CLEANING THE AIR IN NIGERIA – LESSONS FROM AN I/M CAMPAIGN

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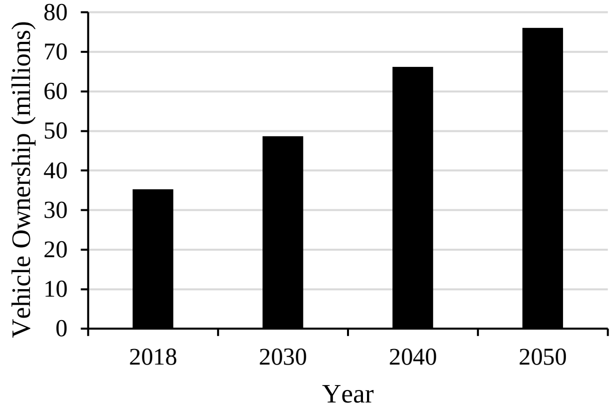
Overview

- Background, motivation and feasibility
- Trial introduction, test protocol and tested fleet characteristics
- Emission results and PTI pass/fail thresholds
- Comparison between Nigerian and Swedish vehicles
- Comparison of Nigerian fleet to US Emission Standards
- Vehicle repair study
- Costs and benefits
- Summary

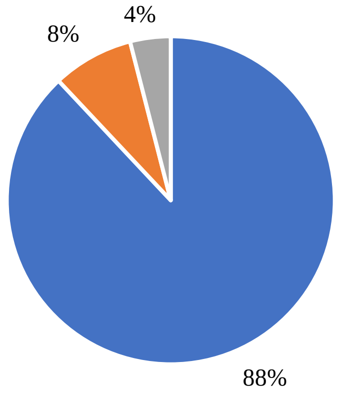
Background and motivation

- Levels of $PM_{2.5}$ in Nigeria are greater than the World Health Organization (WHO) recommended levels, and other pollutants such as CO, NO_2 and SO_2 have also been of concern in Nigeria[3].
- WHO Director-General, Dr Tedros Adhanom Ghebreyesus: “Air pollution is a threat to health in all countries, but it hits people in low- and middle-income countries the hardest”[4].

Nigeria Vehicle Ownership[1]



Nigeria Oil Product Consumption[2]



[1] Ukonze, Ifeoma & Nwachukwu, Maxwell & Chike, Harold & Okeke, Donald & Jiburum, Uloma. (2020). Determinants of Vehicle Ownership in Nigeria. SAGE Open. 10. 215824402092297. 10.1177/2158244020922970.

[2] Enerdata, 2020. https://www.enerdata.net/estore/energy-market/Nigeria/

[3] Obanya HE, Amaeze NH, Togunde O, Otitoloju AA. Air Pollution Monitoring Around Residential and Transportation Sector Locations in Lagos Mainland. J Health Pollut. 2018; **8** (19): doi: 10.5696/2156-9614-8.19.180903.

[4] https://www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution

Feasibility

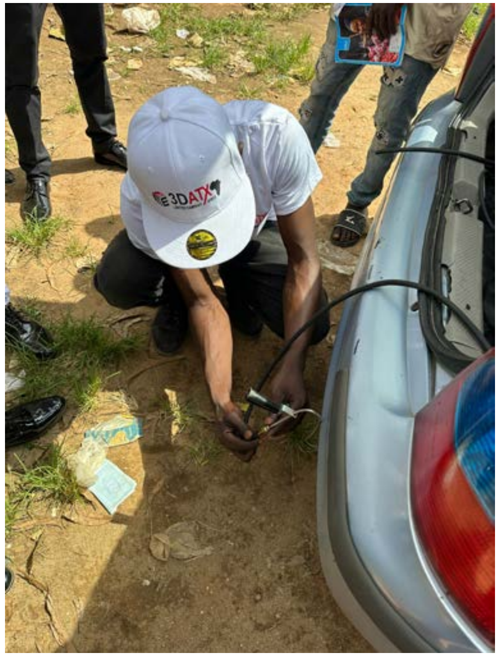
Often, real-world emissions testing is compromised due to issues with:

1. Instrument – uni-purpose, cost (with maintenance), size and weight,
2. Time to complete a test – install, test, uninstall,
3. Human resources – required expertise,
4. Finances – total cost per test per pollutant,
5. Validity – claims of lack of *sufficient* repeatability.

Using the parSYNC® FLEX, 3DATX conducted a feasibility trial that addressed the above issues; measuring real-world emissions and identifying an economically viable action plan to fix the highest polluting vehicles, thus improving air quality.

Trial introduction

- **Trial objective:** Test approximately 100 on-road passenger cars on a first-come first-served basis according to a standard programme to ensure accurate vehicle emissions testing and data integrity.
- **Outcome:** 103 vehicles tested in 5 days.



Equipment used – The parSYNC FLEX iPEMS

- Sensor cartridges:
  - C-GasMOD – CO, CO_2, HC & O_2,
  - N-GasMOD – NO & NO_2,
  - Particulates – PN and PM.
- ECU reader requesting:
  - Vehicle speed, engine speed, mass air flow, throttle position, lambda, fuel rate, absolute throttle position, air intake temperature.

Gases	Non-Dispersive Infrared Spectrometer (NDIR)			Individual Electro-Chemical Cells		
	CO_2	CO	HC	O_2	NO	NO_2
Measurement Range	0-20%	0-15%	0-4000ppm	0-100%	0-5000ppm	0-300ppm
T_{90} Response Time	< 3.5 seconds	< 3.5 seconds	< 3.5 seconds	< 6 seconds	< 5 seconds	< 35 seconds
Accuracy	±0.3% absolute ±3% relative	±0.02% absolute ±3% relative	±8ppm absolute ±3% relative	±0.1% absolute ±2% relative	±15ppm absolute ±2% relative	±5ppm absolute ±2% relative
Repeatability	±0.1% absolute ±2% relative	±0.02% absolute ±2% relative	±6ppm absolute 2% relative	±0.1% absolute 2% relative	5ppm 2% of signal	5ppm 2% of signal
Particulates	PN and PM via Scattering, Ionization and Opacity sensors.					
Particle Size Range	10 to 10,000nm = 0.01 to 10µm					

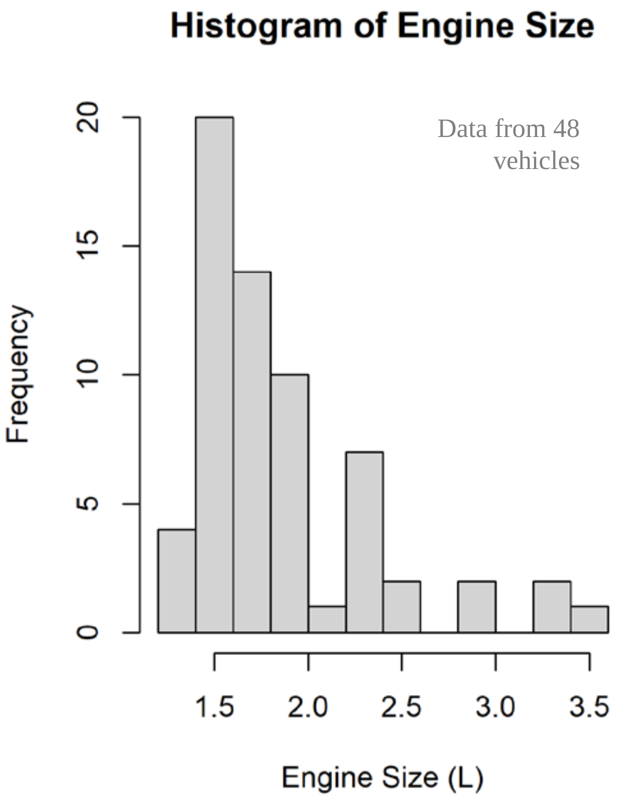
Test protocol followed by each vehicle

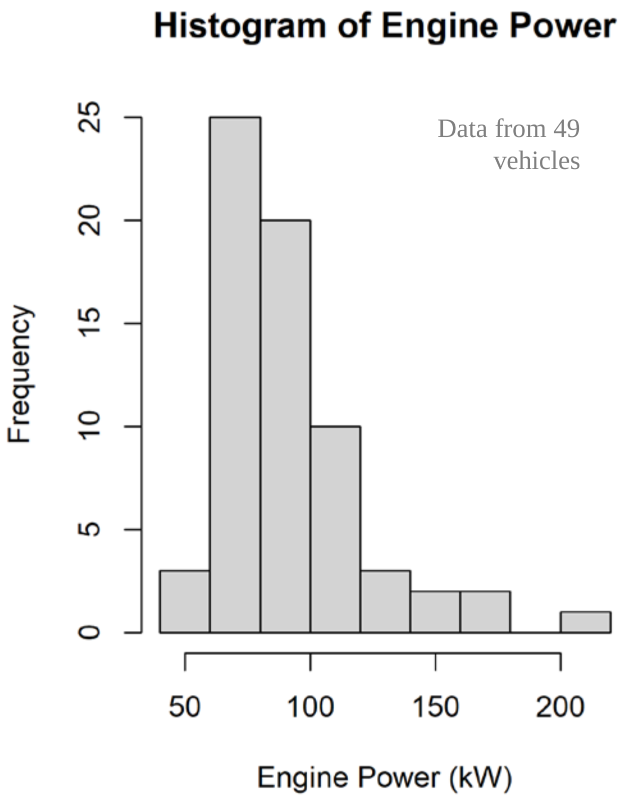
Phase	Objectives
1. Zeroing	Zero the parSYNC® FLEX instrument
2. Measure filtered air	Pre-verification of zero
3. Measure ambient air	Pre-check ambient conditions
4. Measure vehicle exhaust at idle	Verify test vehicle emissions without load
5. Measure vehicle exhaust while driving	Verify test vehicle emissions under load: The vehicle is driven around a standard and repeatable route under safe conditions
6. Measure vehicle exhaust at idle	Reverify test vehicle emissions without load
7. Measure ambient air	Post-check ambient conditions
8. Measure filtered air	Post-verification of zero

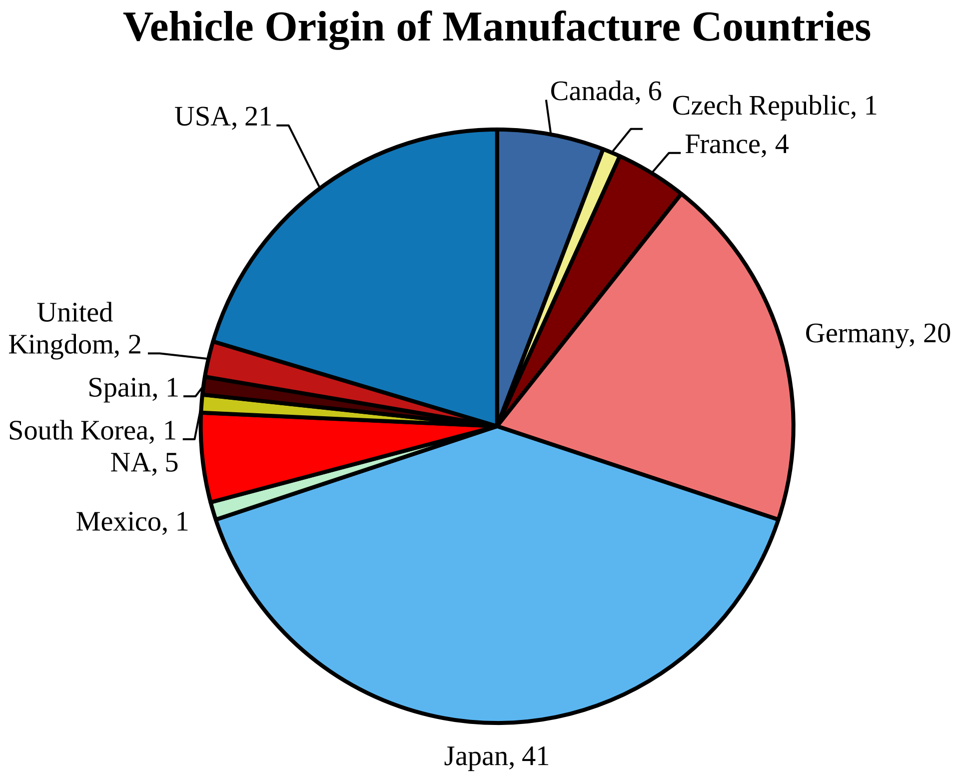
- Test procedure performed in approx. 10 minutes at road-side.
- Drive section took on average 394 ± 12 s to complete, had a mean speed of 26 ± 3 km/h and maximum speed of 55 ± 5 km/h.

Fleet characteristics

103 gasoline-fuelled vehicles were tested during this trial.







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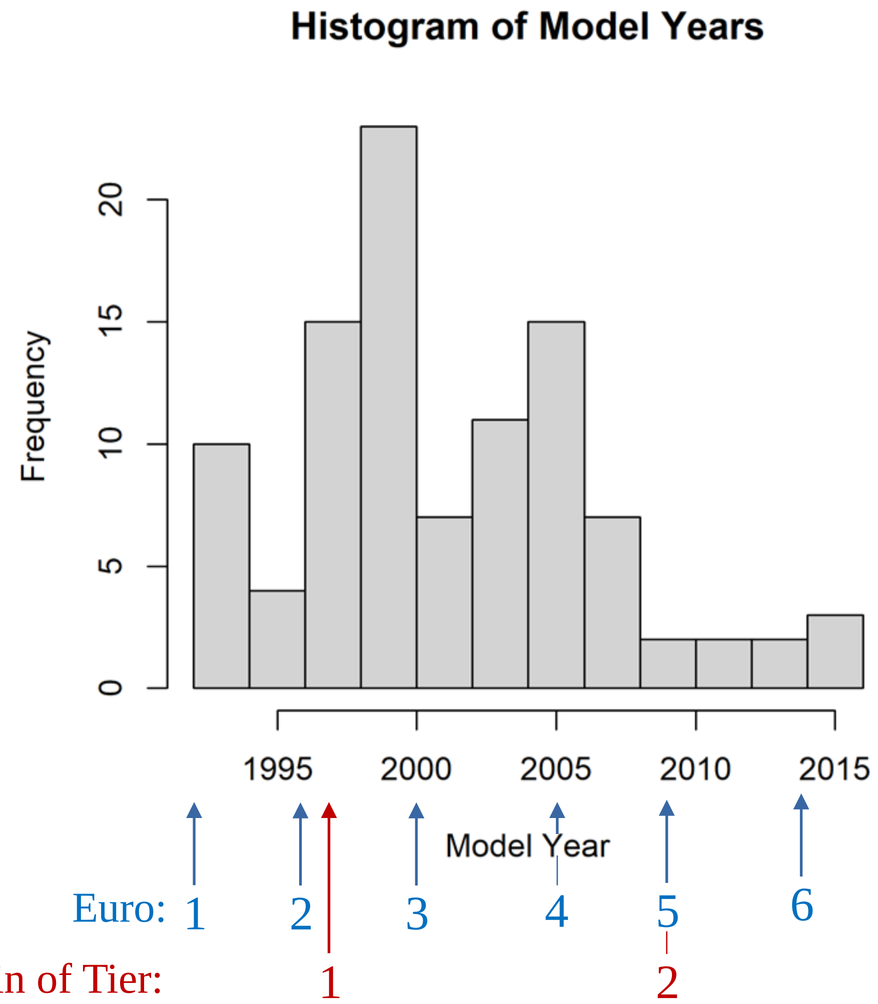
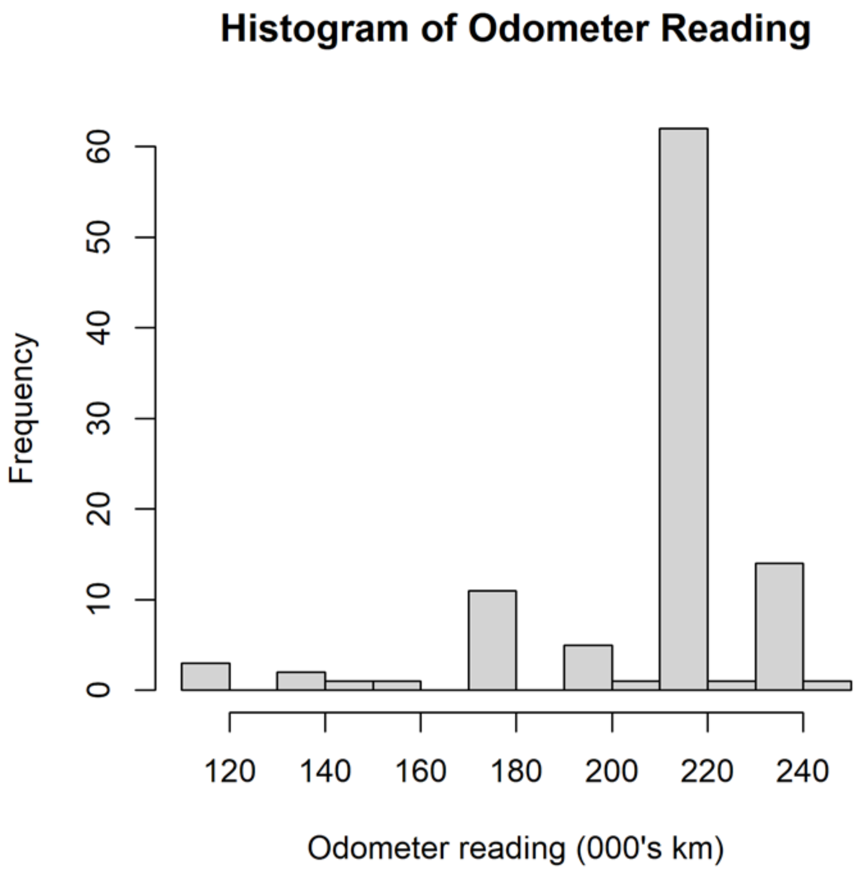


(1 vehicle MY 1963 not plotted)



Emission results and PTI pass/fail threshold calculations

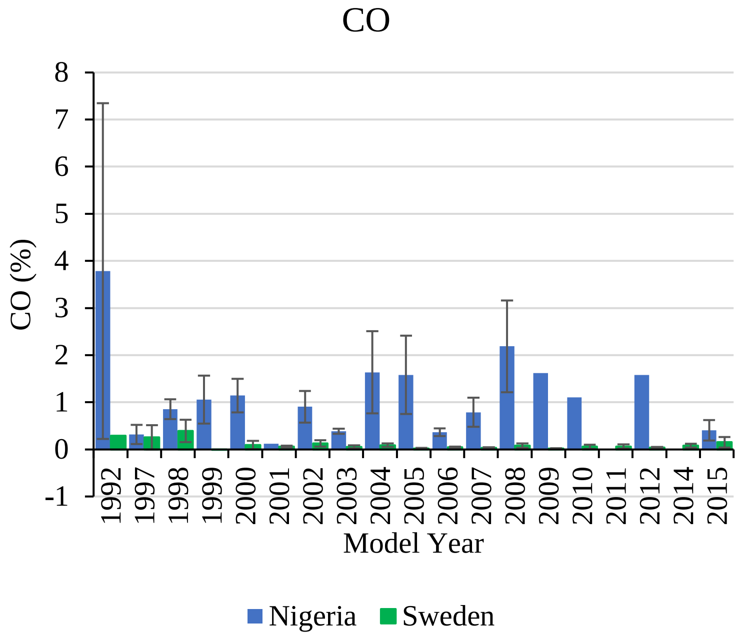
- Mean pollutant concentration results from the idle and drive tests.
- An *example* pass/fail threshold: the 90th percentile of the tested vehicle fleet emissions i.e. 10% of tested vehicles would fail and require repairs.

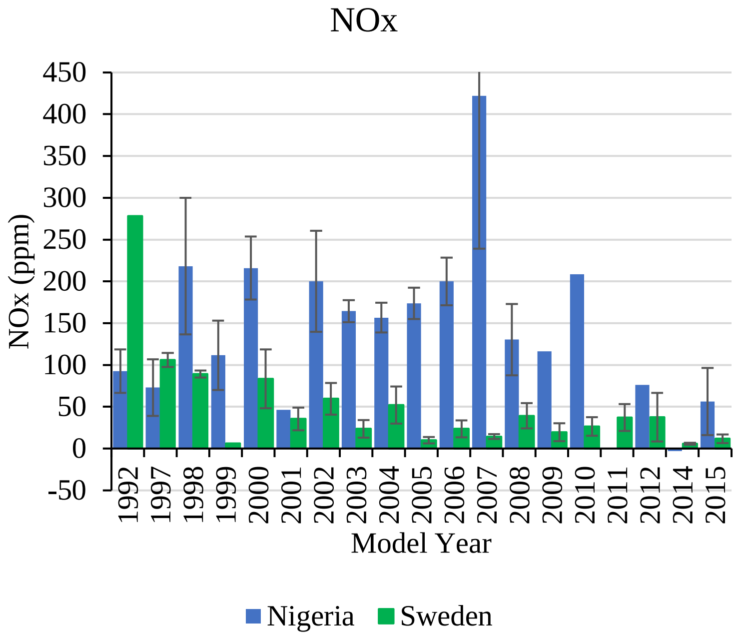
Pollutant	Idle Test		Drive Test	
	Mean value	90th percentile	Mean value	90th percentile
NOx (ppm)*	158	249	1137	1445
CO (%)	0.86	1.50	1.28	1.96
HC (ppm)	671	1130	704	1252
PM (ug/m3)	3340	4092	4670	5430
PN (#/cm3)	1.44×10^7	1.59×10^7	1.51×10^7	1.59×10^7

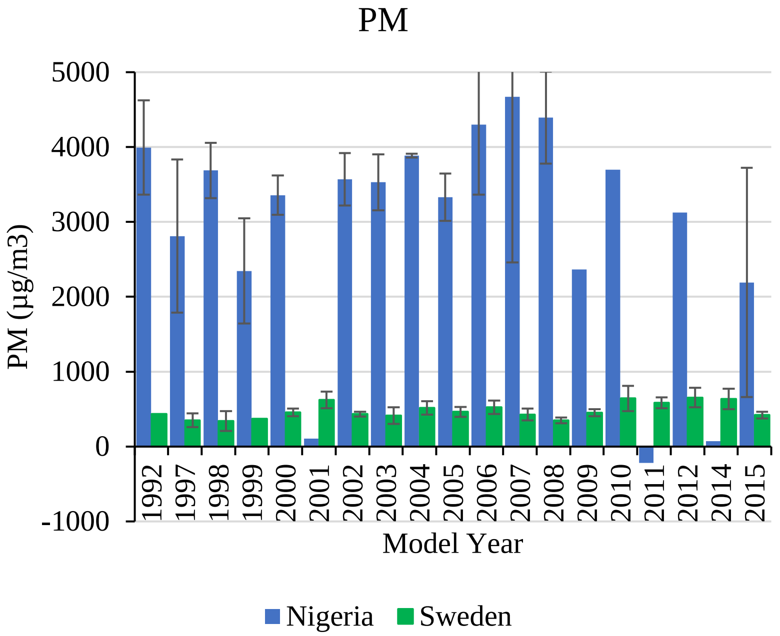
* Over 99% of the NOx is NO and remainder is NO_2

Comparison between Nigerian and Swedish vehicles

- ➢Pollutant concentrations of the idling petrol vehicles from the trial in Abuja, Nigeria are much higher than petrol vehicles from a similar trial in Borås, Sweden:





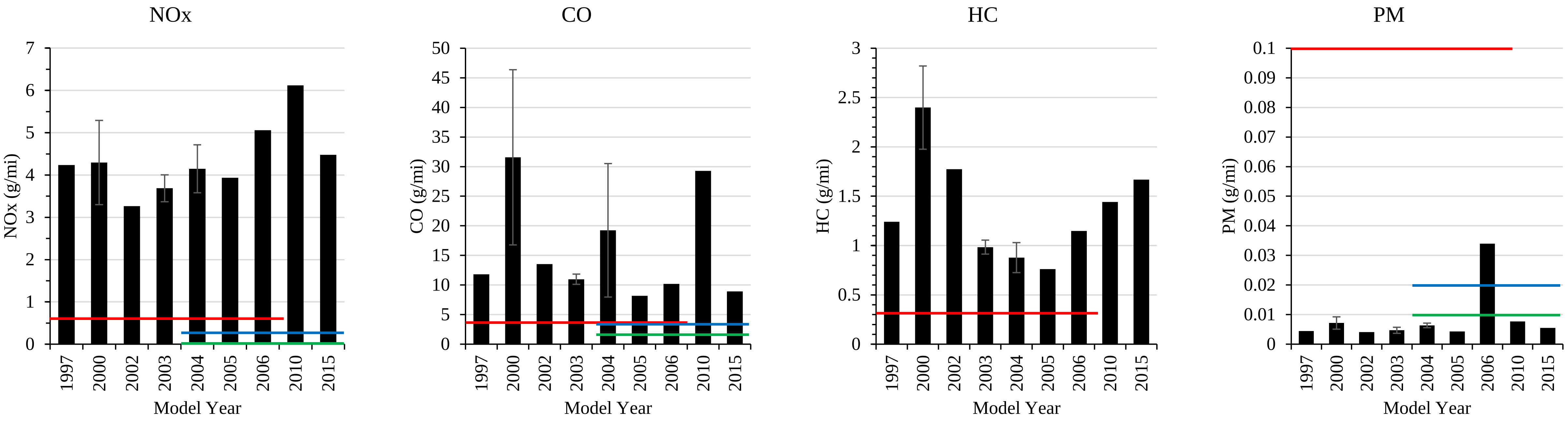


- ➢ Meanwhile, the CO_2 concentrations are generally lower in Nigeria than Sweden.

All results indicate that combustion quality is poorer in Nigeria than Sweden, likely due to worse fuel quality and poorer maintenance/tampering of vehicles in Nigeria, compared to Sweden.

Comparison to US Standards

Vehicle NOx, CO and HC emission factors from the drive test section of the trial in Abuja, Nigeria are far higher than the respective Tier 1 and Tier 2 (FTP 75) standards applicable* to these vehicles at full useful life 100-120,000 miles/10 years. PM is generally lower.

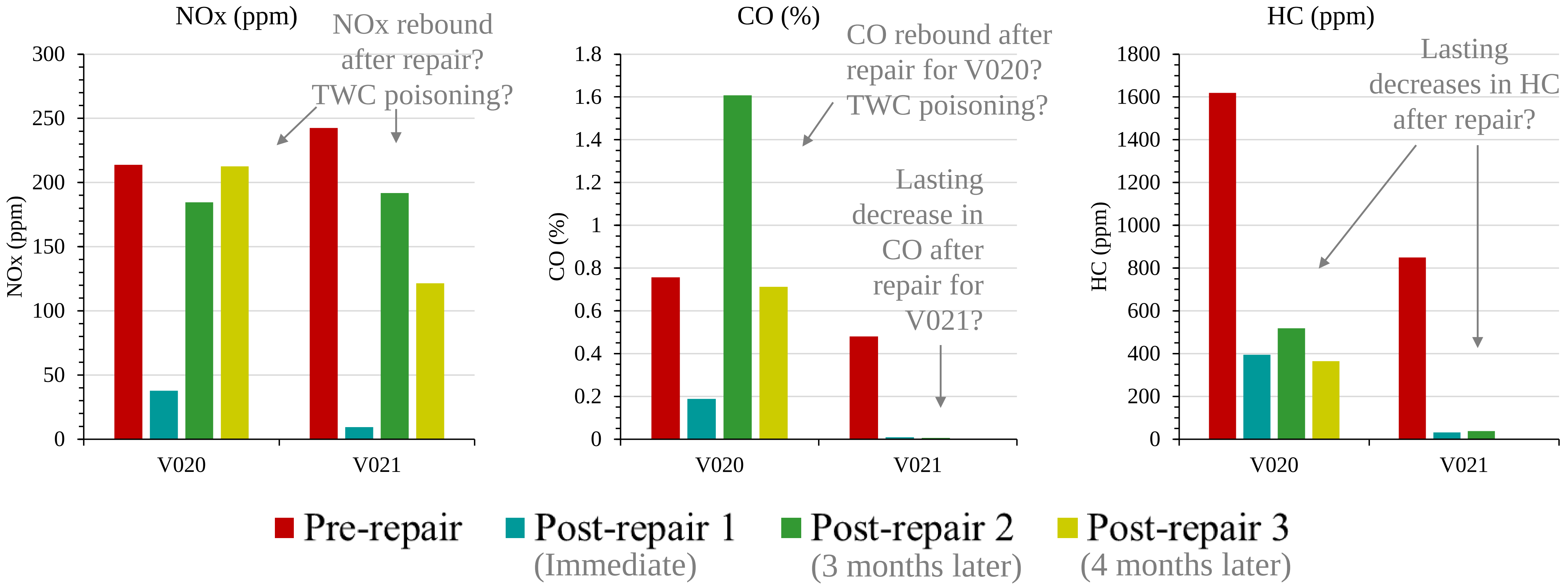


- Tier 1 standards for NOx, CO, NMHC, and PM
- Upper limit of Tier 2 standard bins for NOx, CO, NMHC, and PM
- Lower limit of Tier 2 standard bins for NOx, CO, NMHC, and PM

* Note that the coloured lines denote NMHC limit (not HC, as measured during trial)

Vehicle repair study – Idle test

Two vehicles (V020 and V021) were tested once (‘pre-repair’), then had their TWC replaced with new ones. Following repair they were retested immediately (‘post-repair 1’), after 3 months (‘post-repair 2’), and after 4 months (‘post-repair 3’). Idle test results:



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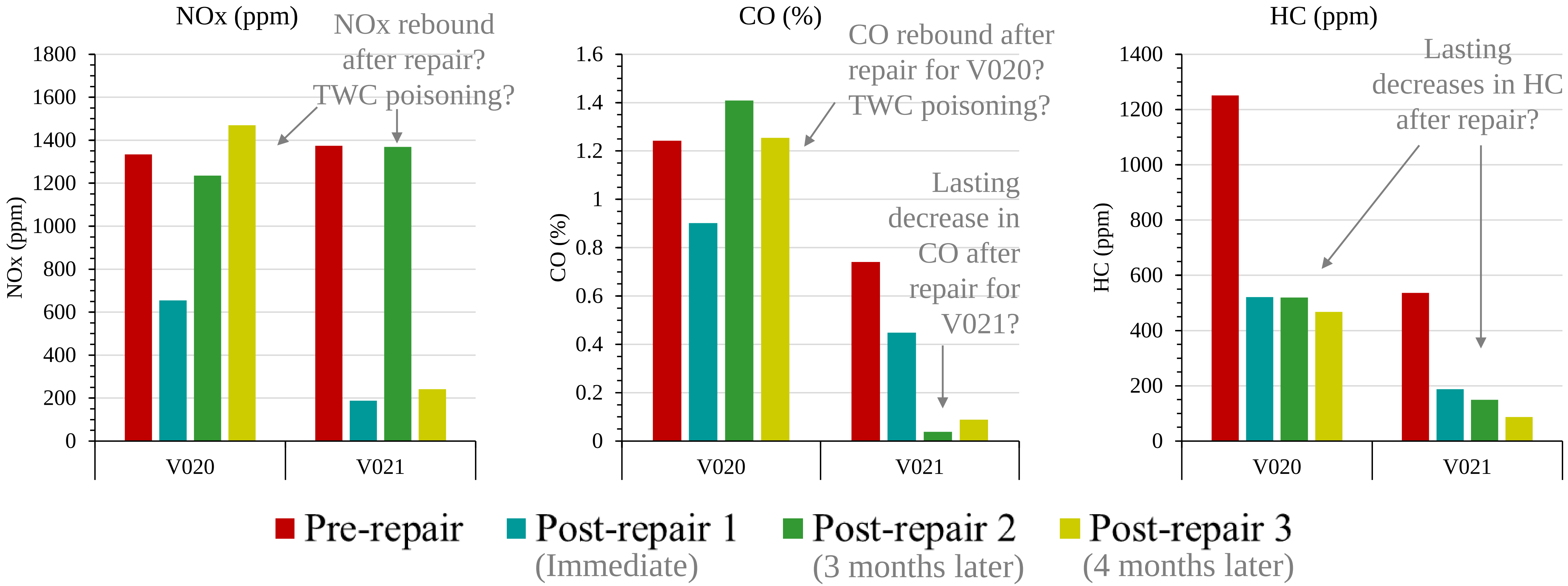
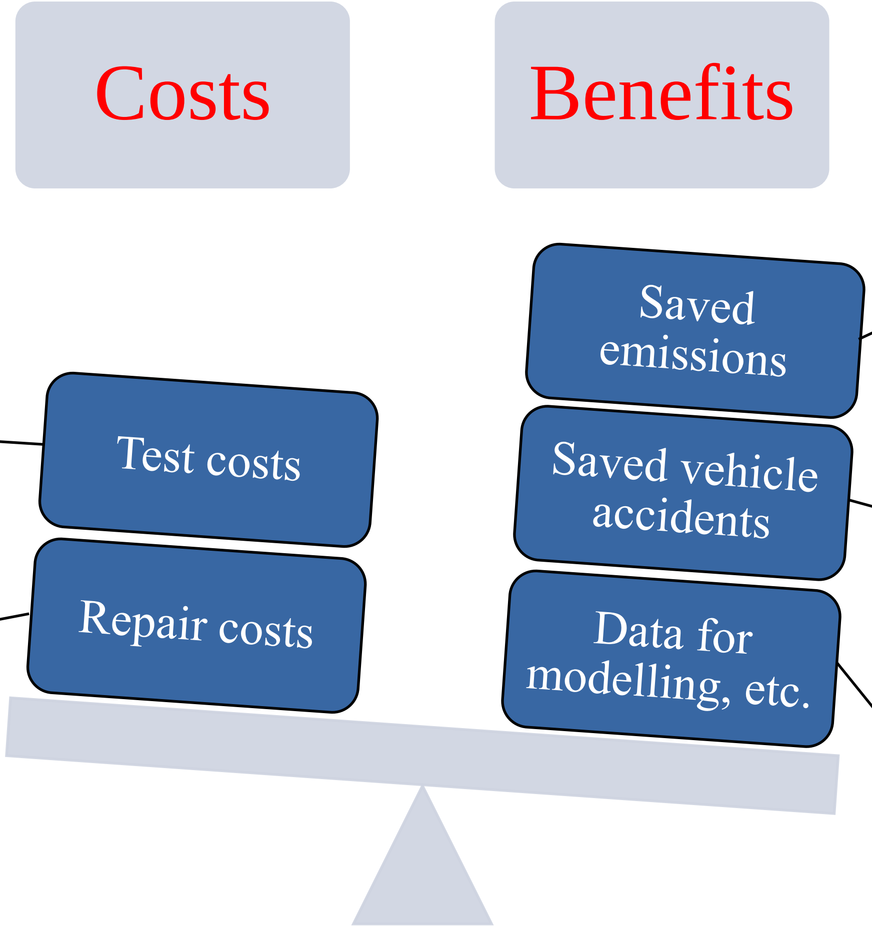


Costs and benefits



Charge per test

Repair/replacement of parts

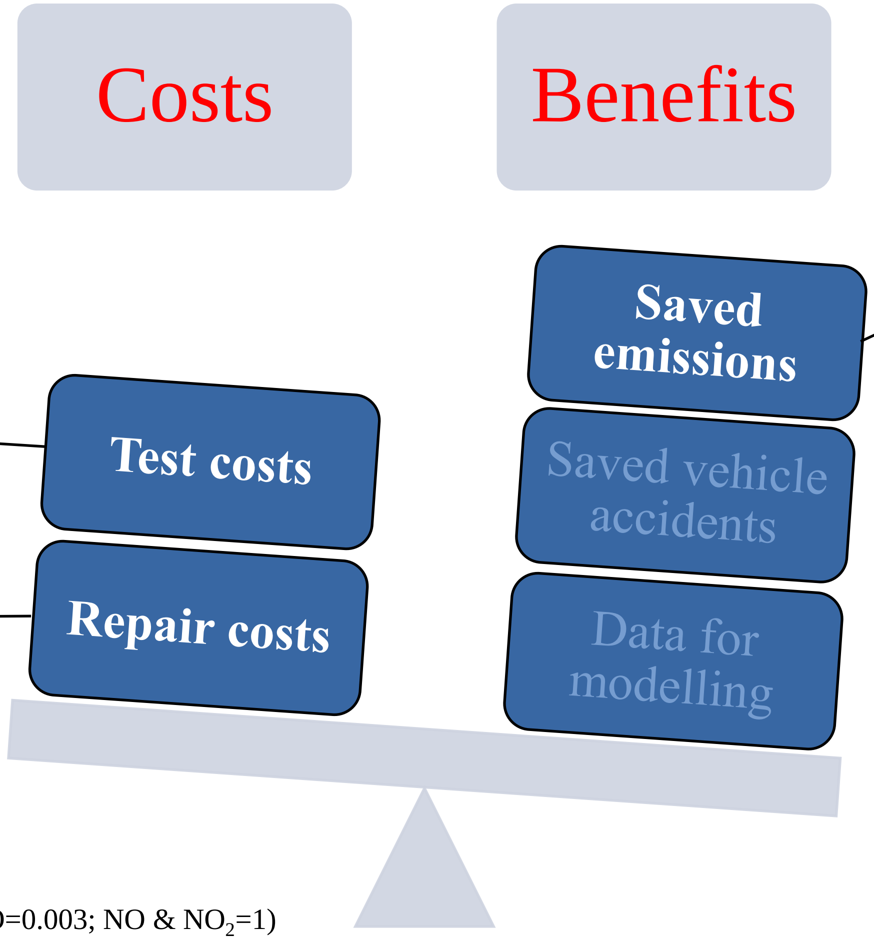
Each repaired vehicle will emit less emissions over the duration of the repaired period

Well maintained cars have fewer accidents, reducing associated morbidity, mortality, healthcare costs and vehicle repair/replacement costs

The test data could be used to build up a database of emissions data for modelling, policy decision-makers etc.

Costs and benefits – an example

Using example values and assumptions, the \$/kg costs to reduce emissions can be estimated:



\$10 per vehicle test

Assumed 10% fail and repair rate

\$300 per repair x 10% = \$30

Overall costs: <u>\$40</u>

Based on the OBD-acquired vehicle fleet top 10th percentile average mass emissions and the first repaired vehicle study, each repaired vehicle could emit approx. 3205 mg/km less $NOx_{equivalent}$[1].

10% x 17,000 annual km/vehicle[2]
x 5 years assumed repair lifetime[3]
x 3205 mg/km NOx_{eq} saved[4]
= **<u>27.24 kg NOx_{eq} saved</u>**

So, rate is **<u>1.47 \$/kg$_{NOxeq}$</u>** (for emissions alone)

Cost unit rates[5] for emissions in EU road transport are 7.33 \$/kg$_{NOxeq}$.

- **<u>System of I/M with sustainable repairs is a cost-effective pollutant reduction</u>**

[1] NOx equivalent calculated using toxicity factors (HC=1.5; CO=0.003; NO & NO_2=1)
[2] Value from the World Bank report on Assessing Low-Carbon Development in Nigeria (2013).
[3] Tier 1 and 2 intermediate life standards (presumably applicable to components repaired) last 5 years.
[4] The average percentage change between pre- and immediately post- repair vehicles was applied to the average mass emissions from top 10 percentile of vehicles tested (for which OBD data could be acquired). Note that the real value may be higher as OBD acquired vehicles were generally the newer (lower emission) studies.
[5] Cost unit rate based on EC-Directive 2009/33 for 2007 (4.4 €/kg), adjusted to 2024 with 2% per year inflation (6.16 €/kg), and 1.19 \$/€ exchange rate.

Summary

- An I/M test protocol has been designed that works in Nigeria.
- Pollutant concentrations were much higher than those in Sweden: Combustion quality is poorer in Nigeria, likely due to worse fuel quality and poorer vehicle maintenance/tampering.
- Gaseous pollutant emission factors of vehicles tested are much higher than the corresponding US EPA standards (PM is generally lower): worse fuel quality and vehicle degradation/tampering.
- Benefit of TWC repairs may have partially rebounded: Did the TWC get contaminated by bad fuel?
- A system of I/M with repairs could be a cost-effective pollutant reduction option.
- There are many potential benefits to the introduction of an I/M test in Nigeria: Controlling emissions and providing much needed fleet emission data useful for modelling, policy decisions etc.

Thank you for listening

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