

Experience Sharing on Remote Sensing (RS) of Exhaust Emissions from On-road Vehicles

Hong Kong Experience

YS Yam & KL Poon

Hong Kong EPD

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1. Experience in the Use of RS Technology

- Start using RS since 1993
 - For fleet emission profiles after introducing unleaded petrol and TWC
 - First for CO & HC and later included NOx measurement
 - Mainly for petrol & LPG vehicles

 - Model of RSDs used:
 - FEAT (prototype), Smog Dog, RSD 3000, MR Inspector, 4-gas Professional, RSD 4500/4600

 - Test & Study Projects
 - Survey for RS measurement sites
 - Co-relation tests with dynamometer using various cycles
 - Determine the cut points for gross emitter control programme
 - Feasibility of using ALPRS system in RS (in progress)
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Remote Sensing Units



Modern FEAT Unit



Smog Dog



4-gas/Professional



RSD 3000

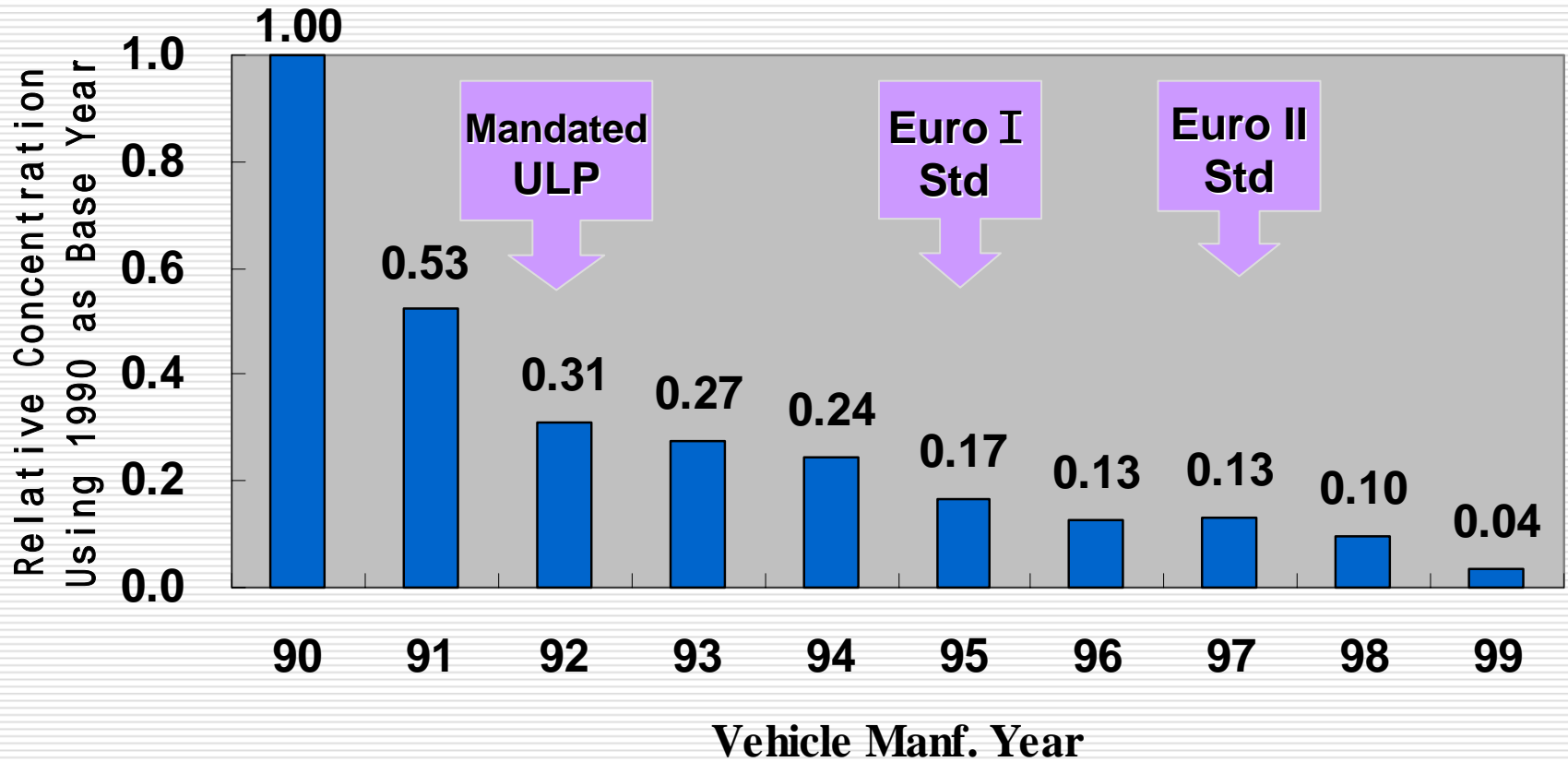


RSD 4500/4600

A Typical Set up of RSD (Single & Dual Units Deployment)



Typical Emission Profile (CO Concentration)



2. Advantages & Limitations

□ Advantages

- Mobile set up
- No interruption of traffic flow, no interaction with drivers & vehicles
- Capture Large quantity of emission data
- Effective emission measurement tool

□ Limitations:

- Snapshot of emission in ½ Second
 - Dry Weather Technology
 - Single lane with positive gradient
 - Skilled operator required
 - Site constraints (capture rate, safety, space restrictions)
 - No standard QC procedure on equipment
 - Need to develop data screening and management technique
-

3. Equipment QA/QC and Site Selection (1)

3.1 Selected Suitable RSD with QC measures

- to suit intended vehicles fleet (petrol & LPG);
 - Hydrocarbon species measurement is problematic
 - Equipment supplier needs to match with intended the vehicle fleet and their fuel specifications to be measured;
 - Equipment supplier to provide Shop test certificate
 - To request new RSD must meet stringent performance requirements (such as BAR) with certificate. If not, conduct local test to confirm compliance
-

RSD's Performance Tests



Instrumented Vehicle



3. Equipment QA/QC and Site Selection (2)

3.2 Testing the Characteristic of RSD Measurement

- ❑ On-road testing of petrol and LPG vehicles
 - ❑ Use of dynamometer with transient cycles
 - ❑ Compare the emission data between RSD and on board 5-gas analyser
-

On-road Testing of RS vs On-board Analyser

- ❑ Diesel, petrol & LPG vehicles were used;
- ❑ Tested both carburetor and injection petrol cars;
- ❑ Attached 5-gas analyser to vehicle ;
- ❑ Tried different speeds and accel./decel modes



Findings

- ❑ Diesel car - cannot provide exact concentration because of assumption of stoichiometric combustion
 - ❑ Petrol/LPG car – observed significant variations, higher RS reading is of concern
 - ❑ Carburetor car – lower variation but still no match
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Comparison of RS & 5-gas Analyser Data for Transient Test on Dynamometer

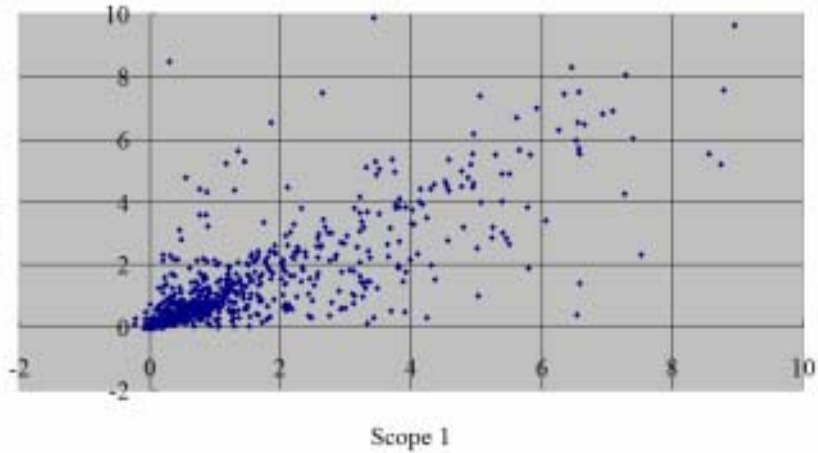
- ❑ Modified RSD to continuous measurement mode (50ms sampling)
- ❑ Used petrol & LPG vehicles on dynamometer with transient cycle
- ❑ Use of gas chamber for vehicle exhaust measurement by both RSD & 5-gas analyser
- ❑ Recorded readings from transient cycles on both equipment



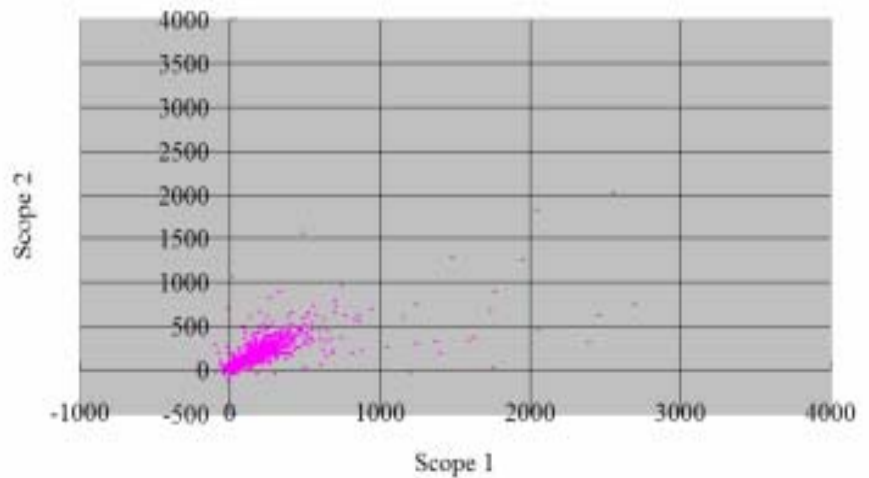
Findings

- ❑ RS capable of capturing the high transient mode of emissions (down to 20 samples/sec) while on-board equipment cannot capture because of 1 second average reading of sampling was given.
 - ❑ Use of 2 or more RSDs to verify if readings are due to transient captured by RS, i.e. look for consistent high readings as true high readings. [see charts]
 - ❑ Combustion equation of both data set was verified from stoichiometric ($\text{Lambda} = 1$) to rich ($\text{Lambda} < 1$) range. Correction factor for LPG vehicles due to different C/H ratio than that of petrol need to be applied. [see 5-gas Lambda charts]
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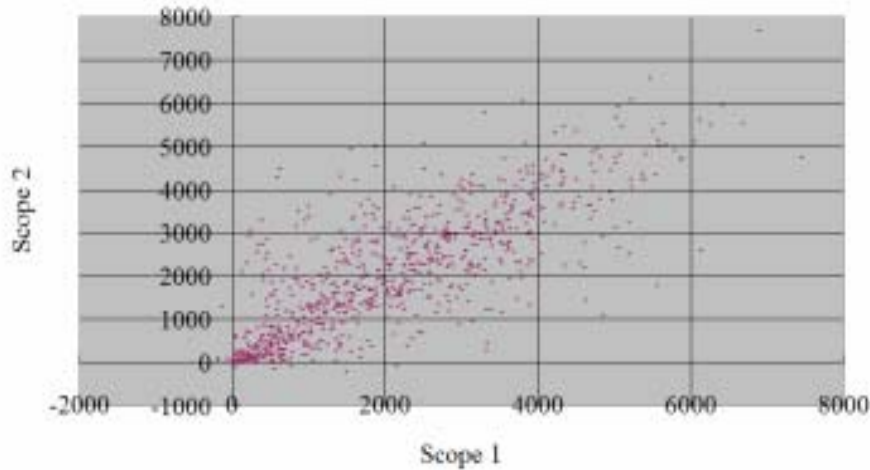
CO (%)



HC (ppm)

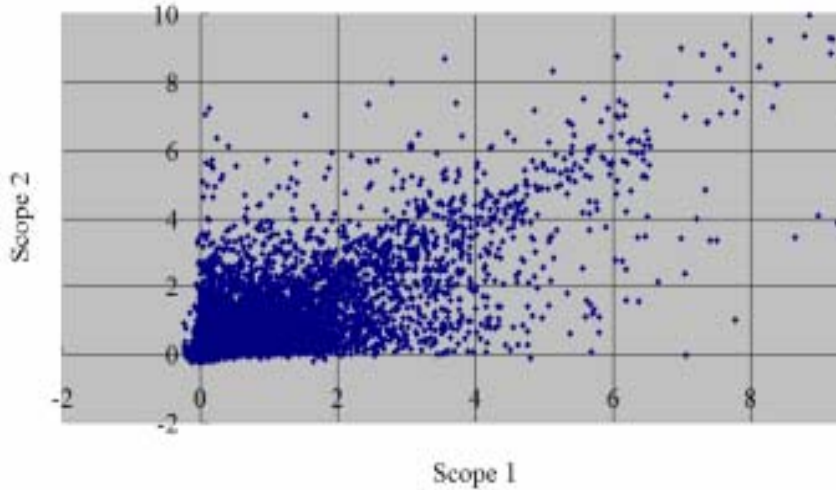


Nox (ppm)

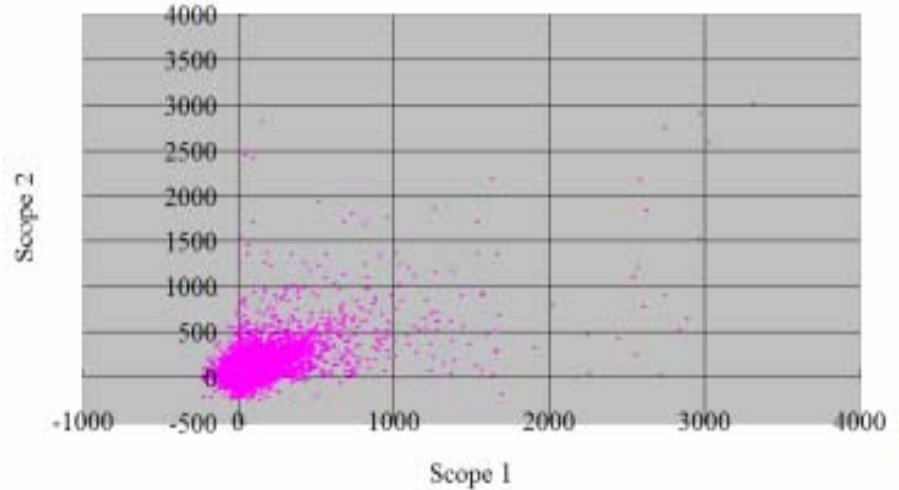


Charts of scattered
2 scope emissions –
Petrol Carburetor
Cars

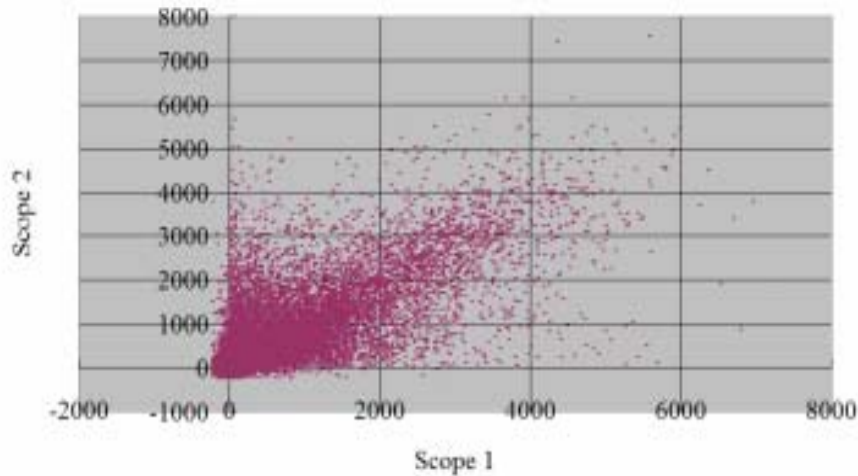
CO (%)



HC (ppm)

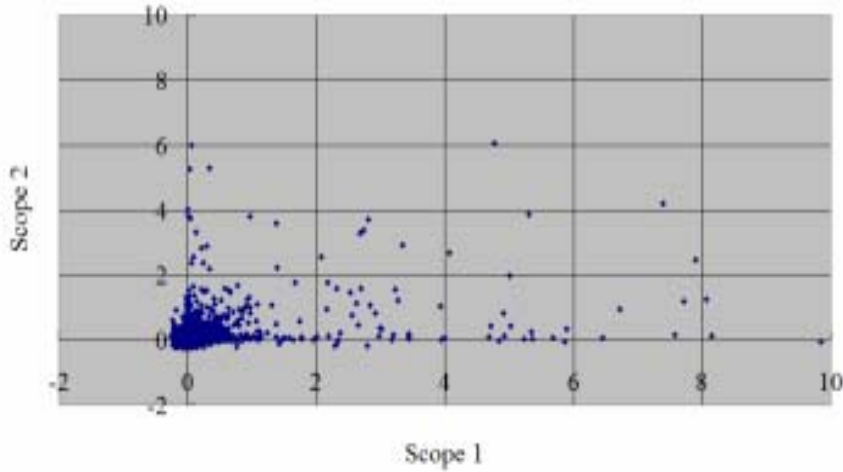


Nox (ppm)

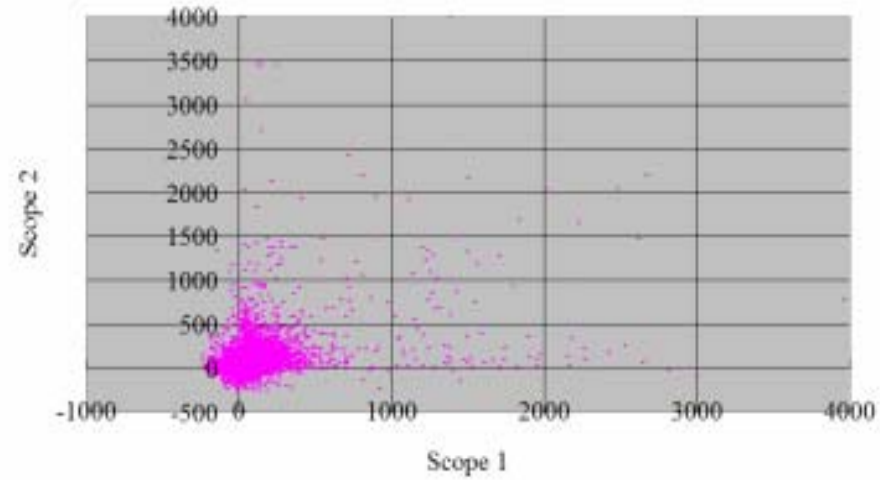


Charts of scattered
2 scope emissions –
Petrol Cars
(TWC/Injection)

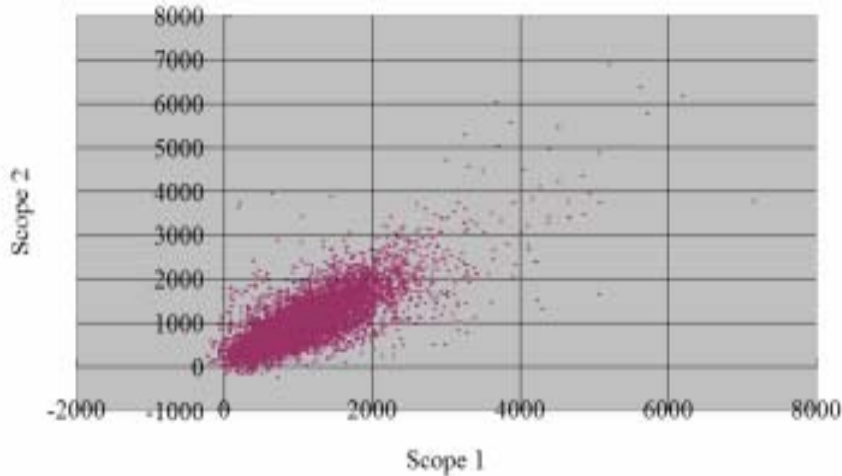
CO (%)



HC (ppm)



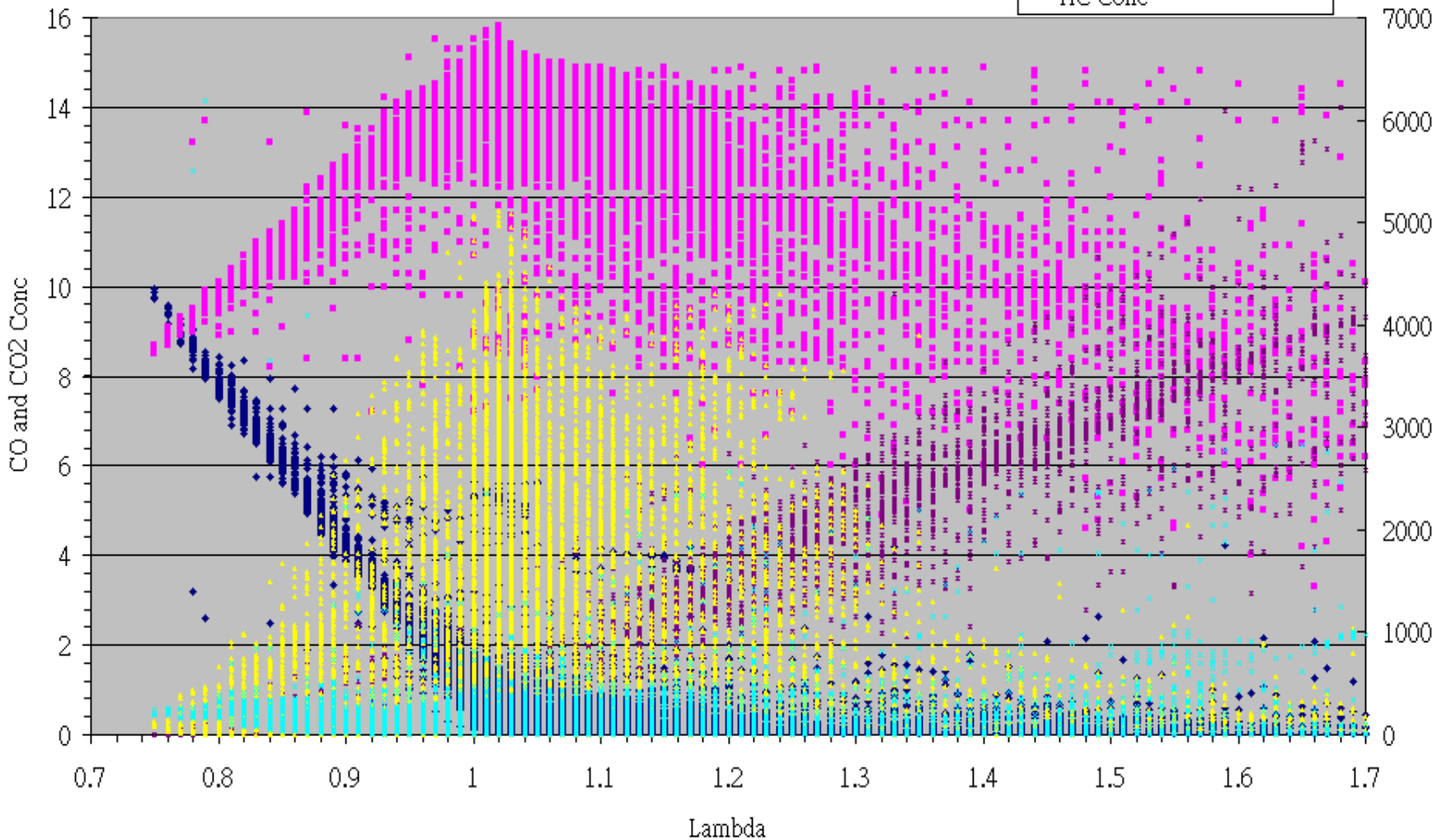
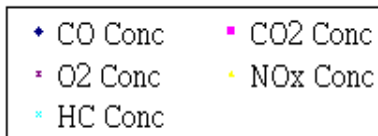
Nox (ppm)



Charts of scattered
2 scope
emissions – Diesel
Vehicles

GAS CONC VS LAMBDA

5 Gas Data (Petrol) (from dyno) vs Lambda



Key considerations for successful RS data collection

- ❑ RS does not measure like traditional I&M analyzer
 - ❑ RS readings can be affected by very short transient emission (e.g. engine Lambda switching) and pressure/temperature correction of the sample
 - ❑ Low plume (exhaust volume) is a challenge for small size cars
 - ❑ High specific engine emission at specific engine operation mode (e.g. high CO at standing start, high HC during deceleration)
-

3. Equipment QA/QC and Site Selection (3)

3.3 Site Selection

- Site Survey :-
 - to obtain detail of road, traffic conditions, gradient, road width & place for operator/equipment
 - Identify the location on road with reference points with photo

 - Vital to ensure:-
 - consistent loading conditions
 - high capture rate and high accuracy
 - avoid capturing unrepresentative emission data (e.g. road bend, cold start)
 - clear road conditions downstream of traffic
 - it is safe for operation personal and equipment
-

3. Equipment QA/QC and Site Selection (4)

3.4 Skilled Operator

- Vital to ensure: -
 - Equipment are setup and operate properly
 - Choosing a right point at the site for measure
 - Able to observe abnormal equipment performance
 - Able to fix mirror performance/operation/setup problems

 - Training of operator
 - Should be provided by equipment supplier
-

3. Equipment QA/QC and Site Selection (5)

3.5 On-site Calibration of RSD

- Allow ample time to order certified gases
 - Gases need time to be prepared and stabilized

 - Use of Certified Standard Gases :-
 - To calibrate Equipment before data taking
 - After reposition of equipment
 - Hourly or any frequency as needed to ensure accuracy performance
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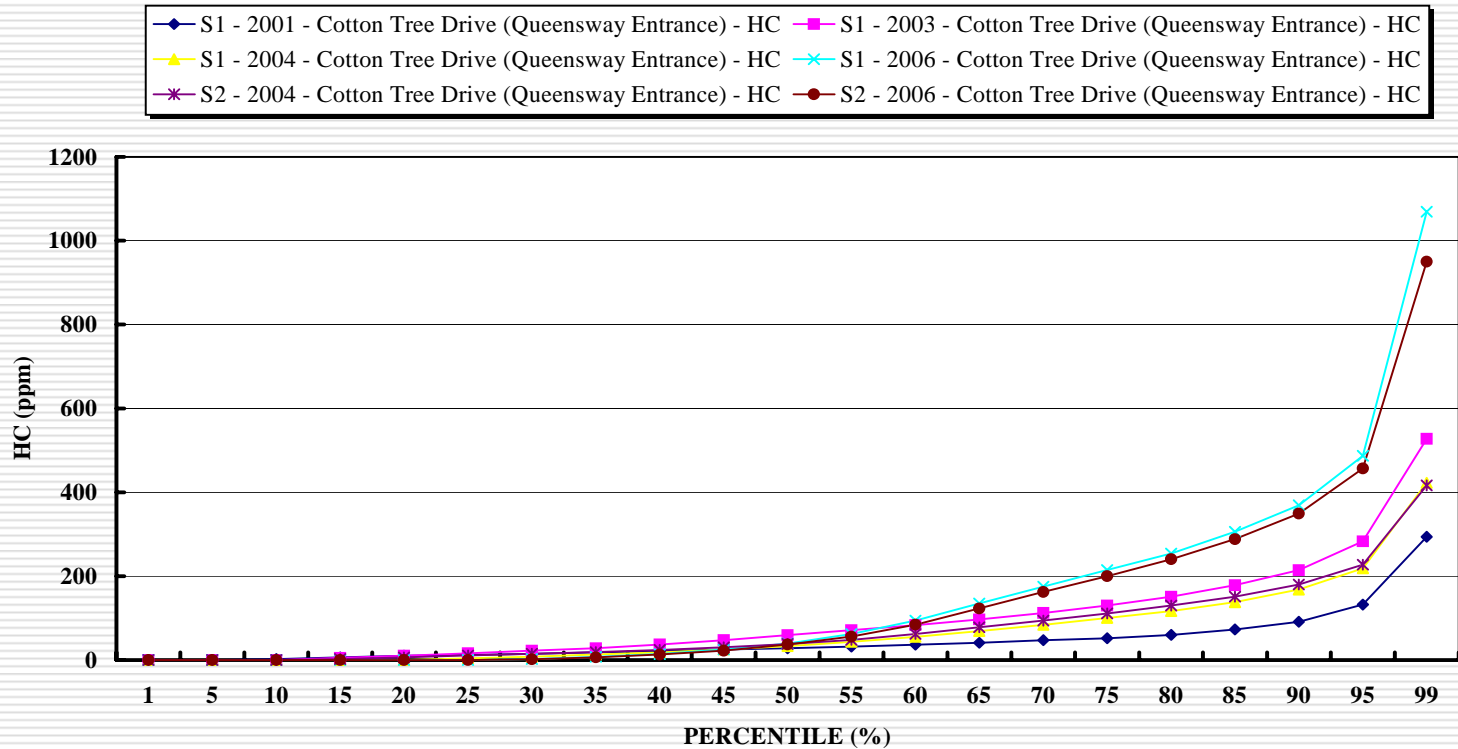
3. Equipment QA/QC and Site Selection (6)

3.6 Built individual Site Emission Profile and Database

- To counter check the accuracy of emission profile for new data collected
 - To keep track of the vehicle speed and acceleration profiles
-

Build up Emission Profile and DataBase for Individual Site (HC Profiles)

COTTON TREE DRIVE - HC



4. Factors that Affect RS Data Accuracy

4.1 Weather Conditions

- Rain and snow
 - Obstruct beams passage ways and scatter beams

 - Strong wind
 - Affect plume dispersion
 - Safety concern for equipment & personnel on site

 - Hence, no operation under those conditions
-

4. Factors that Affect RS Data Accuracy

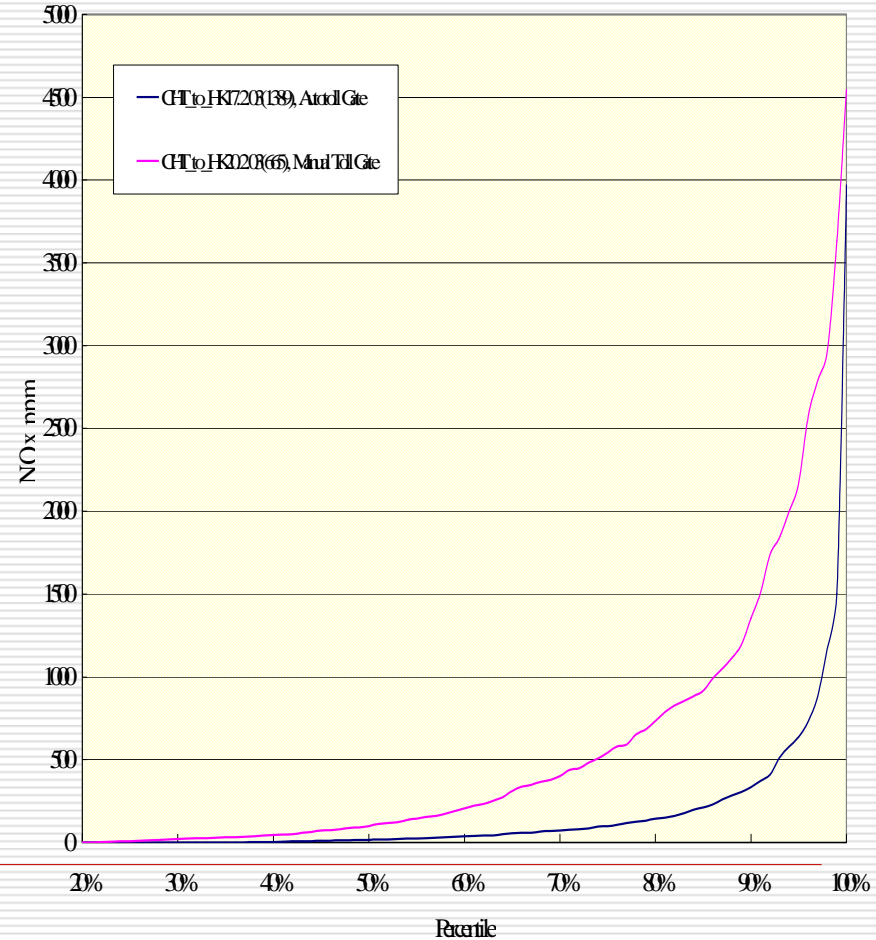
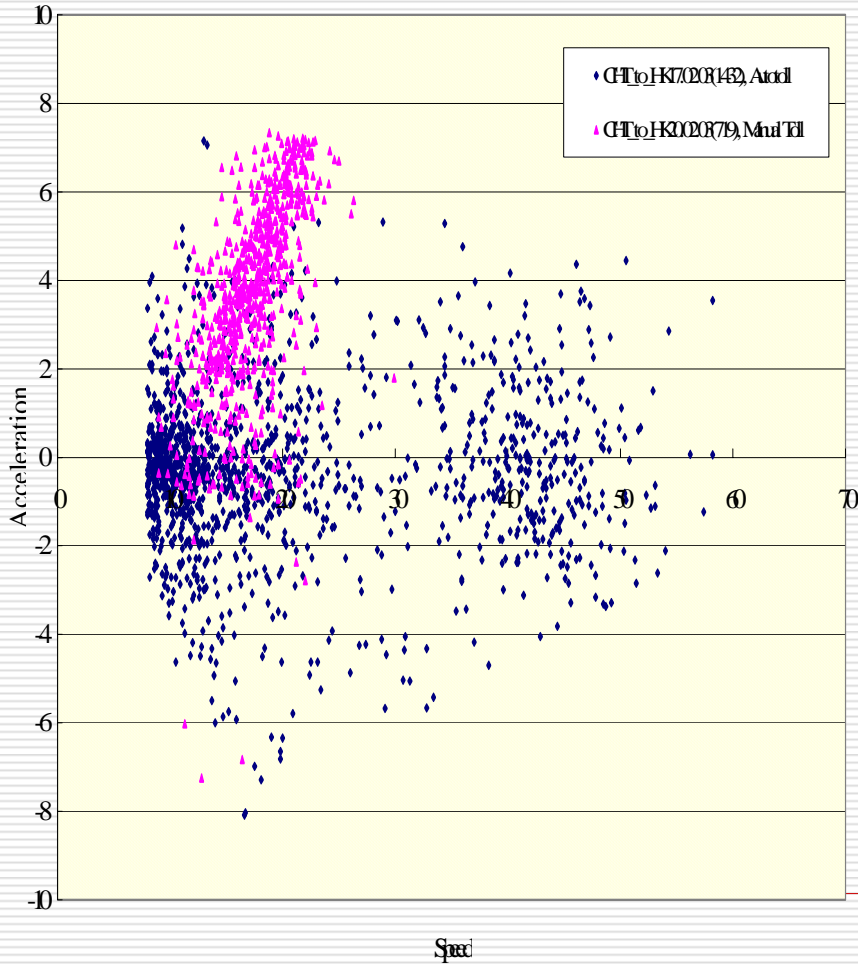
4.2 Road Conditions

- ❑ Vehicle tends to decelerate when approaching bends or anticipating slow traffic ahead – low plume/ low capture rate and abnormal high HC
 - ❑ Straight road – vehicles passing freely
 - ❑ Traffic light/Paytoll – vehicles stop or and accelerate during start up
-

4.2 Road Conditions (Road Bend & Entrance of Upslope)



4.2 Road Conditions (Effect of Auto and paytoll)



4. Factors that Affect RS Data Accuracy

4.3 Driver's Responses

- Natural Reaction - to avoid test
 - Human nature - Curiosity
 - Suddenly change of Driving Mode

 - Therefore, avoid too many operators on sites and conceal equipment would yield better result
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4.2 Driver Responses

(Attract Attention)



Road Too Open



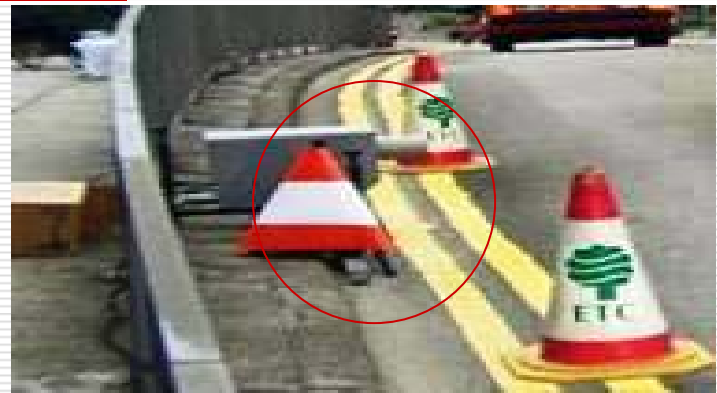
Operators

4.3 Driver Responses

(Covert Operation-Equipment / Operators)



Covert Operation



Hiding Equipment



Remote Control

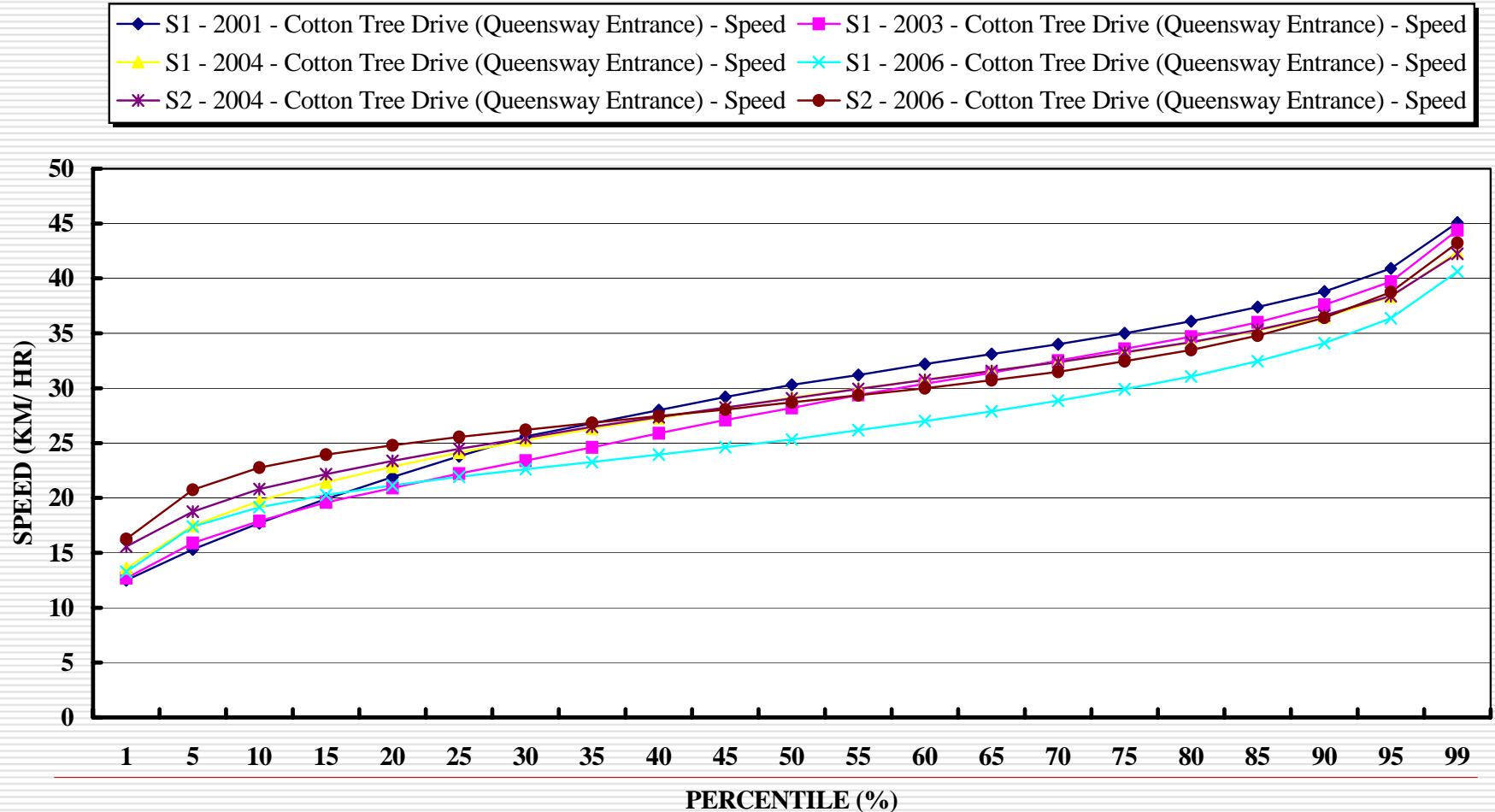
4. Factors that Affect RS Data Accuracy

4.4 Equipment Malfunctioning and Inexperience Operator

- ❑ Any of emission measurement channel may be malfunctioning
 - ❑ Speed/Acceleration Equipment or camera unit may be mal-functioned
 - ❑ Equipment mis-alignment
 - ❑ Poor measurement location
 - ❑ Operator fails to take proper action and allows measurement to be continued
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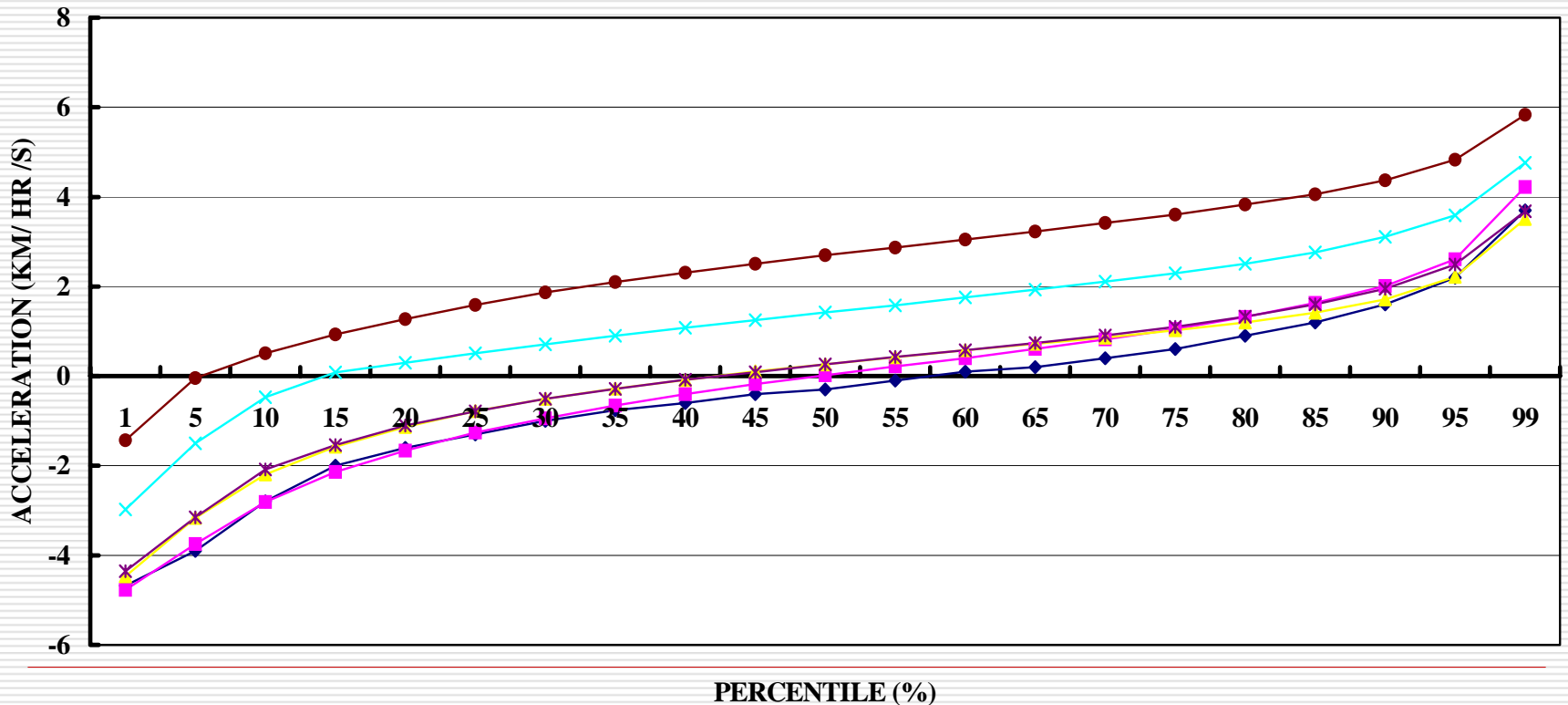
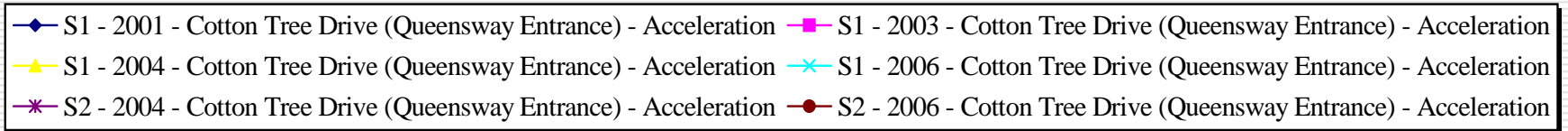
4.4 Equipment Malfunctioning and Inexperience Operator (Speed/Accel Bar Malfunctioning)

COTTON TREE DRIVE - SPEED



4.4 Equipment Malfunctioning and Inexperience Operator (Speed/Accel Bar Malfunctioning)

COTTON TREE DRIVE - ACCELERATION

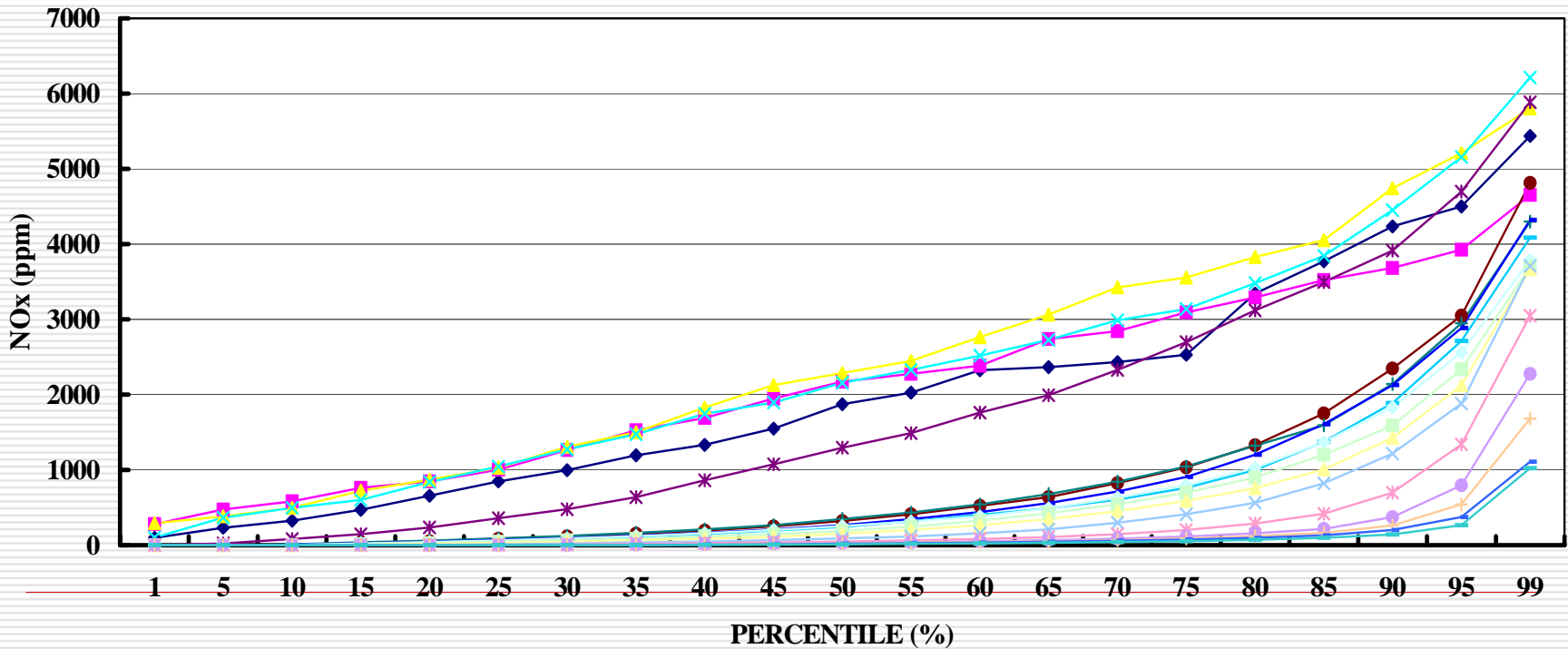
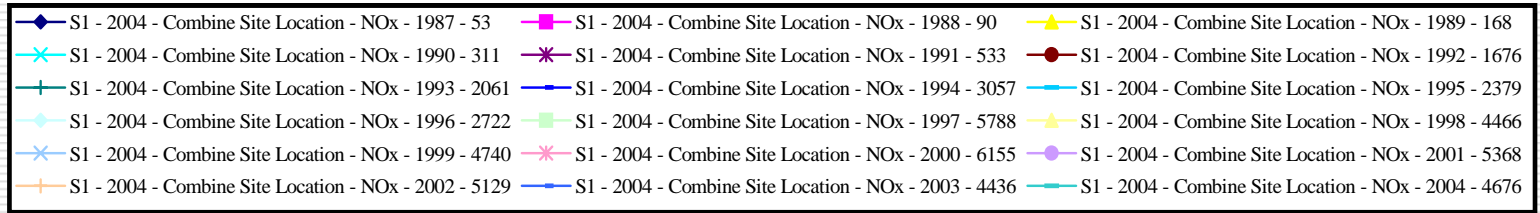


5. The application of RS Technology in Hong Kong

- Fleet Monitoring – need to combine all variables as discussed and form profiles of the fleet [see emission profile charts]
 - Baseline and trend – isolate specific information and monitor the trend e.g. gross emitter percentage [see taxi and petrol multi sighting charts]
 - Gross Polluter Control Programme in petrol & LPG vehicles – combine with transient dynamometer drive cycle
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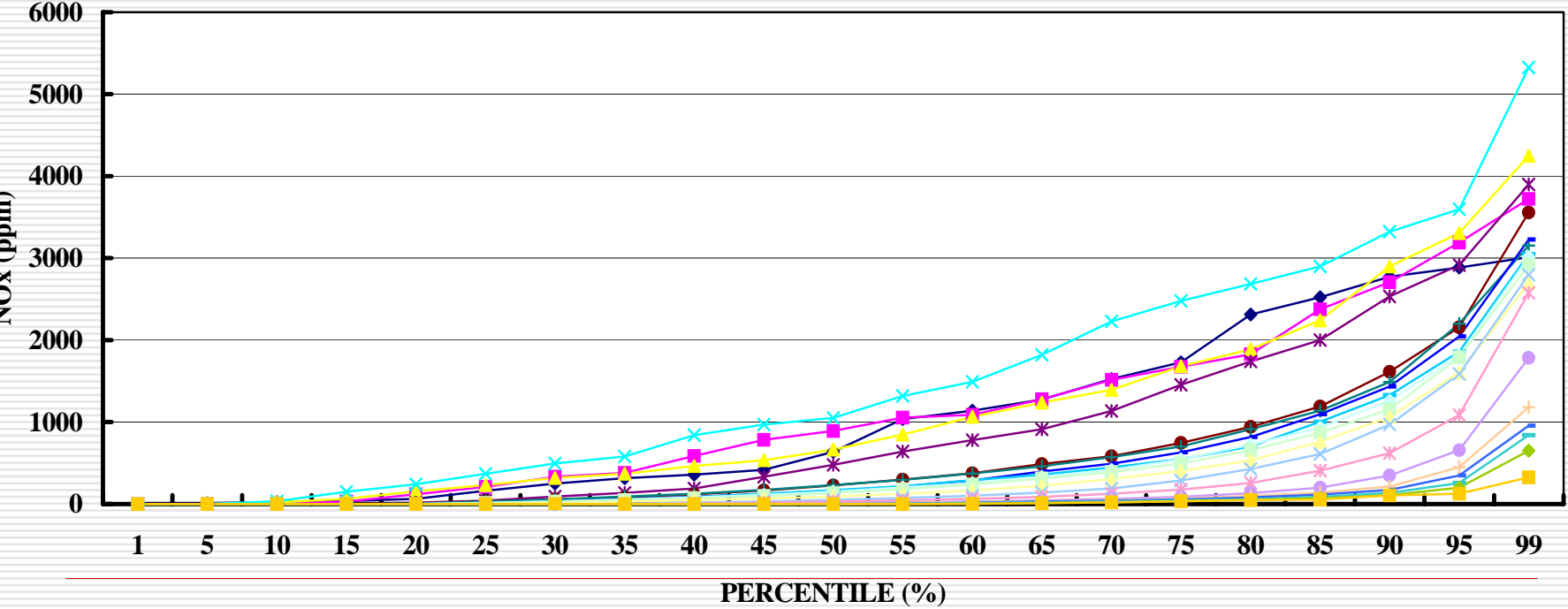
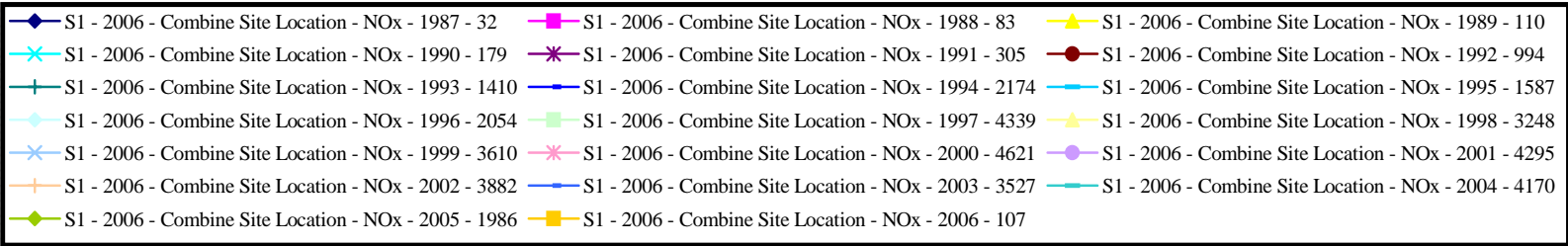
EMISSION PROFILES

RS2004 - NO_x



EMISSION PROFILES

RS2006 - NO_x



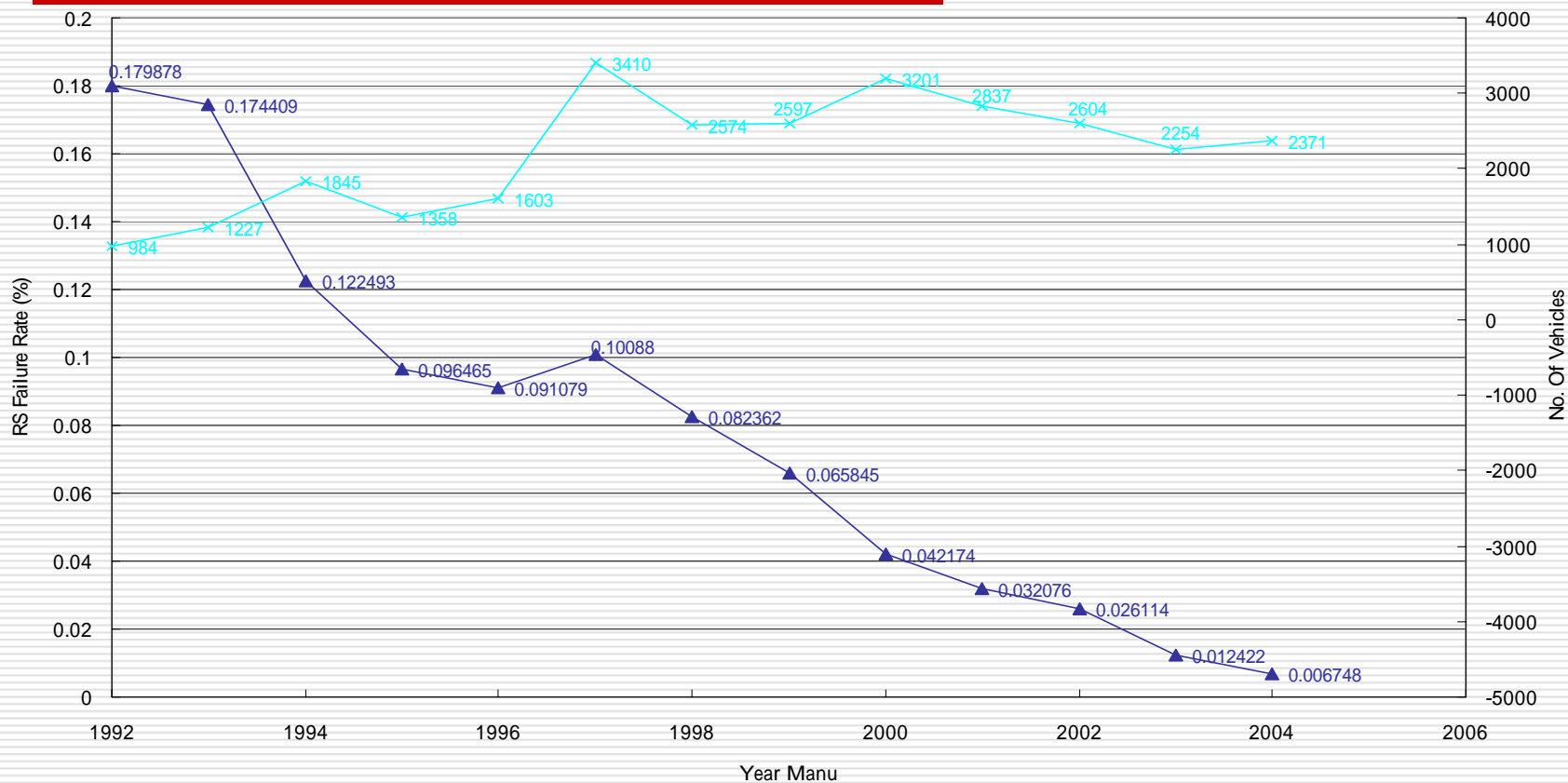
GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Petrol Cars Failure Rate

▲ Petrol Private Car (2004) Failure

× No. of Vehicles (Petrol PC 2004)



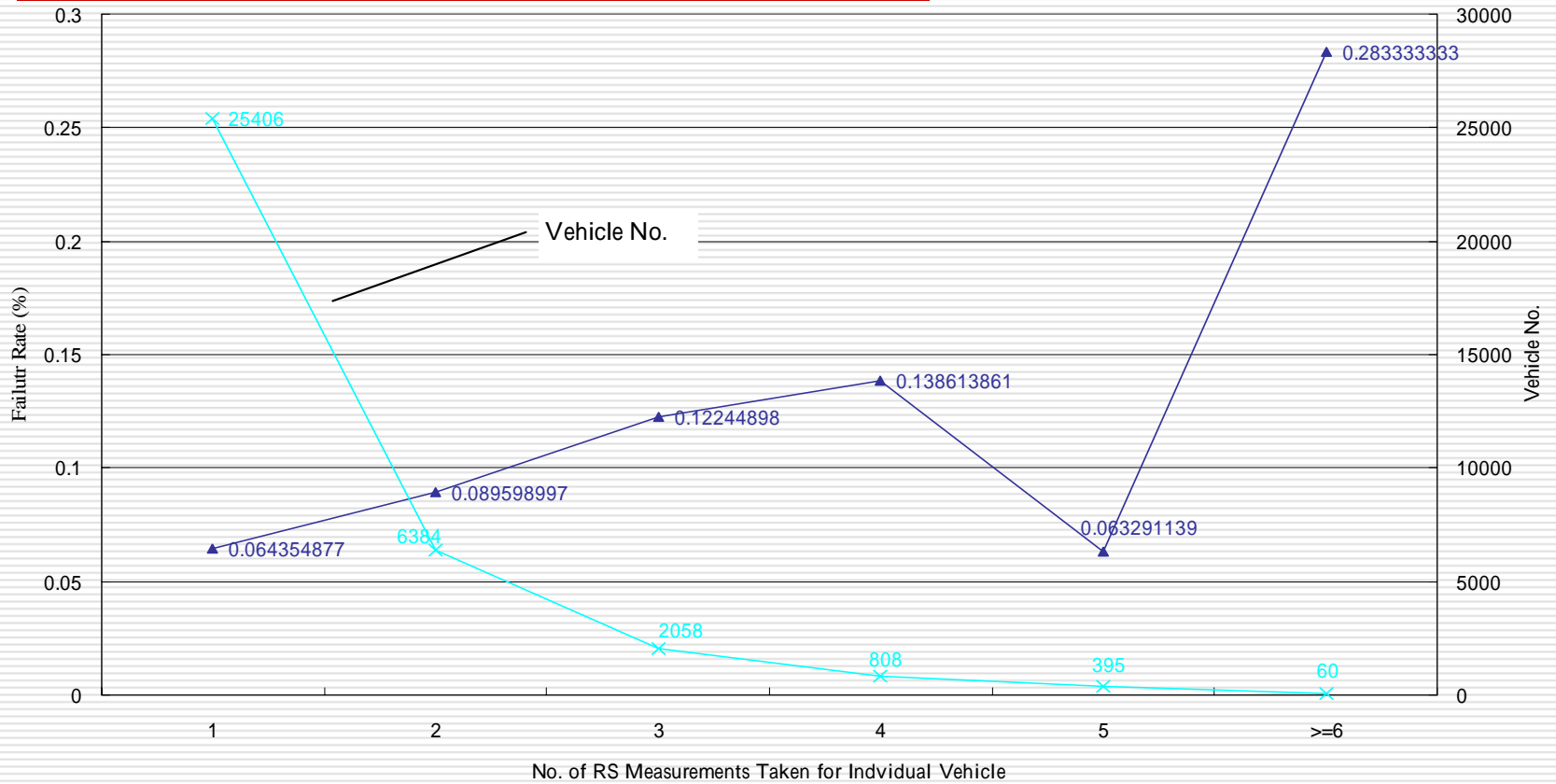
GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Petrol Car Failure Rate

▲ Petrol Private Car (2004) Failure

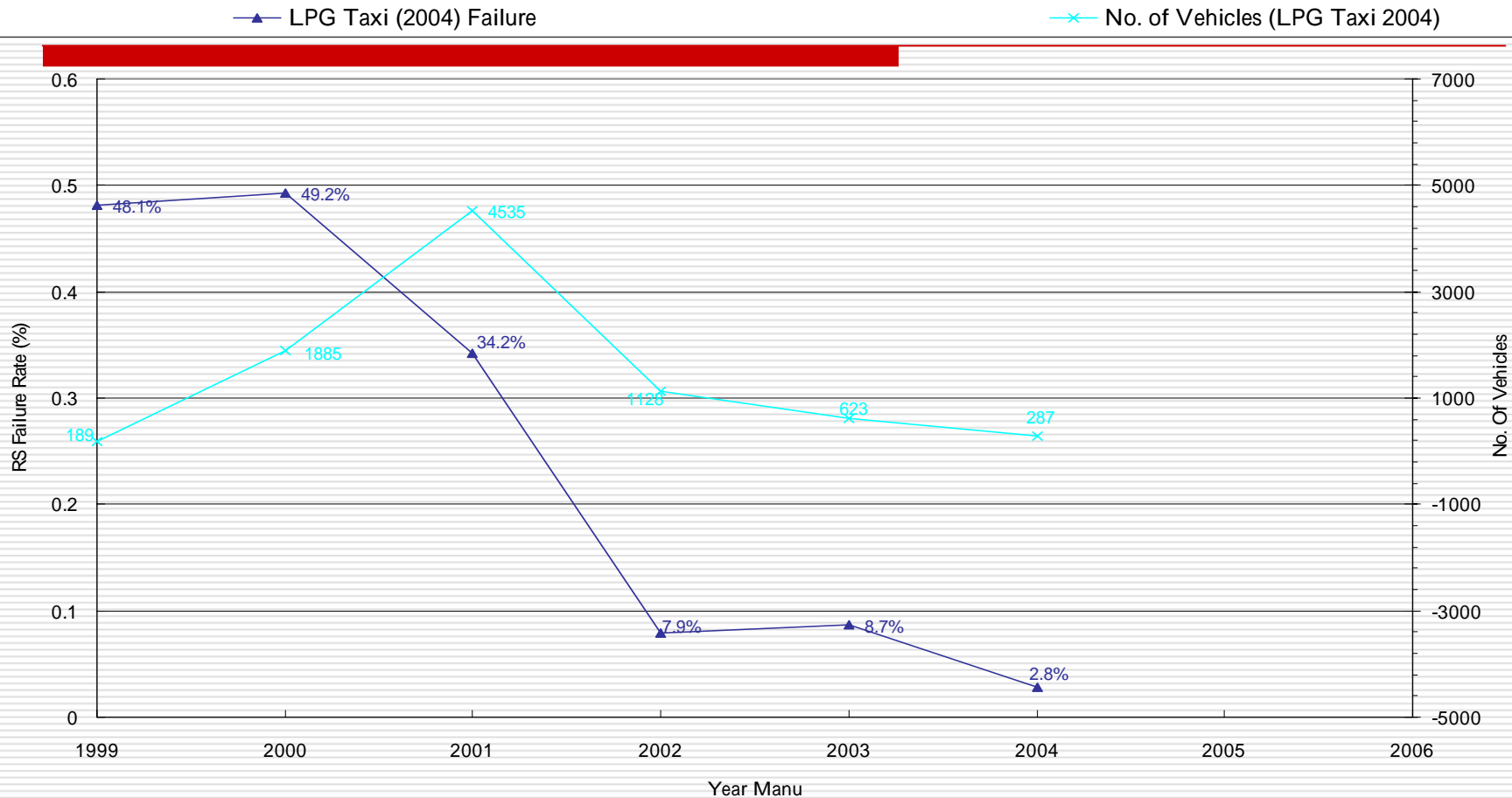
× No. of Vehicles (Petrol PC 2004)



GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

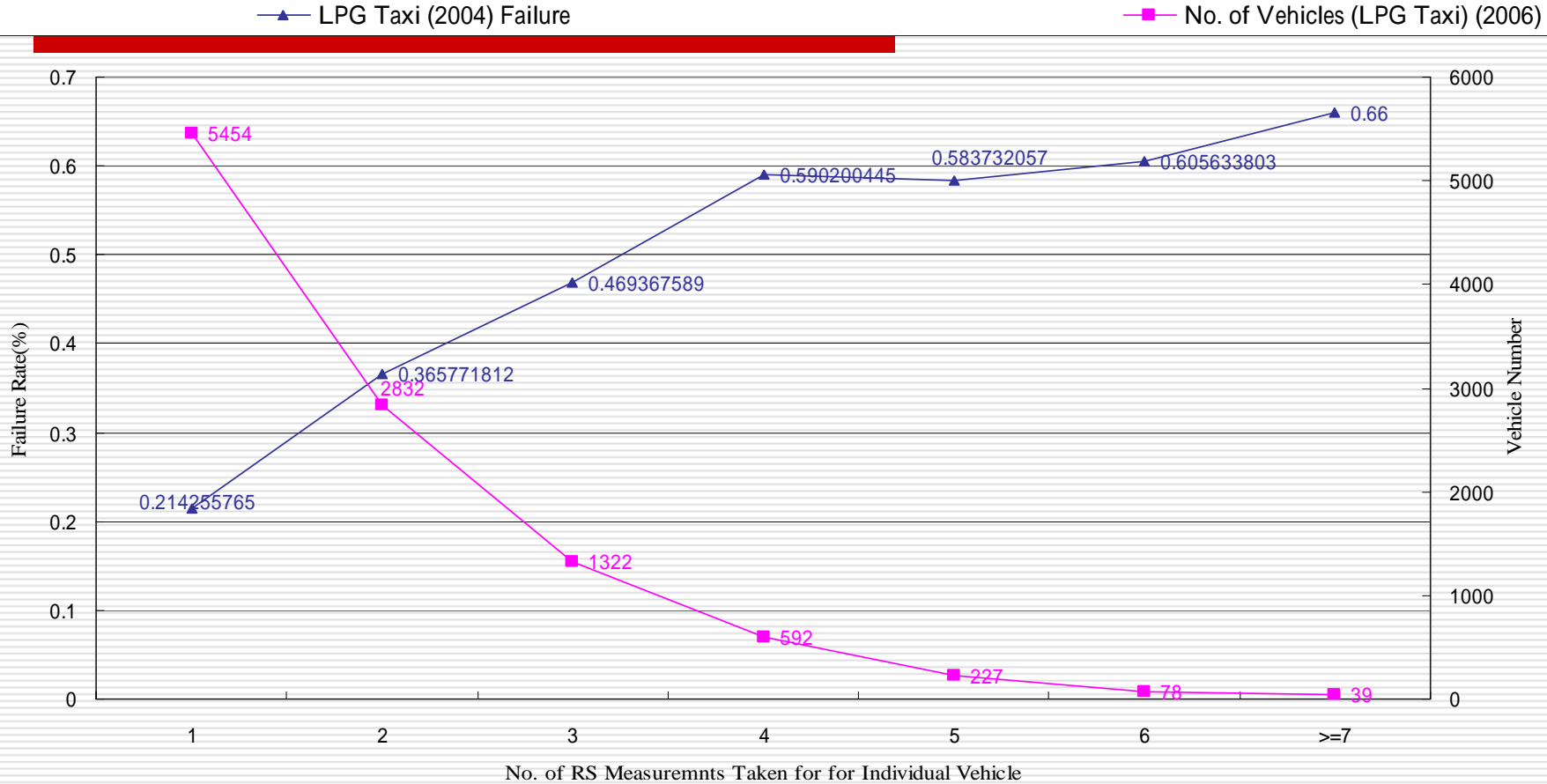
RS 2004 Tax Failure Rate



GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Taxi Failure Rate



Concept of Gross Polluter Control using RS and Dynamometer

- Dynamometer cycle gm/km determined by transient emission during acceleration
 - Find out the corresponding concentration limits from dynamometer test data making reference to the gm/km results and technology classes
 - Assume all RS measurements (true high readings using two RS devices in series) are under transient driving mode
 - Our study on 34 vehicles shows no error of commission
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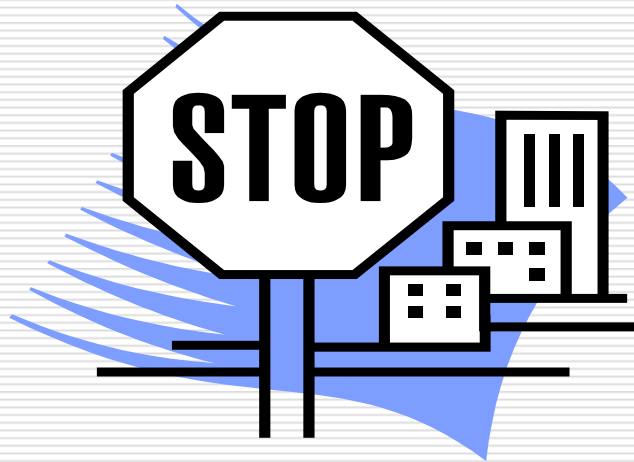
6. Good Remote Sensing Equipment

- ❑ High valid percentage - gas, speed /acceleration, photo
 - ❑ Good productivity – quick setup, easy calibration and audit even during heavy traffic, night mode operation
 - ❑ Lower detection limits for NO_x – for newer and future vehicles
 - ❑ Improve value for money – provide data for intended use of equipment and adoptable to specific programmes
-

7. Preferable Future Model of RS

- Compact in Size
 - Ease of setup
 - Ease of Calibration
 - Automated procedures and real time check of key operation parameters
 - Less Connection Cables
 - Battery-operated
 - Remote Control Function
 - Incorporated ALPRS system if practicable
 - Possible to detect cold catalytic converter
-

THANK YOU !



y_s_yam@epd.gov.hk ; kl_poon@epd.gov.hk
