Suitability of iPEMS for Inspection and Maintenance in Nigeria

Daisy Thomas, Ph.D.

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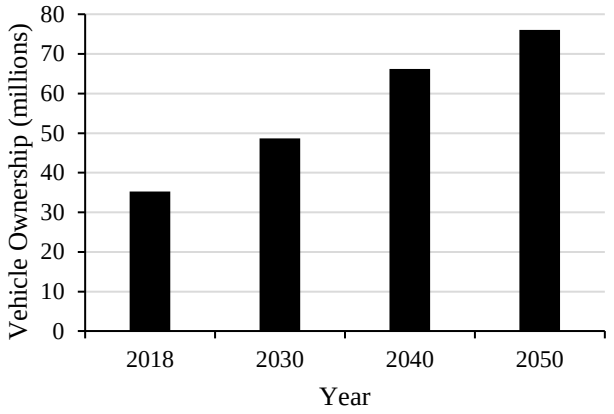
Overview

- Background, motivation, feasibility and trial introduction
- Test protocol and tested fleet characteristics
- OBD acquisition success rate
- Alternatives to OBD data
- Is concentration sufficient for emissions?
- Prospects for vehicle repairs
- Costs and benefits
- Summary

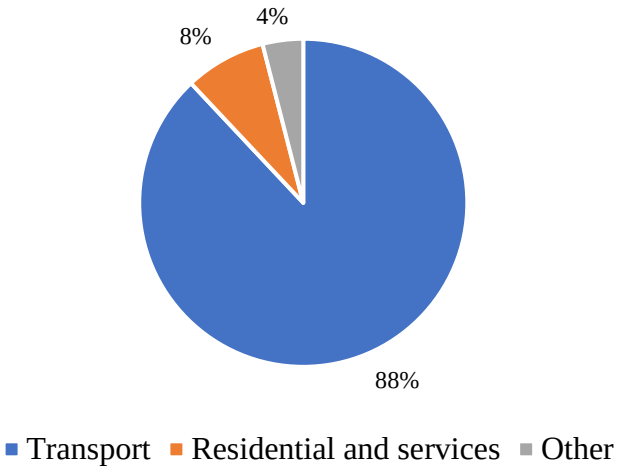
Background and motivation

- 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].
- Air pollution is one of the biggest environmental threats to human health, alongside climate change.

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.

Feasibility

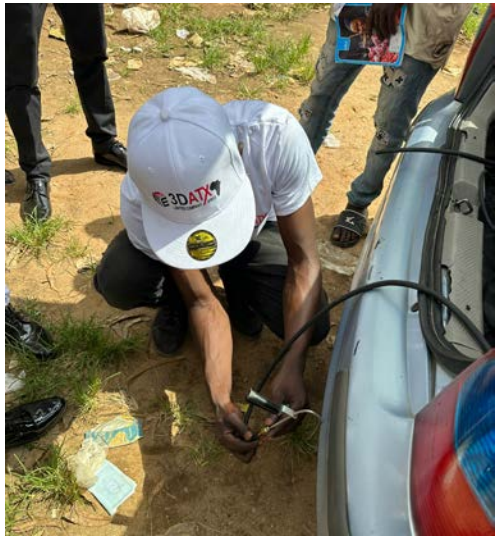
Often, real-world emissions testing is compromised due to issues with:

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:** Assess ability to test Nigerian on-road passenger cars according to a standard programme, ensuring accurate vehicle emissions testing and data integrity.
- **Outcome:** 9 previously untrained staff were used for testing, and each was trained for 1 day in preparation. Results were that 103 vehicles were tested in 5 days.



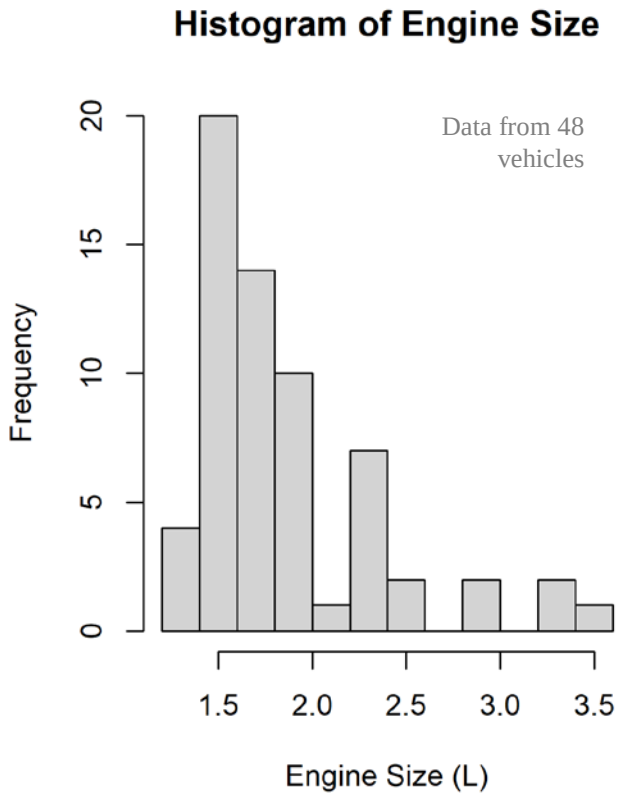

Equipment used – The parSYNC FLEX iPEMS

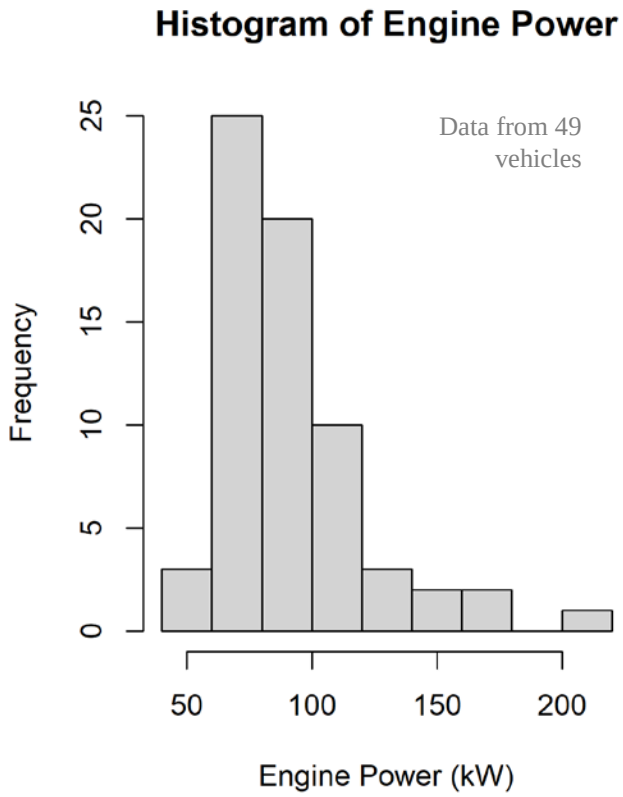
- Sensor cartridges:
  - C-GasMOD – CO, CO_2, HC & O_2,
  - N-GasMOD – NO & NO_2,
  - Particulates – PN and PM.
- ECU reader requesting:
  - Vehicle speed, engine speed, mass air flow, throttle position, lambda, fuel rate, absolute throttle position, air intake temperature.

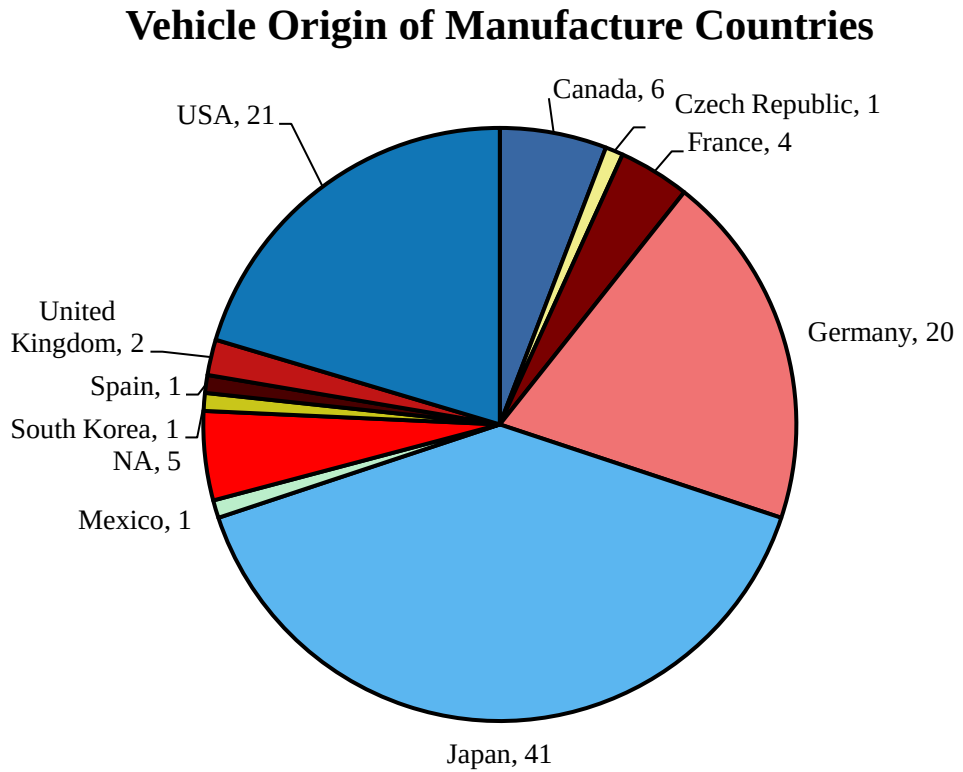
Gases	Non-Dispersive Infrared Spectrometer (NDIR)			Individual Electro-Chemical Cells		
	CO_2	CO	HC	O_2	NO	NO_2
Measurement Range	0-20%	0-15%	0-4000ppm	0-100%	0-5000ppm	0-300ppm
T_{90} Response Time	< 3.5 seconds	< 3.5 seconds	< 3.5 seconds	< 6 seconds	< 5 seconds	< 35 seconds
Accuracy	±0.3% absolute ±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					

Fleet characteristics

103 gasoline-fuelled vehicles were tested during this trial.







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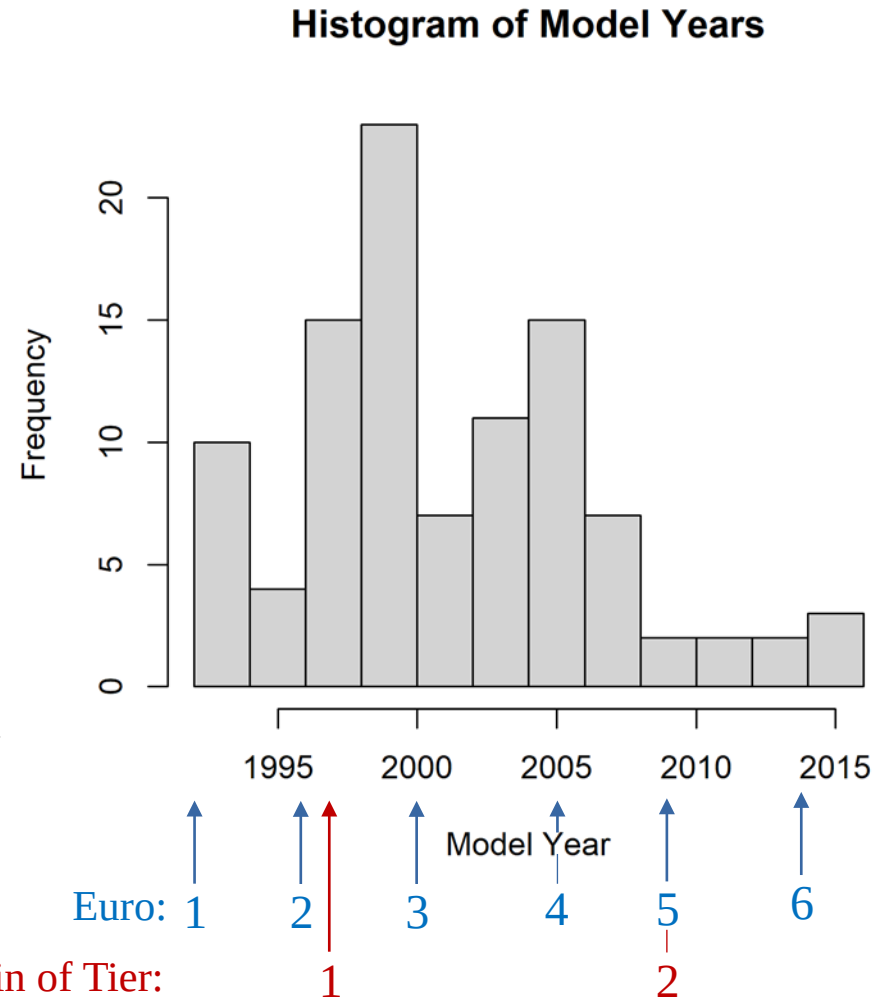
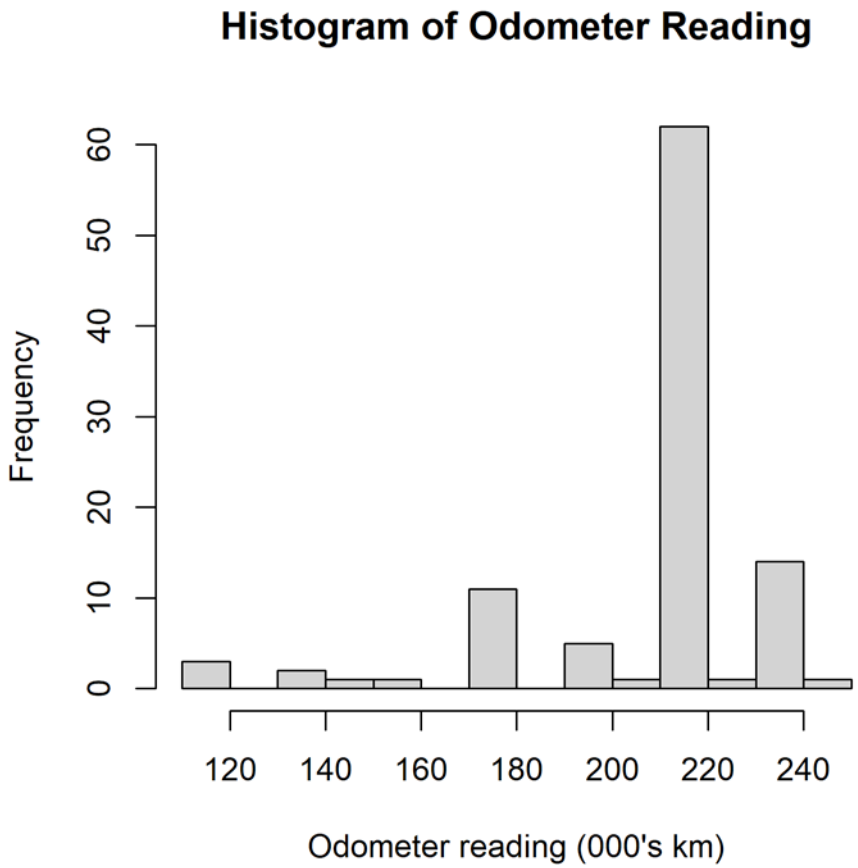


(1 vehicle MY 1963 not plotted)

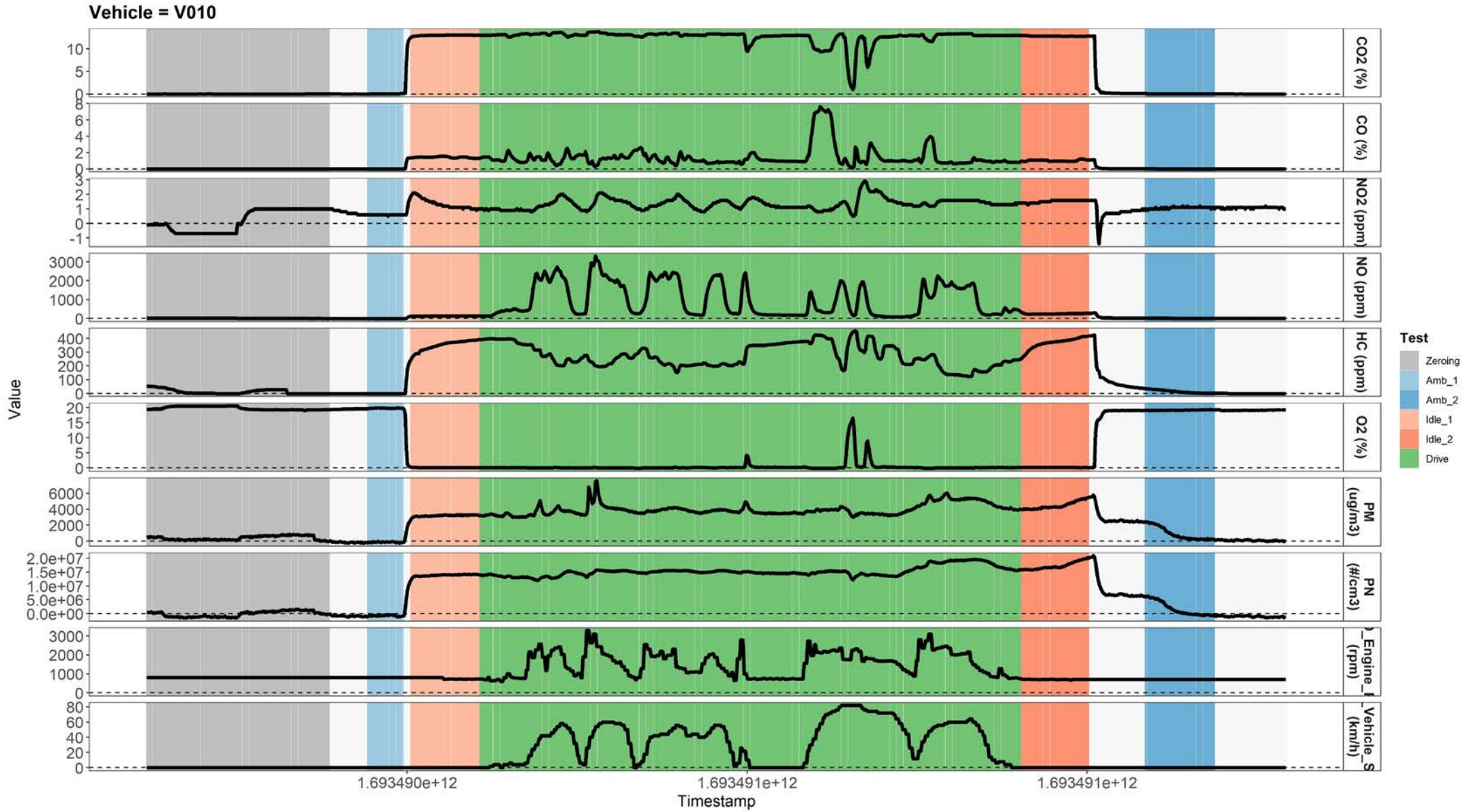


Test protocol followed by each vehicle

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.

Test example



Variability

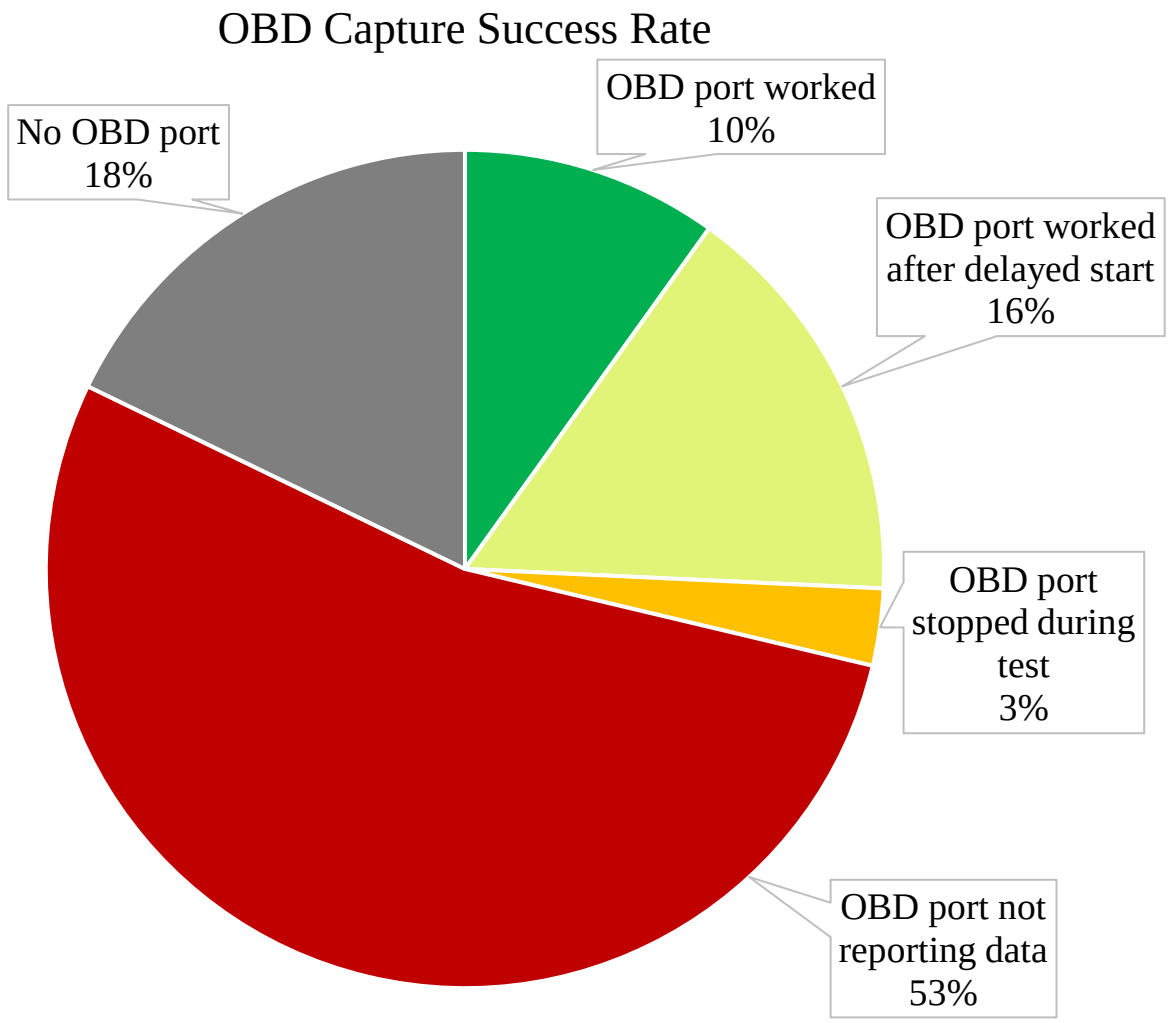
- The coefficients of variation (COV) for were calculated across vehicle data for each test type

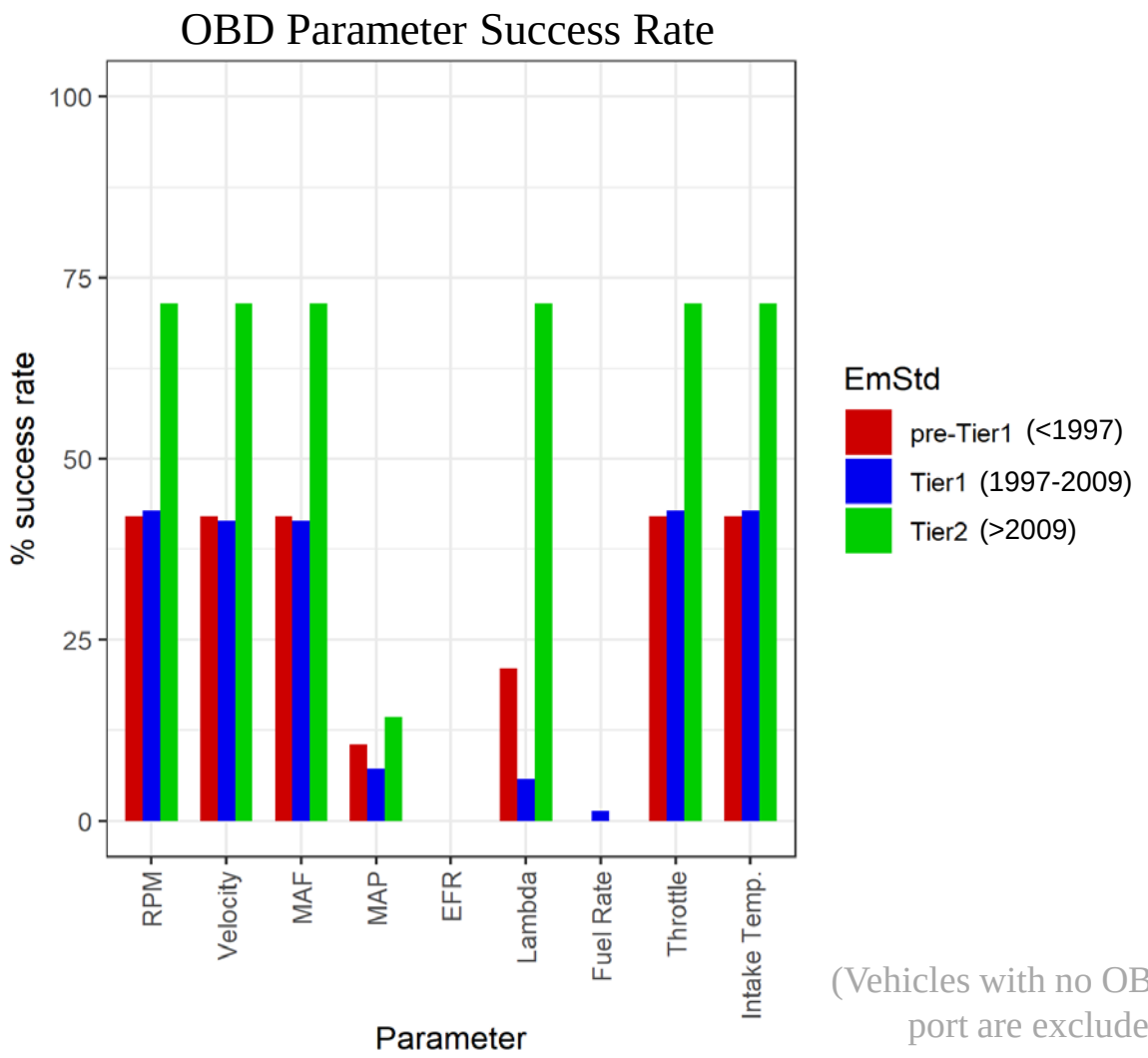
$$COV = \frac{Standard\ Deviation}{Mean}$$

- The COV for pollutant emissions are much greater than for engine or dynamic parameters – the tests are highlighting differences in performance between vehicles

COV Quantity	Idle Test	Drive Test
Average NOx (ppm)	37%	34%
Average CO (%)	117%	73%
Average CO_2 (%)	9%	9%
Average HC (ppm)	48%	47%
Average PM (ug/m3)	18%	42%
Average NOx (mg/s)	49%	38%
Average CO (mg/s)	118%	83%
Average CO_2 (g/s)	25%	24%
Average HC (mg/s)	50%	51%
Average PM (mg/s)	35%	92%
NOx (mg/km)	NA	37%
CO (mg/km)	NA	91%
CO_2 (g/km)	NA	22%
HC (mg/km)	NA	52%
PM (mg/km)	NA	90%
Average Engine RPM	11%	8%
Average Mass Air Flow (g/s)	24%	21%
Average VSP_{pos} (kW/tonne)	NA	39%
va_{pos}[95]	NA	30%
RPA	NA	1%

Low OBD acquisition success rate



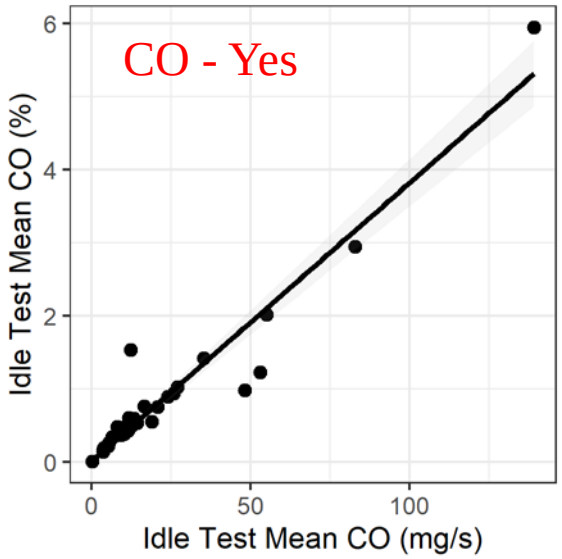


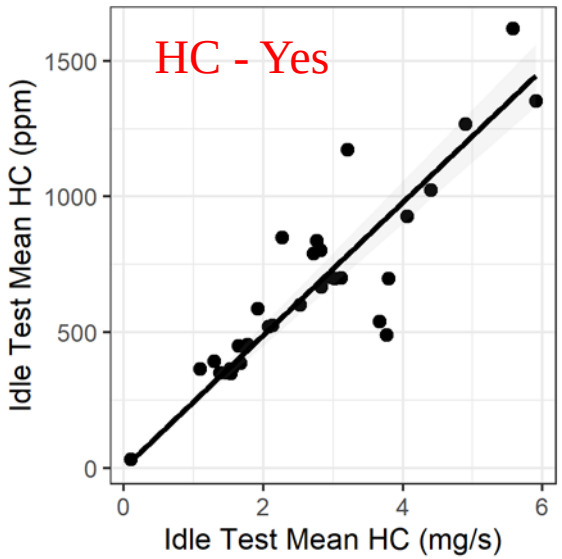
(Vehicles with no OBD port are excluded)

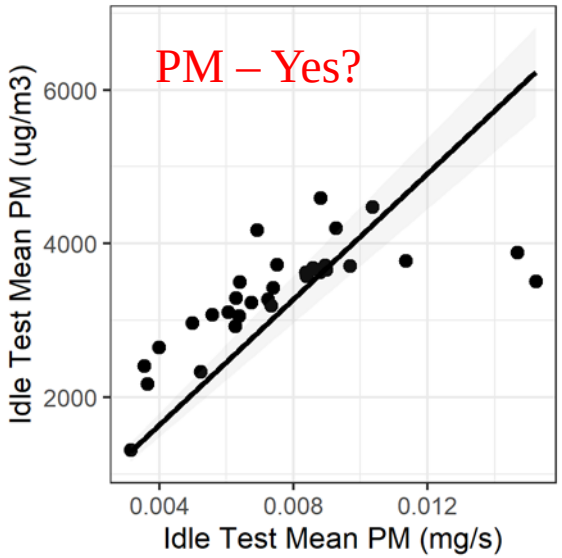
Alternatives to OBD

- OBD info can be scarce for these older vehicles in the Nigerian fleet
- With the use of parSYNC's SCOTTY GPS and Weather system, vehicle speed and ambient conditions can be available for all tests
- Calculation of lambda is also possible from concentrations of CO_2, CO, O_2, NO and HC, based on the Modified Brettschneider Equation
- What about mass emission calculation?

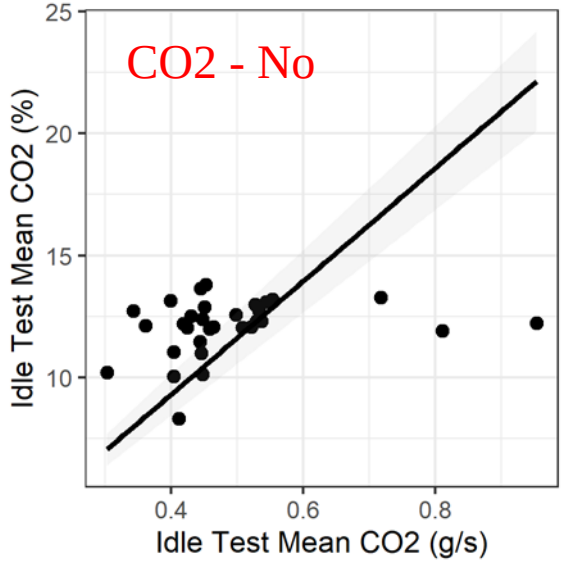
Is concentration sufficient for emissions on idle test?

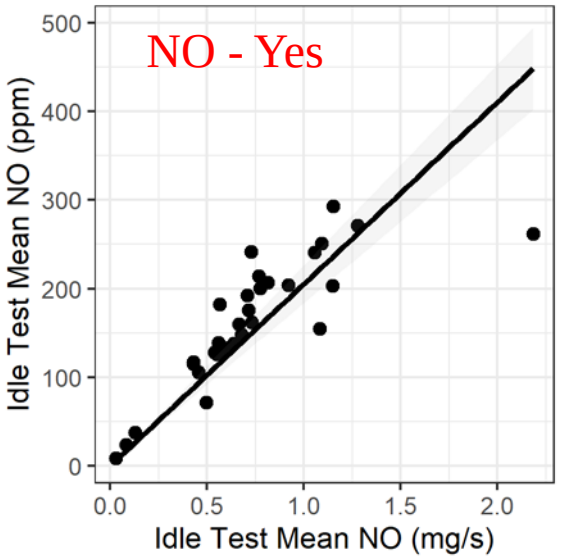


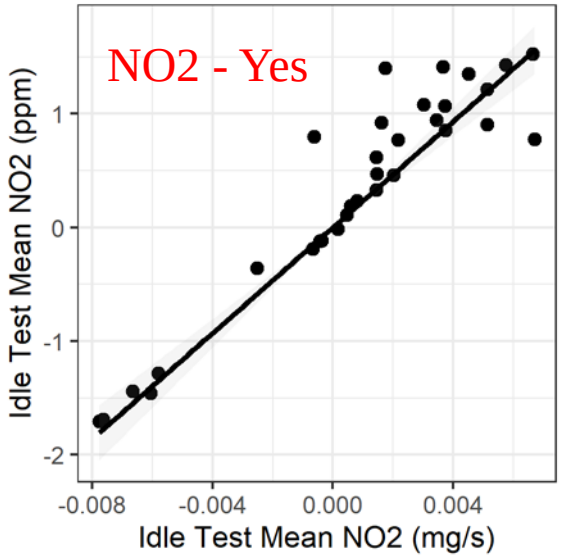


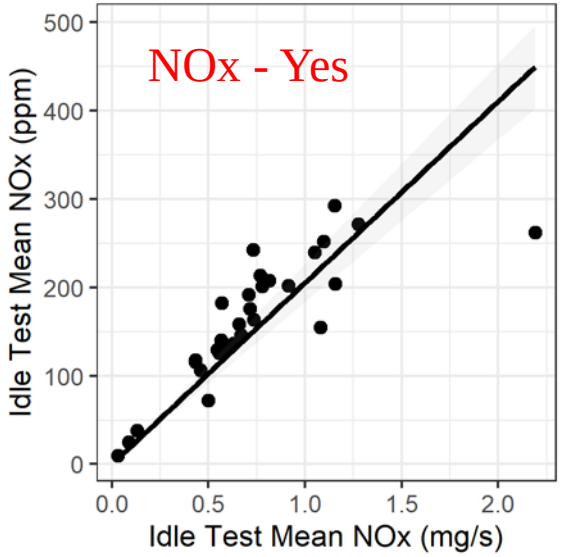


CO2 concentration is not correlated to mass emissions due to stoichiometry of gasoline combustion

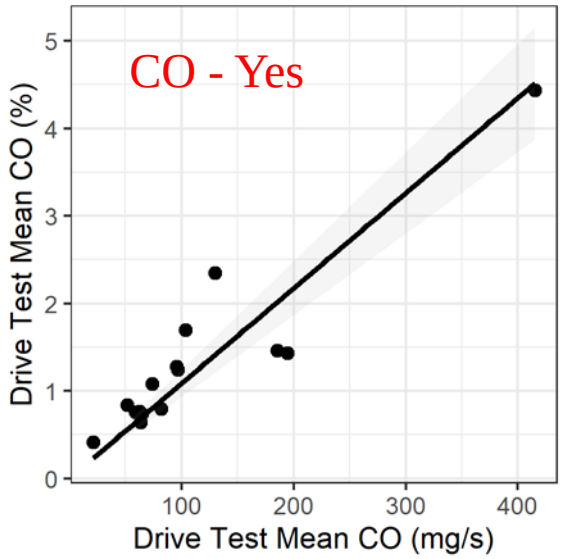


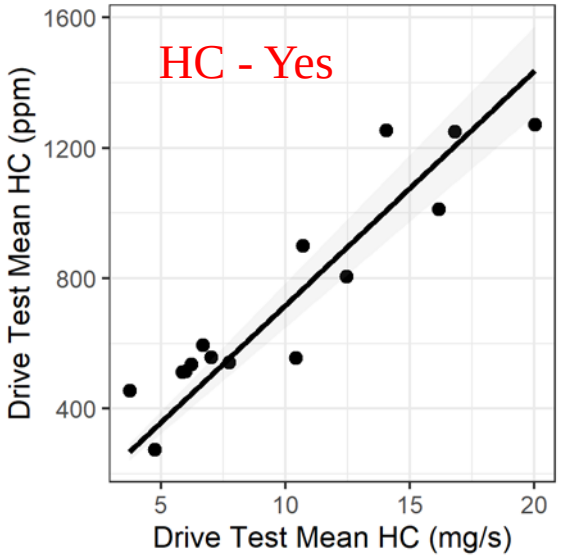


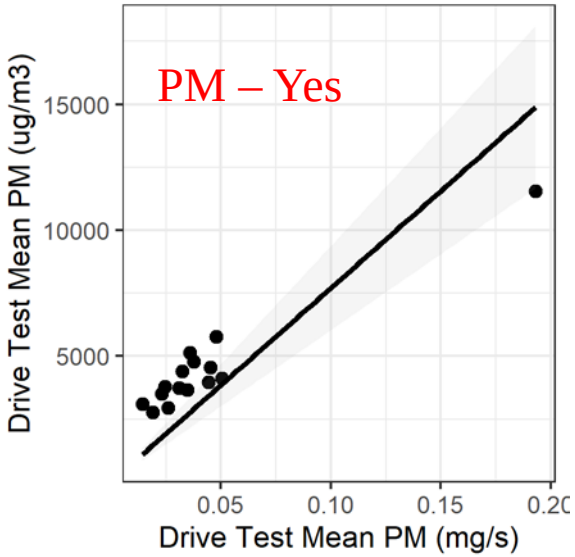




Is concentration sufficient for emissions on drive test?







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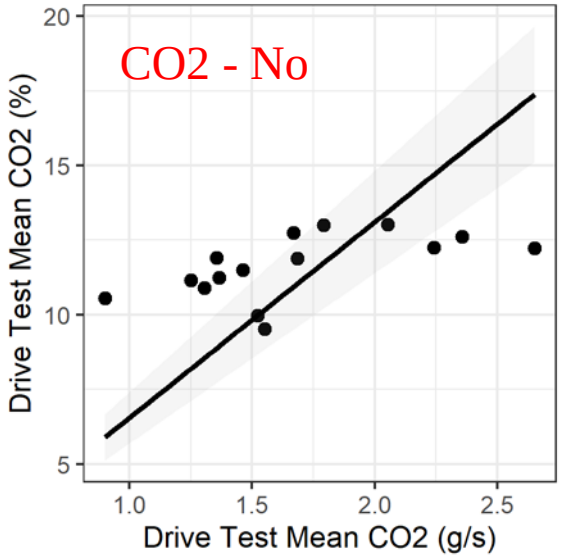
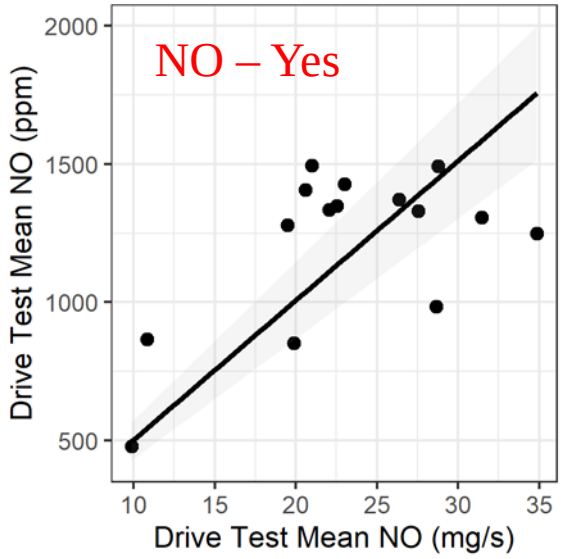
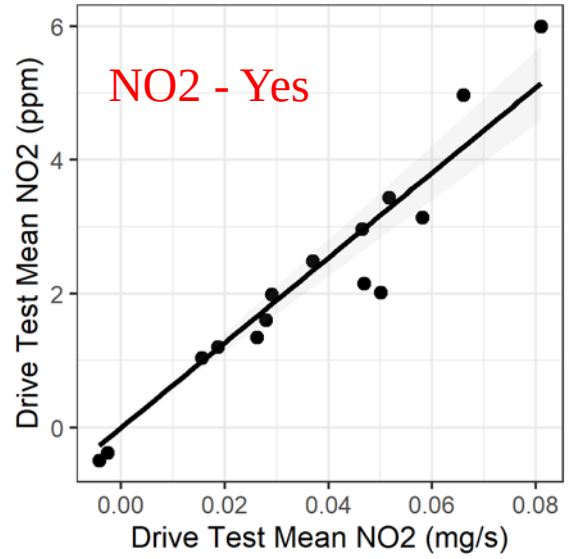
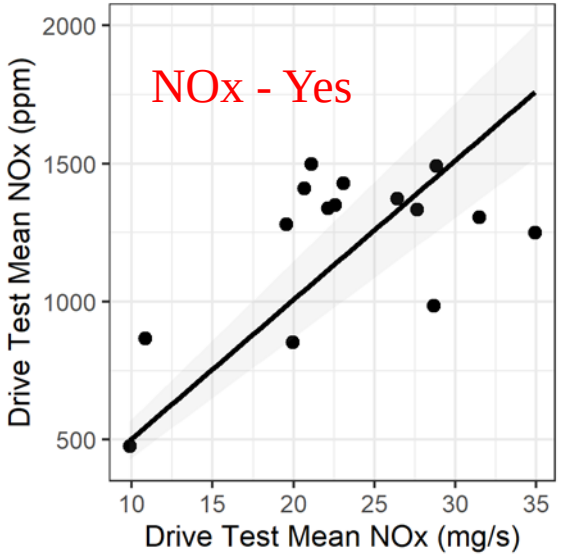
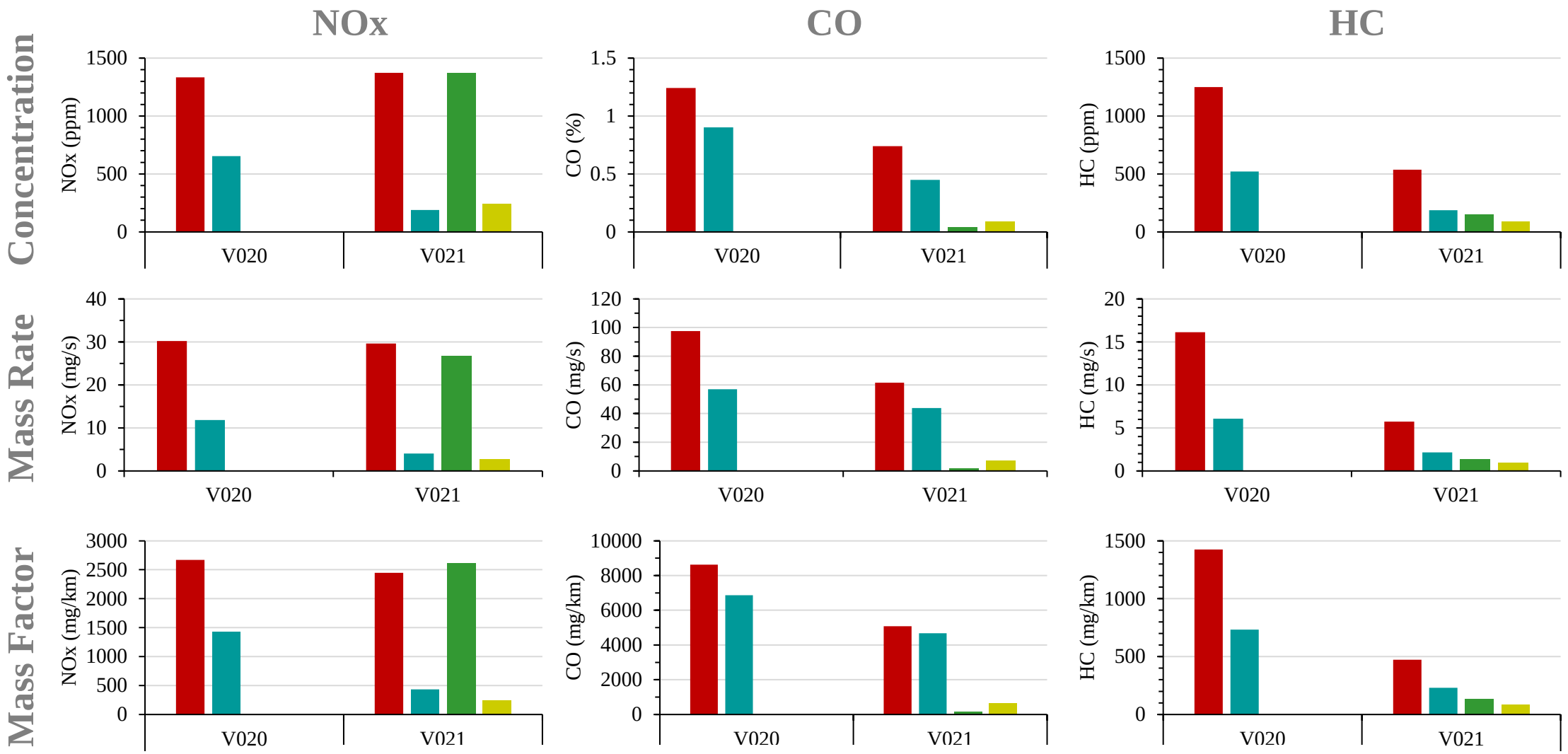






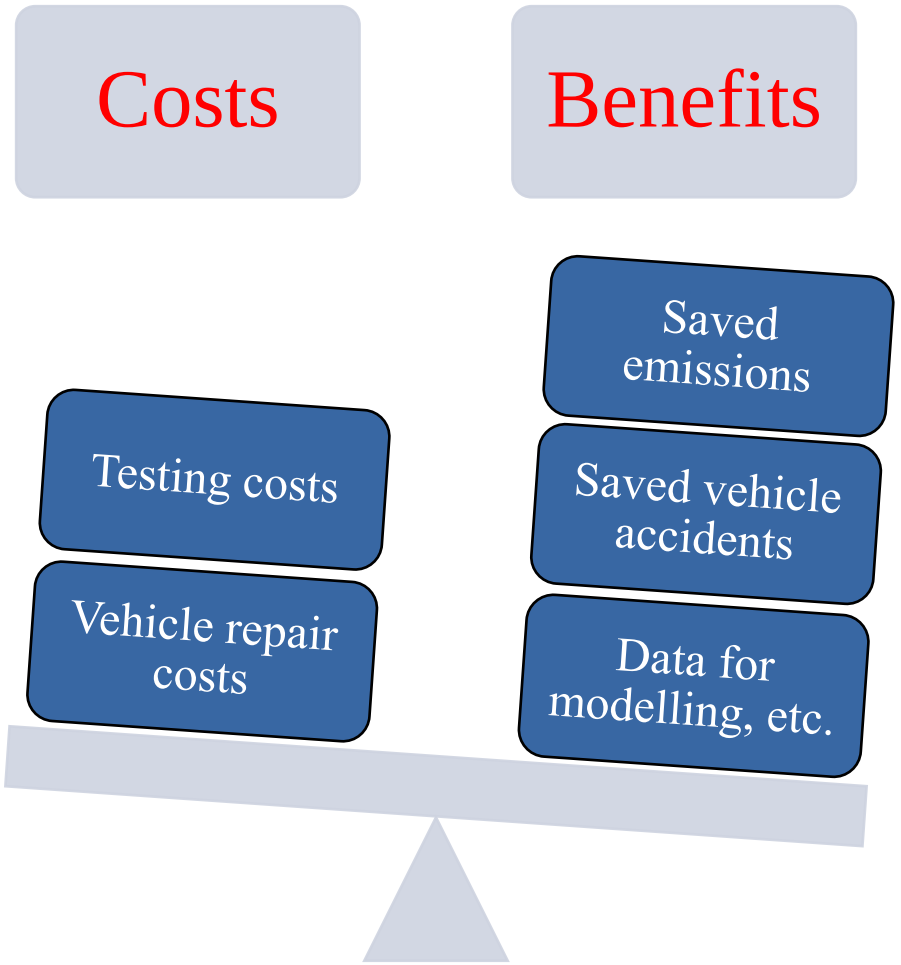


Prospects for vehicle repairs on a drive test



Changes in mass emission rates and mass emission factors are reflected in concentration values from drive test

Costs and benefits



- More developed economies can afford to spend large sums of money on ‘golden standard’ methods and equipment, while developing economies have less to spend
- Golden standards can be a big impediment to other nations tackling their emissions issues
- If developing economies made some concessions on these golden standards, it would make testing more practically achievable in these nations
  - e.g. Conformity factors could account for decreased repeatability

“It is better to do something than to do nothing while waiting to do everything.”

- Sir Winston Churchill

Summary

- Nigeria has poor air quality and low vehicle maintenance levels, and I/M testing could help to tackle this.
- A test protocol has been designed that works in Nigeria, and was tested on over 100 vehicles representing the Nigerian fleet in Abuja
- OBD acquisition success rate was poor
- Alternatives to OBD data allow collection of vehicle speed, ambient conditions, and lambda, but mass air flow rate is challenging
- Concentration is sufficient for criteria pollutant emissions
- There are many potential benefits to the introduction of a simple I/M test in Nigeria: Controlling emissions, reducing accidents and providing much needed fleet emission data useful for modelling, policy decisions etc.

Thank you for listening

3DATX Contact Info

USA

info@3datx.com +1.844.303.3289

David W. Miller

davidmiller@3datx.com

EU

info@3datx.eu +32.2.639.39.39

Daisy Thomas, Ph.D.

daisythomas@3datx.com

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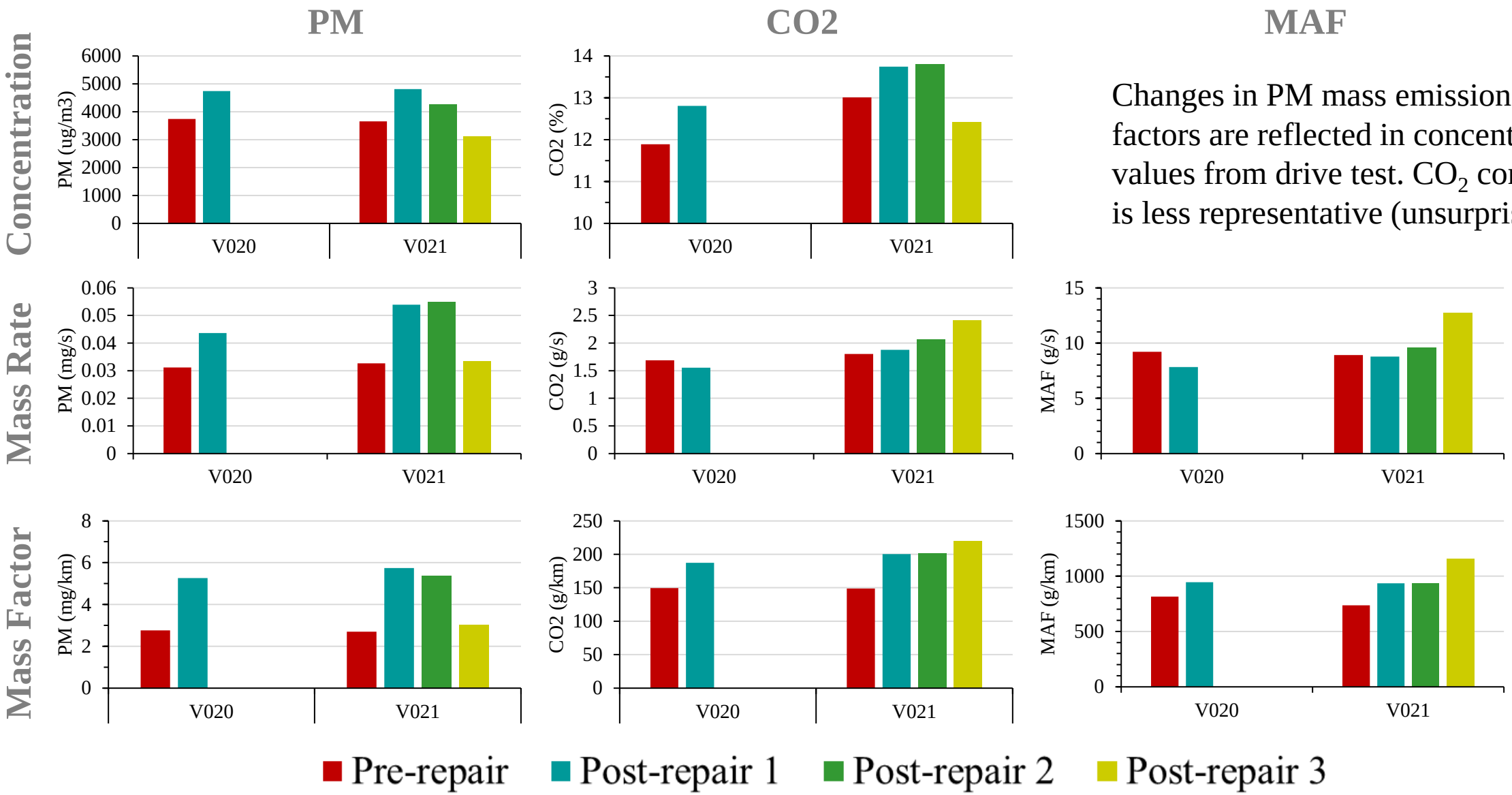
Thanks also to the rest of the 3DATX team, including Shirly Jeyarajan.

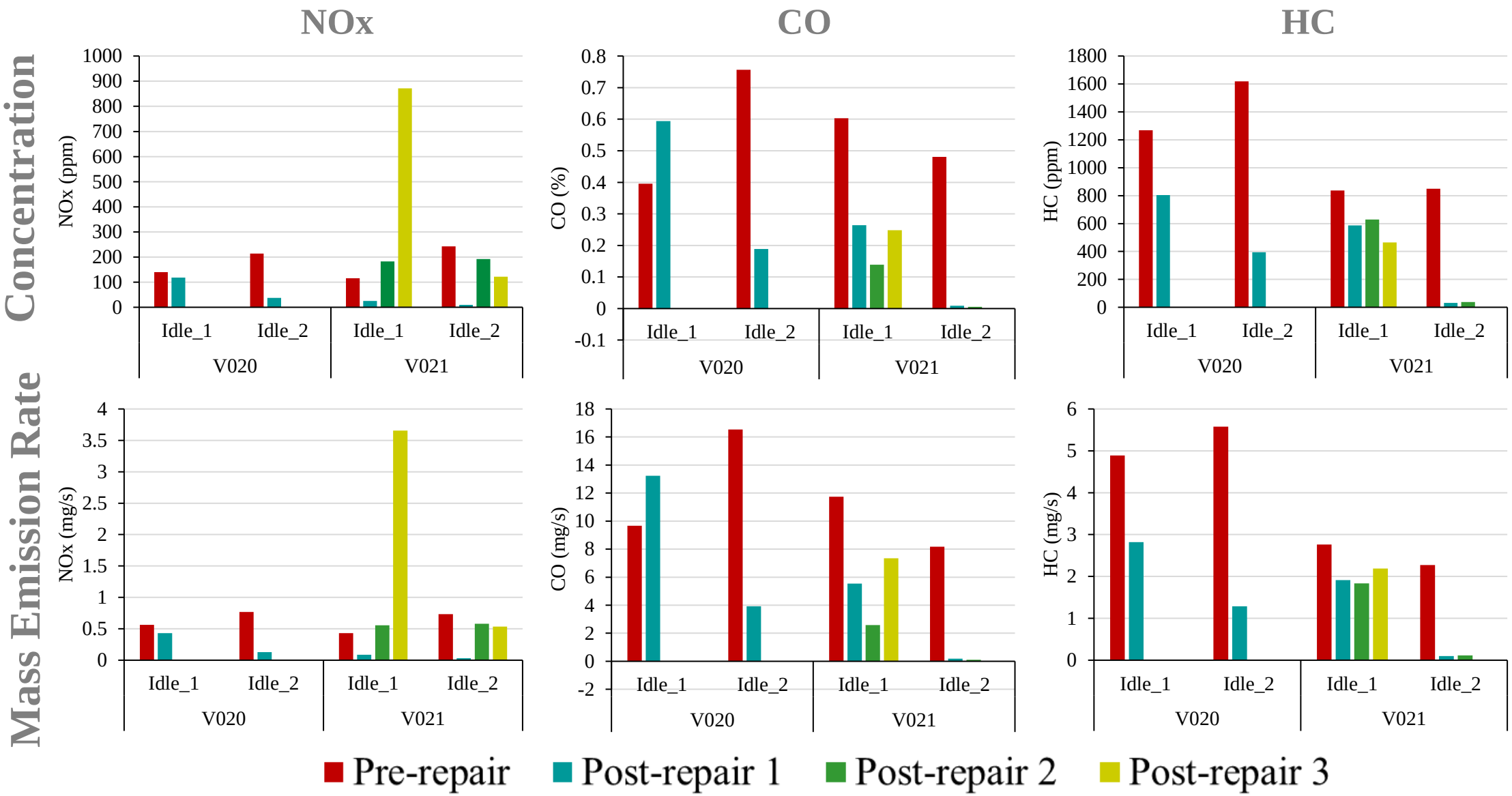
Additional Slides

Prospects for vehicle repairs on a drive test



Changes in PM mass emission rates and factors are reflected in concentration values from drive test. CO_2 concentration is less representative (unsurprisingly).

Prospects for vehicle repairs on an idle test



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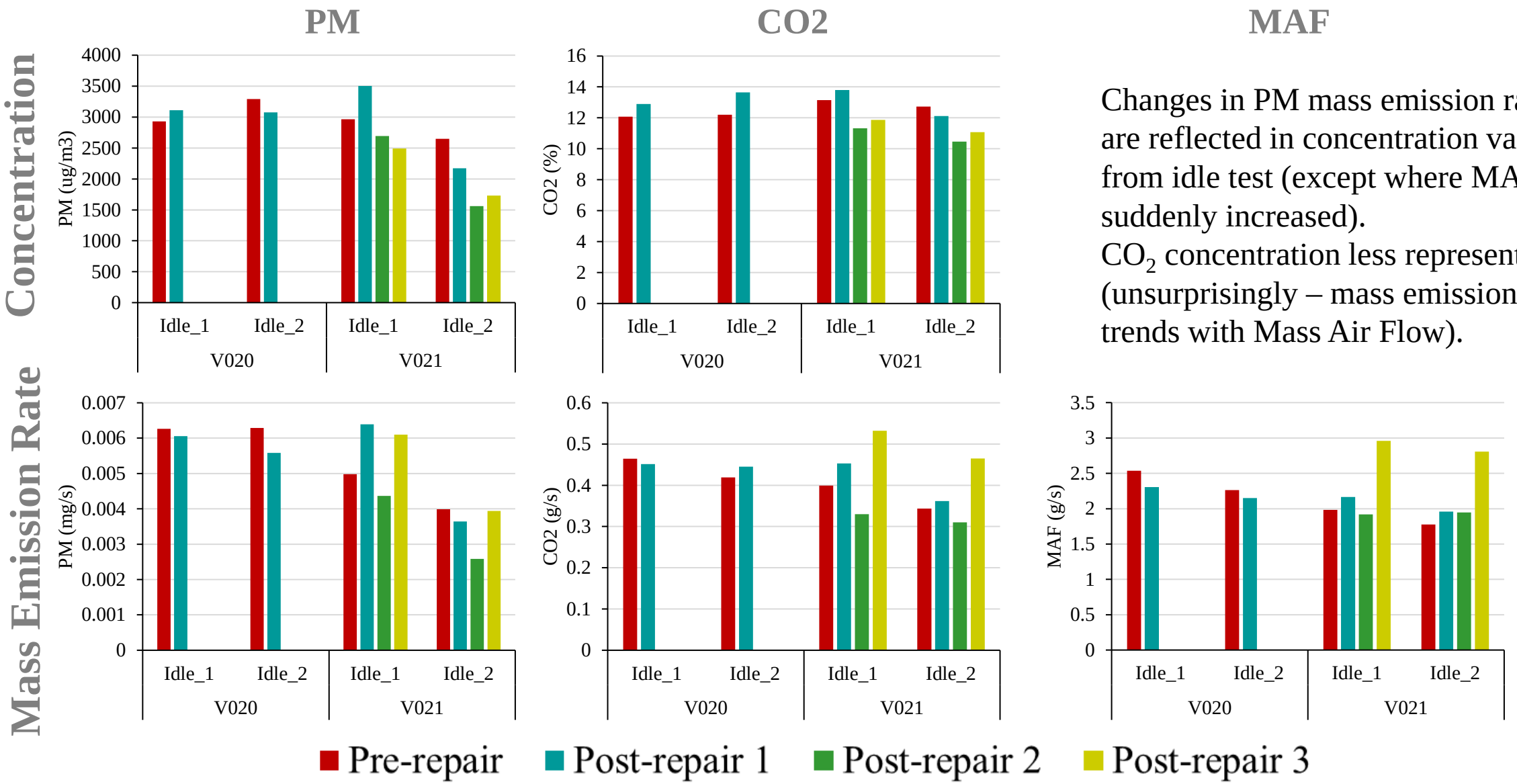
Prospects for vehicle repairs on an idle test



Changes in PM mass emission rates are reflected in concentration values from idle test (except where MAF suddenly increased).
CO_2 concentration less representative (unsurprisingly – mass emission rate trends with Mass Air Flow).