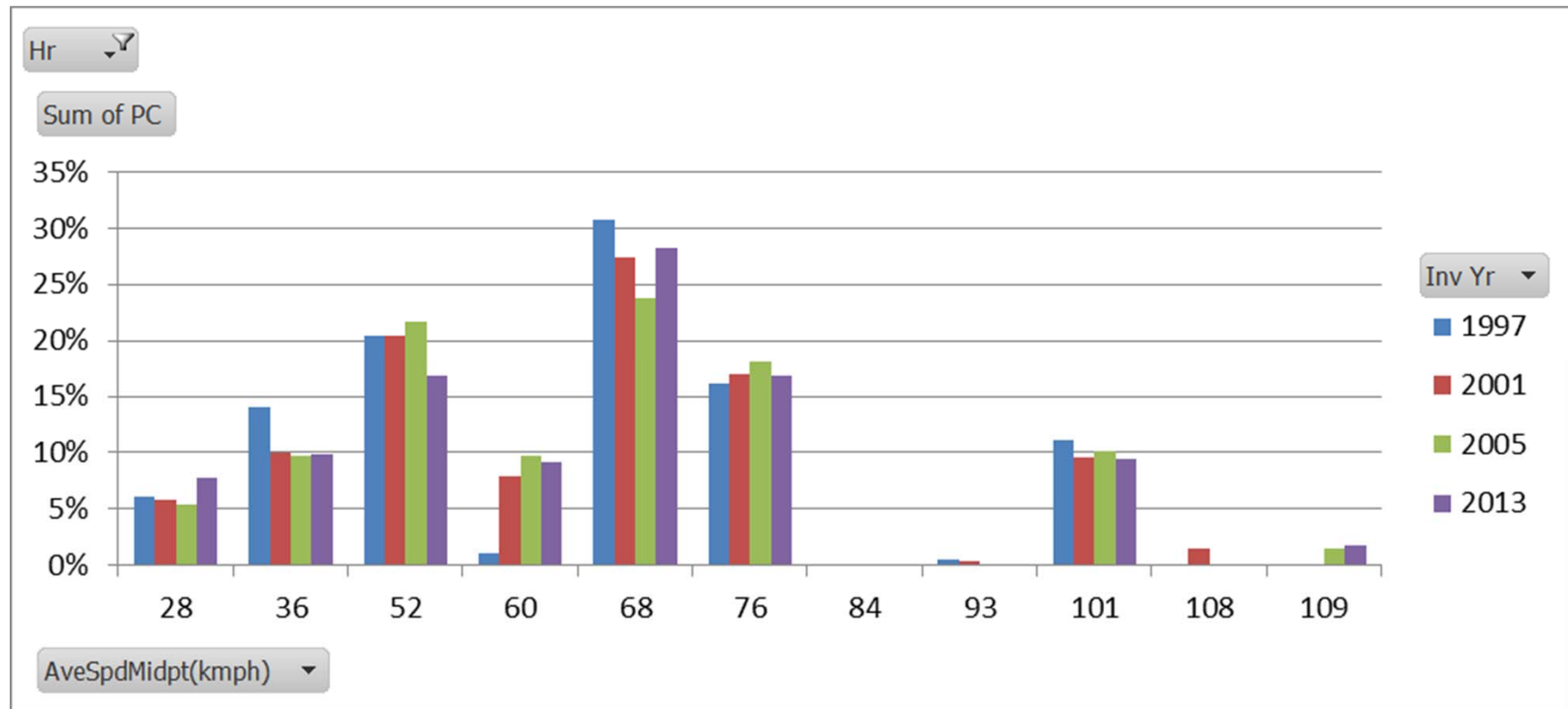
# Speed Fractions for Private Cars at Peak Hours



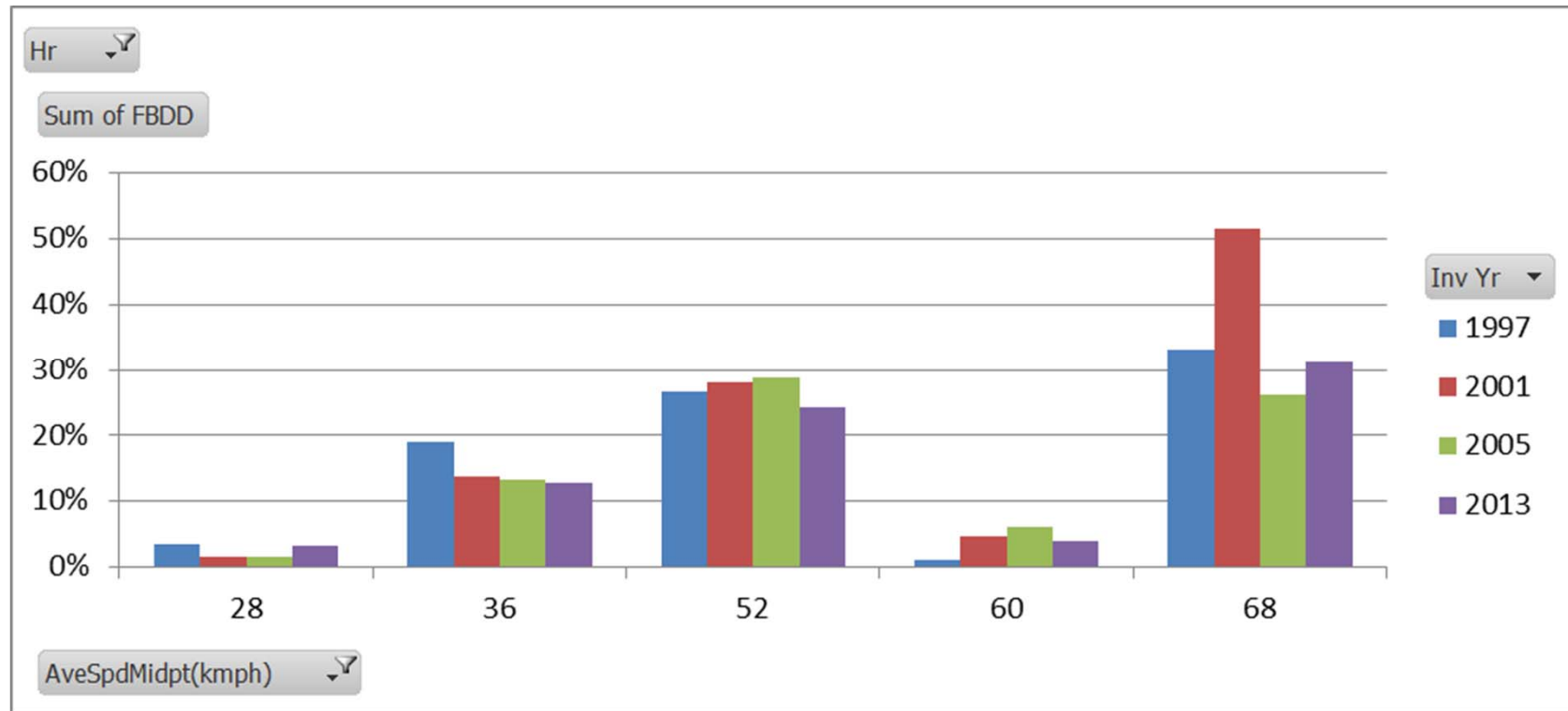
# Speed Fractions for Franchised Buses at Peak Hours



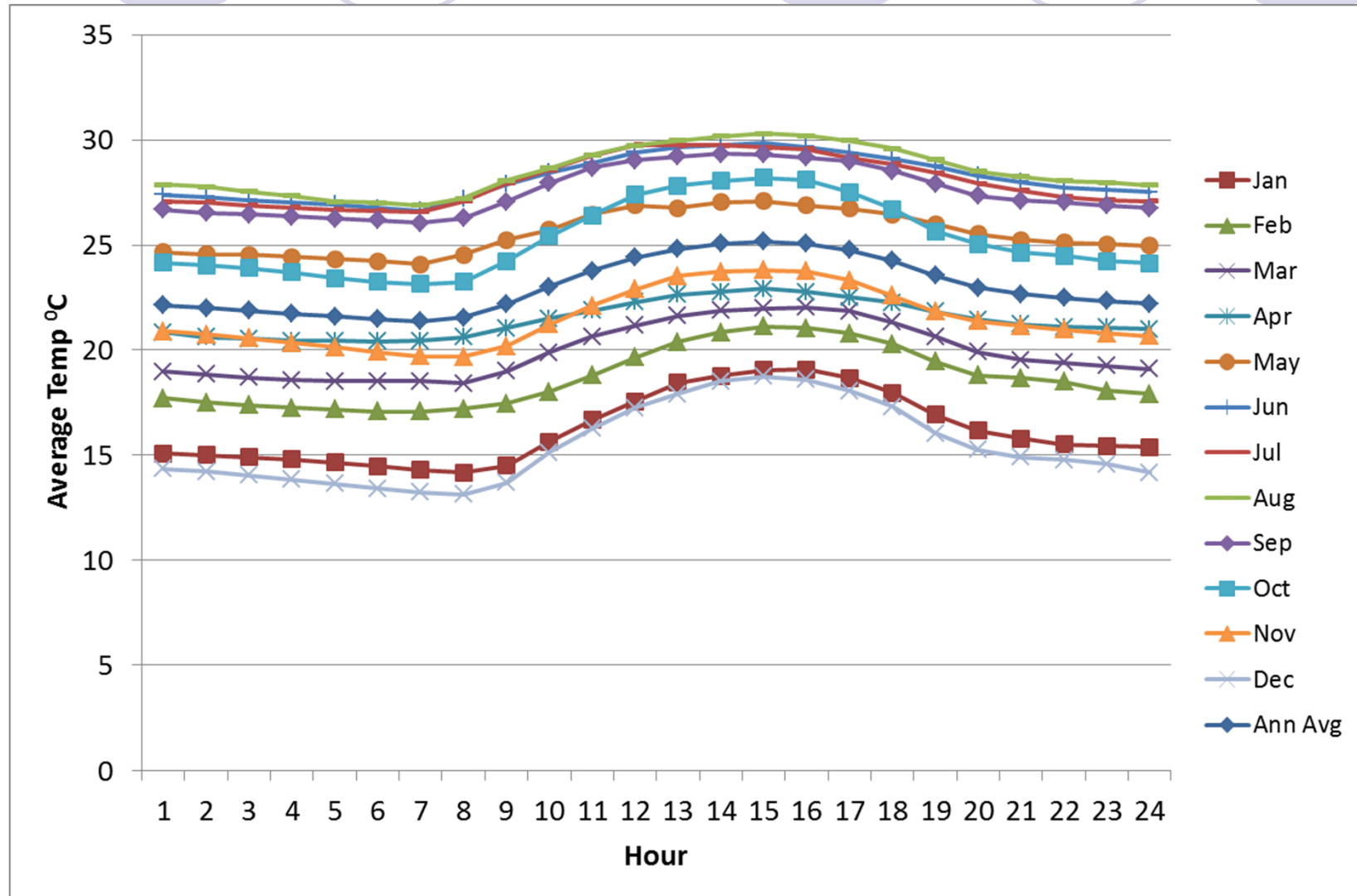
# Speed Fractions for Petrol Cars at Daytime non-peak Hours



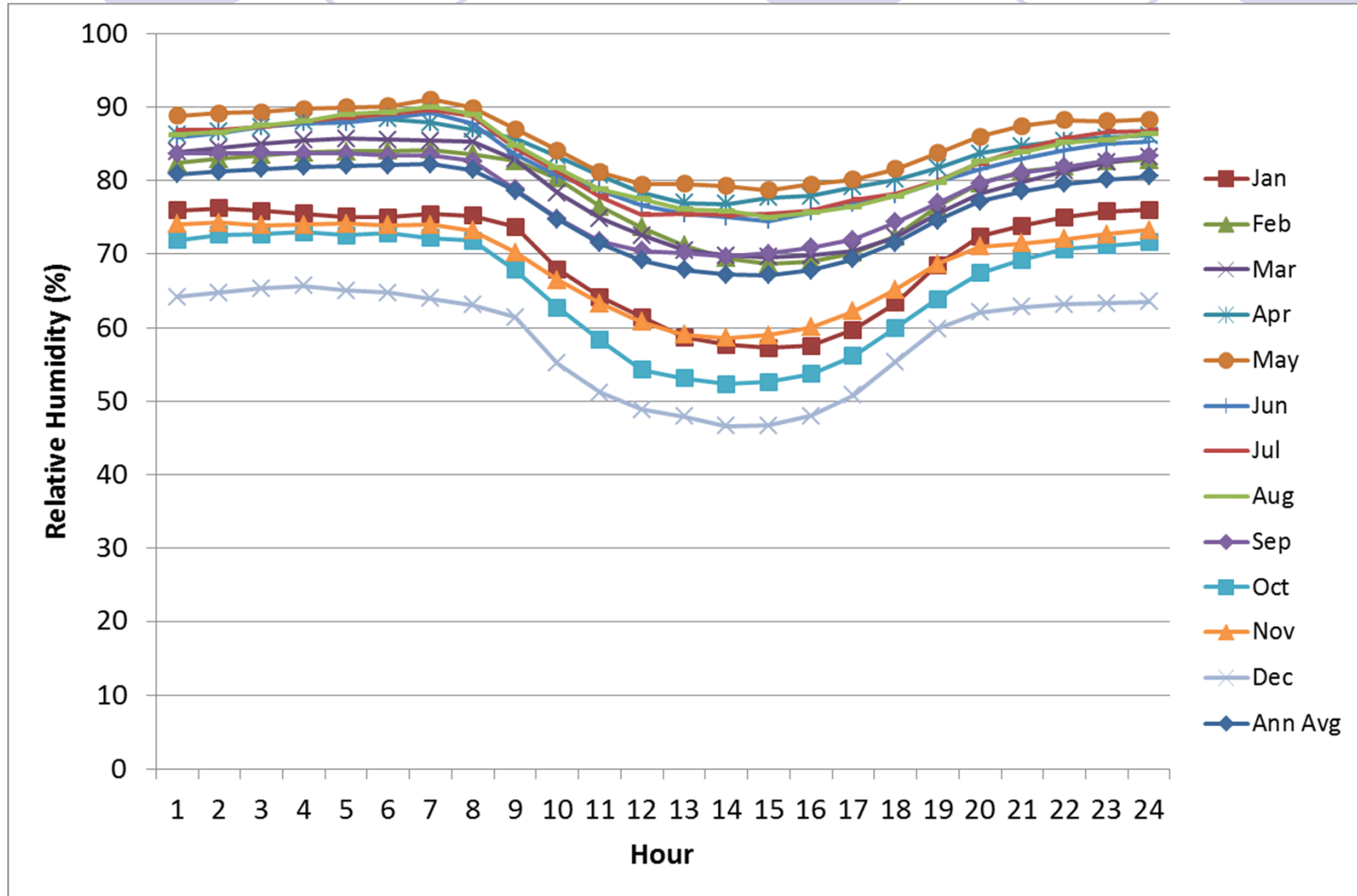
# Speed Fractions for Franchised Buses at Daytime non-peak Hours



# Monthly Average Temperature by Hour in 2013



# Monthly Average Relative Humidity by Hour in 2013





# 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



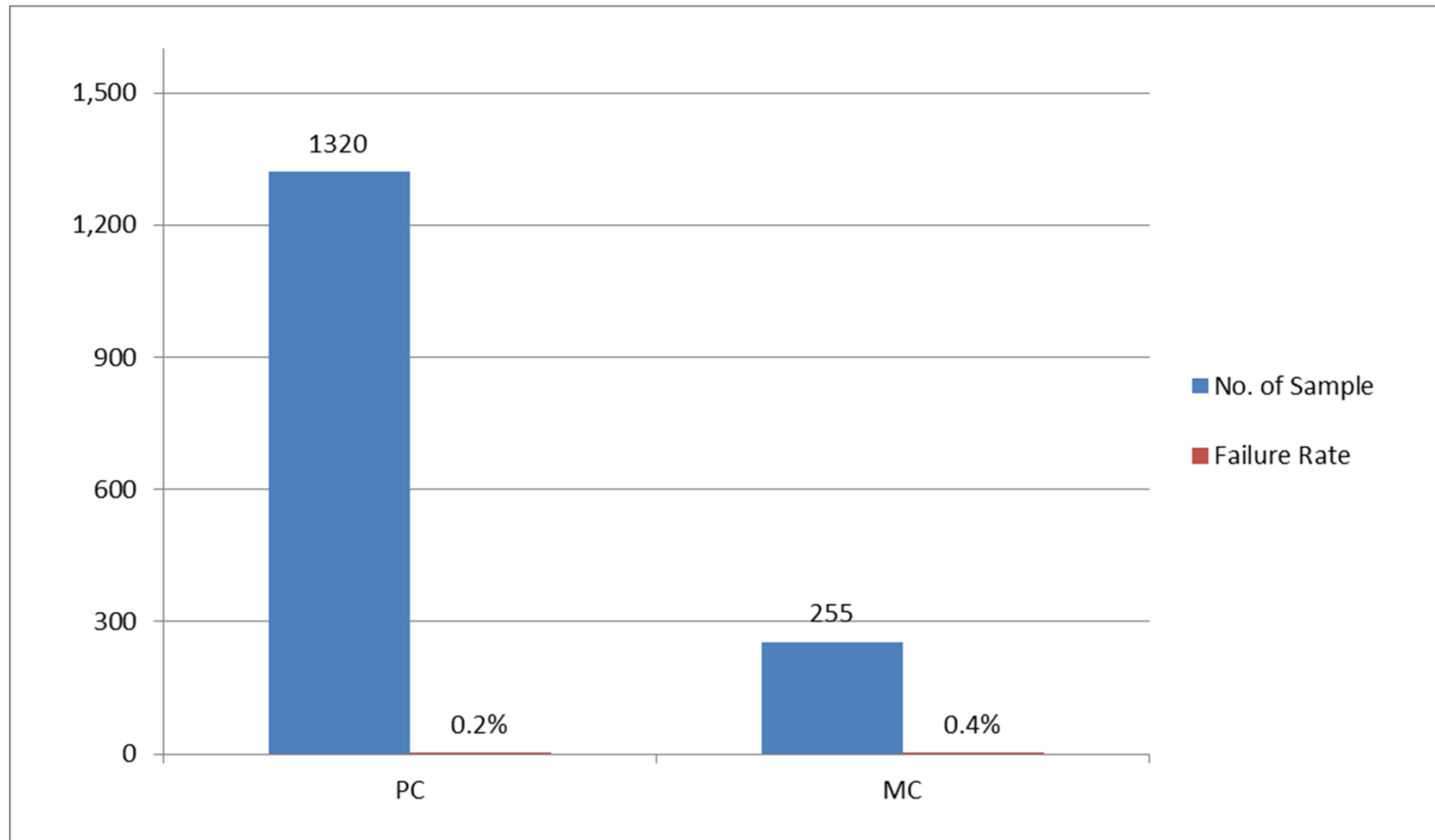
Wash & Wax Shop



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



# Comparison of EMFAC-HK V2.6 & V3.1

## Emission Factor Related

<b>EMFAC-HK V2.6</b>	<b>EMFAC-HK V3.1</b>
The zero mile emission factors (ZMEF) and deterioration rates (DR) were chosen from those in U.S. models including EMFAC2007, MOBILE5/6 and MOVES based on our local vehicle emission data measured by PEMS.	Updated Speed Correction Factors as well as ZMEF and DR. More real-world vehicle emission data are used to determine these factors. Also, international emission factors are used as references, e.g. COPERT, EMFAC2007/2014, MOBILE6.
2010 smoky vehicle data for PM super emitters except for diesel public light buses where 2004 smoky vehicle data were used	2013 smoky vehicle data for PM super emitters were used
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.	Same methodology with more recent measurements

# Comparison of EMFAC-HK V2.6 & V3.1

## Modelling Methodology Related

<b>EMFAC-HK V2.6</b>	<b>EMFAC-HK V3.1</b>
Removed the upper and lower limits on new vehicle sales in the population forecast function	Revised the population forecast methodology (except franchised buses) in order to mitigate sharp anomalies in population estimates
Cycle correction factors are applied	Removed cycle correction factors
Work for multi-calendar years	Work for single calendar year ONLY and allow population forecast from alternate base year with custom population

## Input Format Related

<b>EMFAC-HK V2.6</b>	<b>EMFAC-HK V3.1</b>
Accrual rates, vehicle kilometer travelled (VKT) and temperature are US unit in input file (INP)	All parameters inside INP are set to SI unit
I&M program parameters are hidden and the program cannot be disabled	I&M program parameters are shown in the graphical user interface. Users are allowed to enable/disable and modify the program
	header of the input file provides additional information including I&M parameters, units identifier and info on alternate base year

# Comparison of EMFAC-HK V2.6 & V3.1

## Policy Related

<b>EMFAC-HK V2.6</b>	<b>EMFAC-HK V3.1</b>
Some Euro II & III franchised buses with previously retrofitted DPF would be retrofitted with SCR in 2013	Some Euro II & III franchised buses with previously retrofitted DPF have been retrofitting with SCR since 2014
Used Tech Groups and code changing to implement subsidy programme for the replacement of catalytic converters and oxygen sensors on LPG/petrol taxi and LPG light bus	Modified the methodology for LPG Taxi and LPG light bus to implement subsidy programme for the replacement of catalytic converters and oxygen sensors on LPG/petrol taxi and LPG light bus
I/M programs for taxis, private cars, light buses and goods vehicles from 2014 is assumed.	I/M programs for taxis, private cars, light buses and goods vehicles from Sep 2014 is assumed. Parameters are editable in input files.
Implemented the programme on mandatory retirement of pre-Euro IV diesel commercial vehicles (excluding franchised buses)	Same policy.

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## Activity Related

<b>EMFAC-HK V2.6</b>	<b>EMFAC-HK V3.1</b>
2010 vehicle population distribution	2013 vehicle population distribution
2010 VKT from TD	2013 VKT from TD
2010 survey on vehicle classification on 100 road segments from TD;	2013 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	local surveys conducted in 2004-07 & 2010-13 on vehicle classifications to supplement TD's data (from 11 p.m. to 7 a.m.) and 64 additional road segments
2010 speed limits from TD	2013 speed limits from TD
2010 speed surveys from TD	2013 speed surveys from TD
2010 ambient temperature & relative humidity from HKO	2013 ambient temperature & relative humidity from HKO
2010 mileage and age relationship from EPD's own surveys	2013 mileage and age relationship from EPD's own surveys
	Updated Population Growth rates for private cars (PC) and motorcycles (MC) according to TD's updates.

Thank you.

