

Emission Performance and Evolution over Mileage of Modern Two-Stroke Scooters in Statutory and Real-World Cycles

Robert Alvarez, Martin Weilenmann, Christian Bach

Empa, Swiss Federal Laboratories for Materials Testing and Research

(Particle)Emissions of 2-stroke Scooters – science, problems, solutions & perspectives

June 11th – 12th 2009, Monza (Milano), Italy

Motivation

- Two-stroke scooters represent a common transportation system for individual mobility in urban areas
- Contribution to local air pollution is judged to be relevant*
- Newer pollutant emission legislation implies the use of oxidation catalytic converters (OCC)
- Not included up to certification category Euro-3:
 - Effect of cold start
 - In-use compliance

*Chen K.S., Wang W.C., Chen H.M., Lin C.F., Hsu H.C., Kao J.H., Hu M.T. (2003)

Motorcycle emissions and fuel consumption in urban and rural driving conditions. Science of the Total Environment, No. 312, pp 113-122.

Experimental Program

- Sample of 6 scooters of certification category Euro-2
 - all 2-stroke engines and equipped with OCC
 - 2 feature electronic fuel injection, 4 a mechanical carburetor

- Roller test bench measurements
 - Statutory and real-world cycle
 - pre-/post-OCC measurements @ constant speeds

- Repetitions at mileages 0 / 200 / 500 / 1000 km
 - Normal real-world on-road operation in between

Vehicle Sample

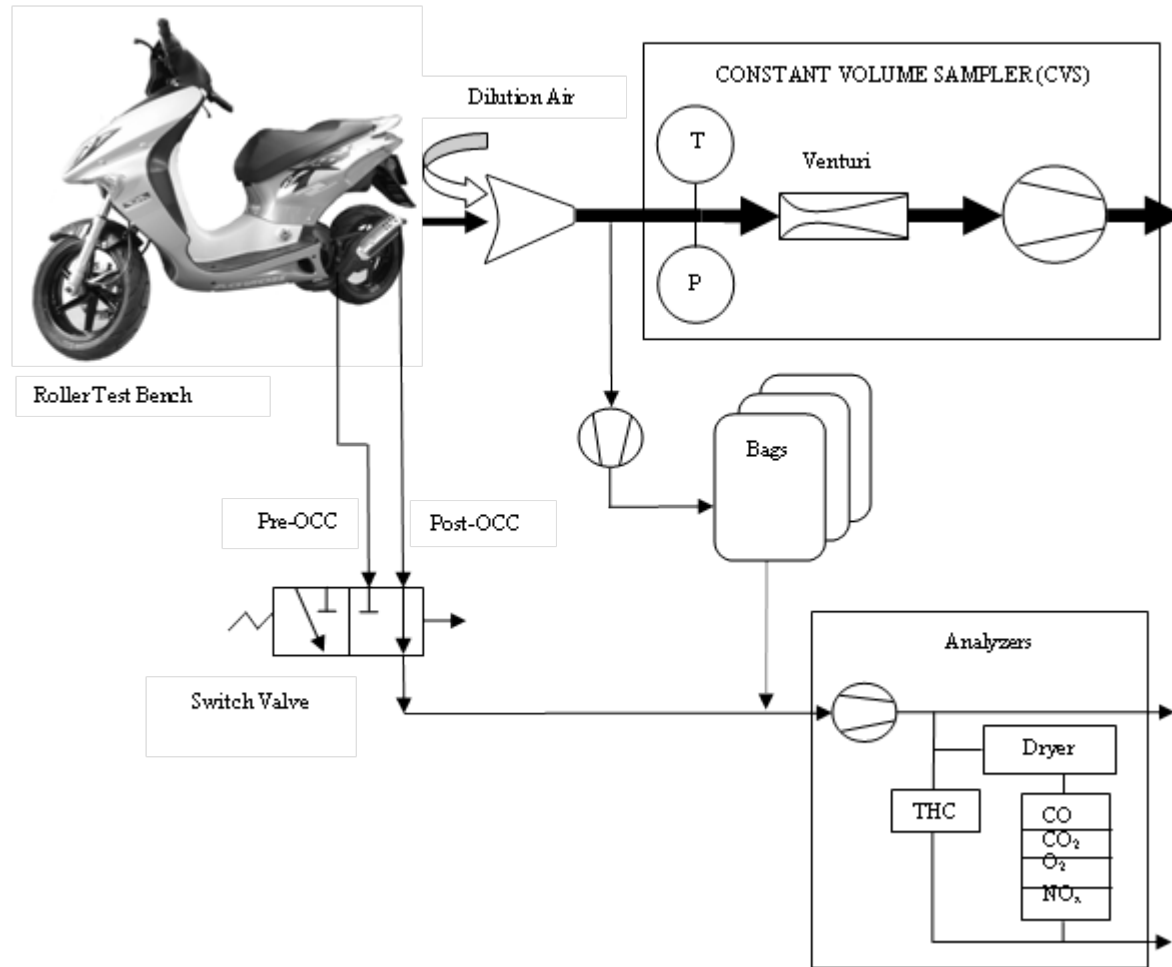
Vehicle No.	Make and Model	Displacement [cm ³]	Power [kW]	Mass* [kg]
1	Aprilia SR 50 Ditech	49 ccm	3.90 kW	181 kg
2	Peugeot Jet Force	49 ccm	4.80 kW	190 kg
3	Kymco Super 9	49 ccm	3.94 kW	181 kg
4	Yamaha Aerox R	49 ccm	2.75 kW	172 kg
5	Honda SZX50S1	49 ccm	3.95 kW	173 kg
6	Piaggio Zip 50	49 ccm	3.50 kW	161 kg

*Empty mass of the vehicle plus average driver mass of 75 kg

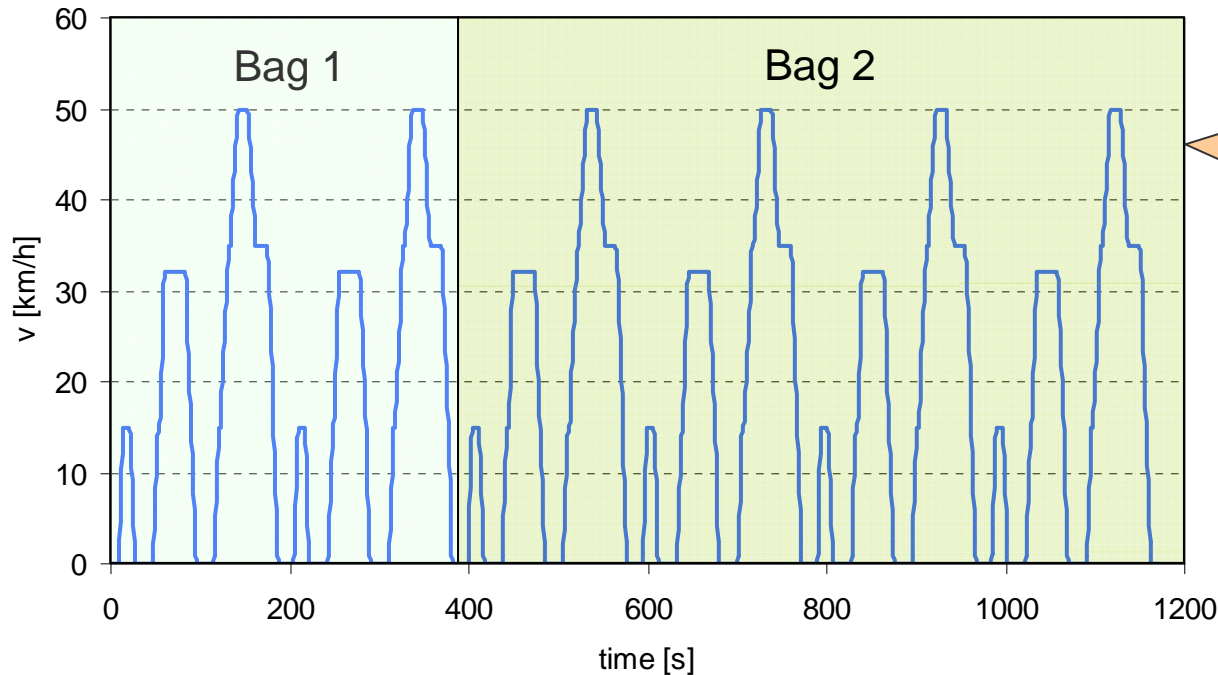
Electronic fuel injection

Mechanical carburetor

Experimental Setup



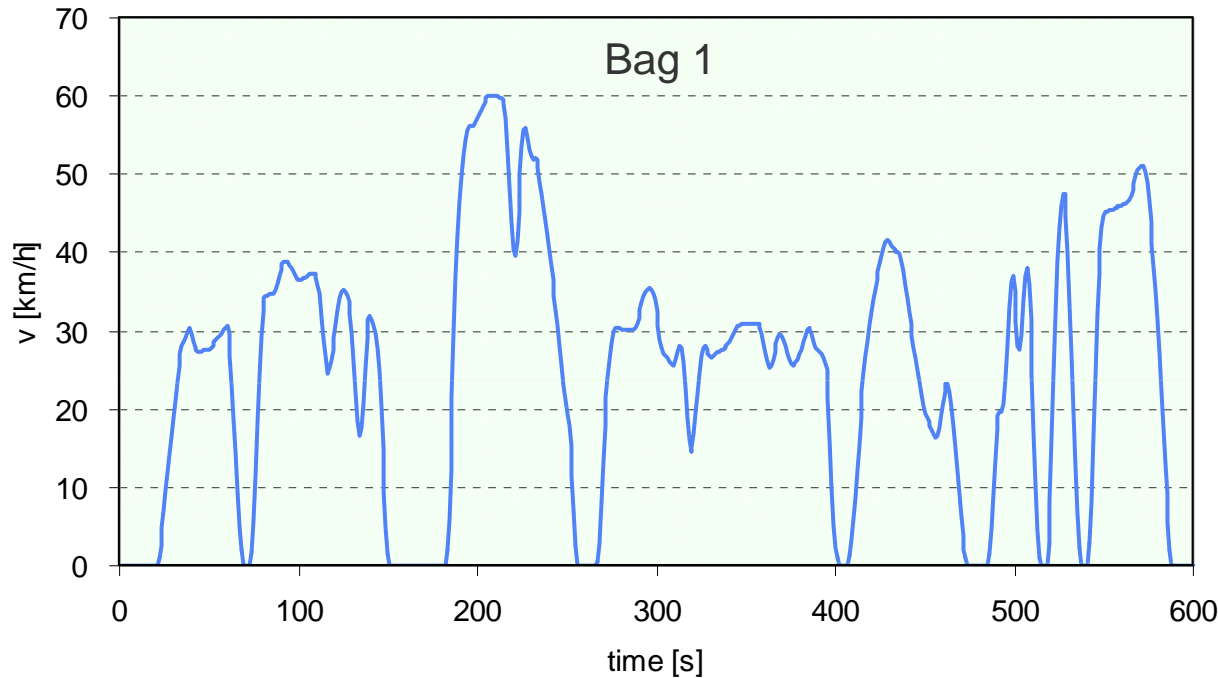
Statutory Driving Cycle



Emission limits:
CO: 5.5 g/km
HC: 1.2 g/km
NO_x: 0.3 g/km

- For Euro-2 certification: ECE 40m
- Only Bag 2 relevant for emission limits – no cold start effect!

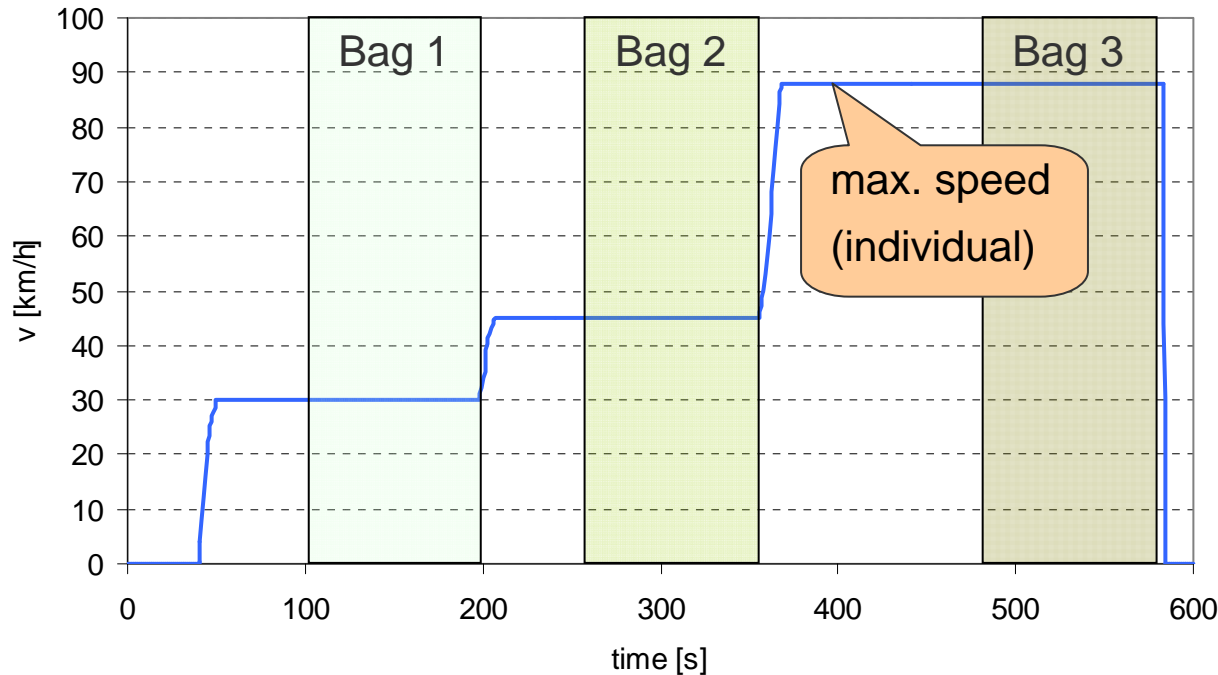
Real-World Driving Cycle



- WMTTC - 1 (Version 8)*: reflects real-world urban driving
- Warm started; for comparison reasons with ECE 40m

*GRPE (2003) Worldwide Harmonised Motorcycle Emissions Certification Procedure, UNECE, <http://www.unece.org/trans/doc/2003/wp29grpe/TRANS-WP29-GRPE-45-inf09e.pdf>.

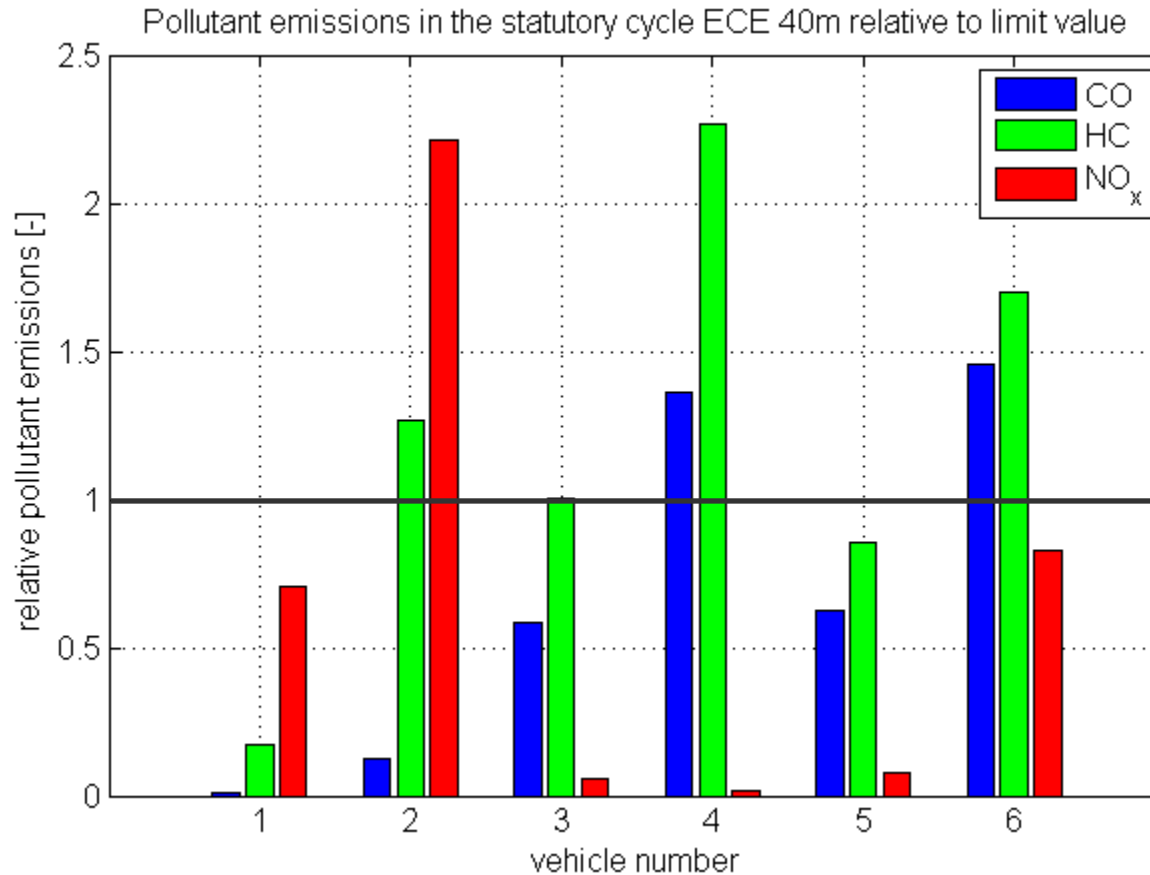
Constant Speeds



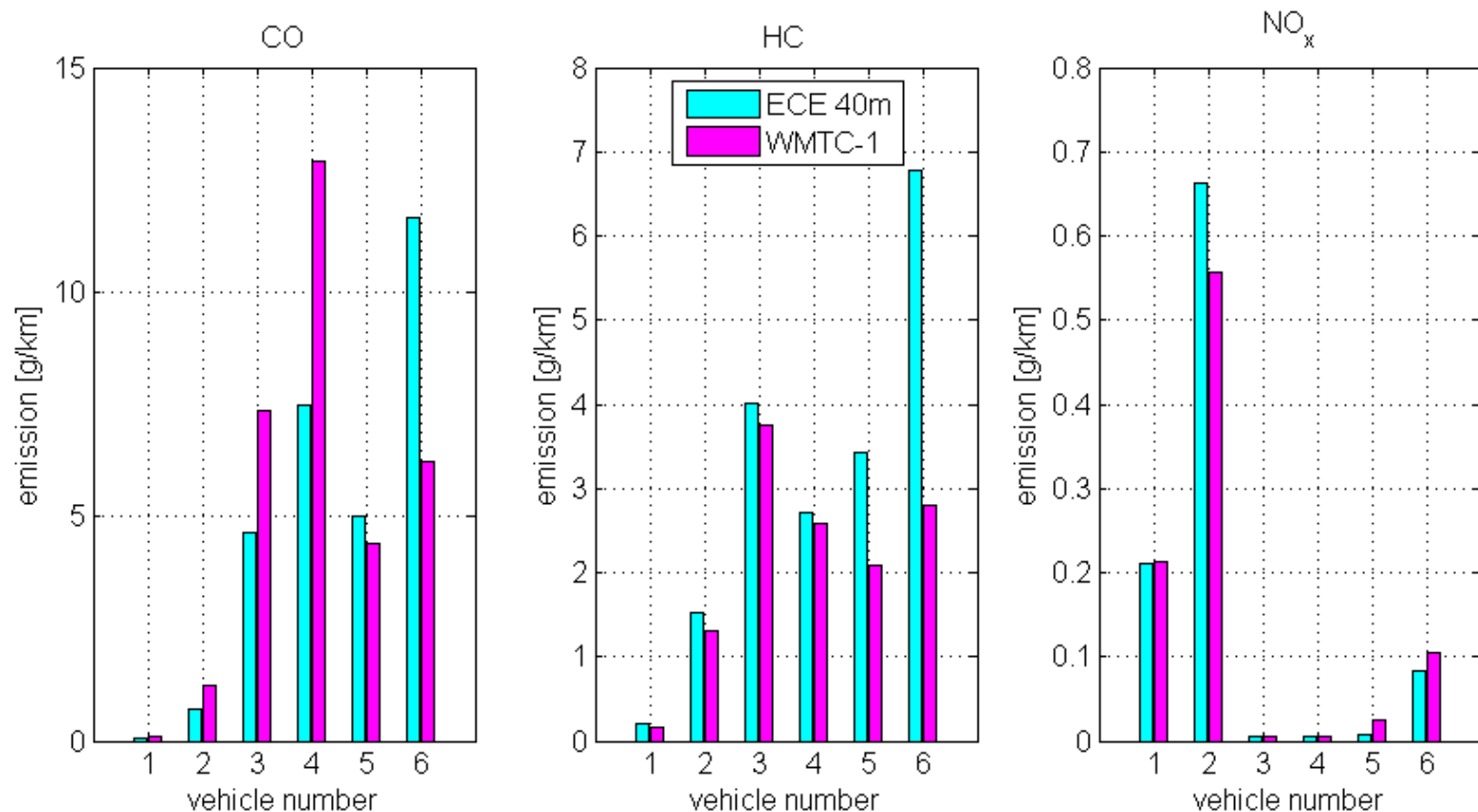
- 30 km/h, 45 km/h and maximum vehicle speed (individual!)
- Additionally pre-/post-OCC measurements

Emission Results of New Vehicles

Statutory Cycle

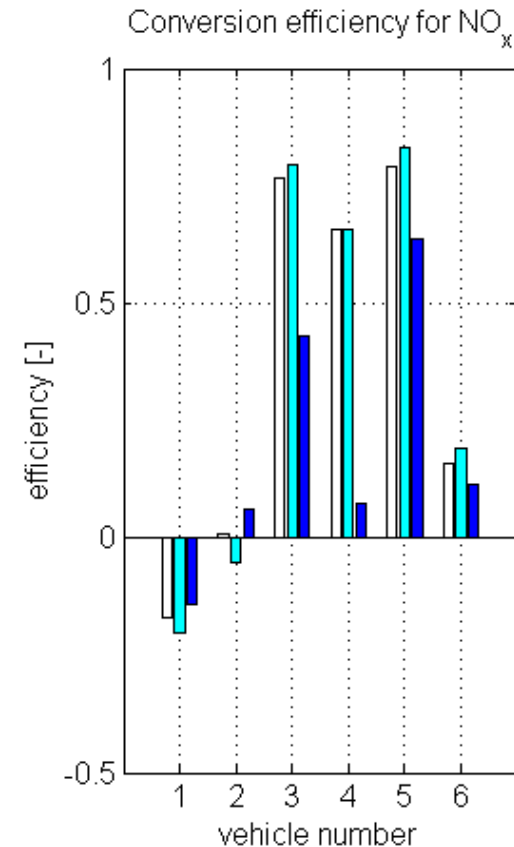
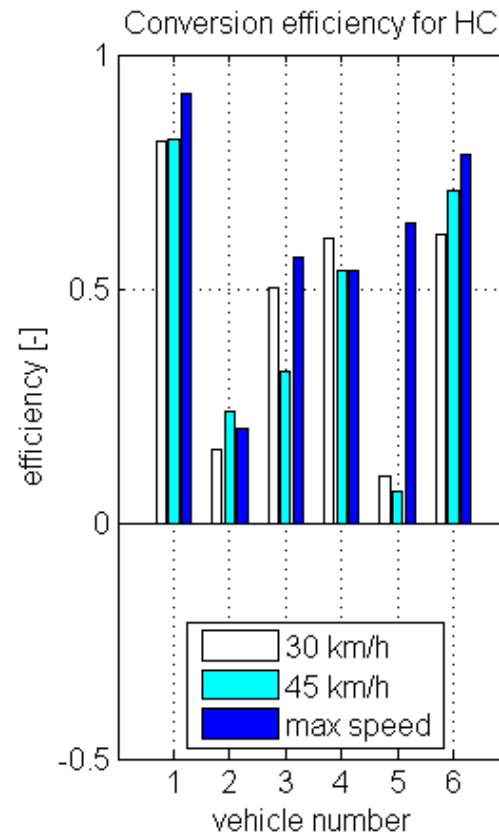
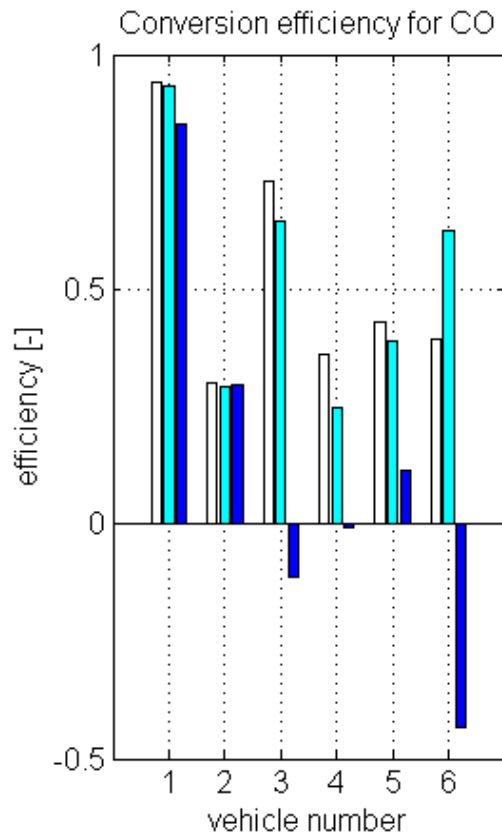


Real-World Cycle WMTc



OCC Efficiency

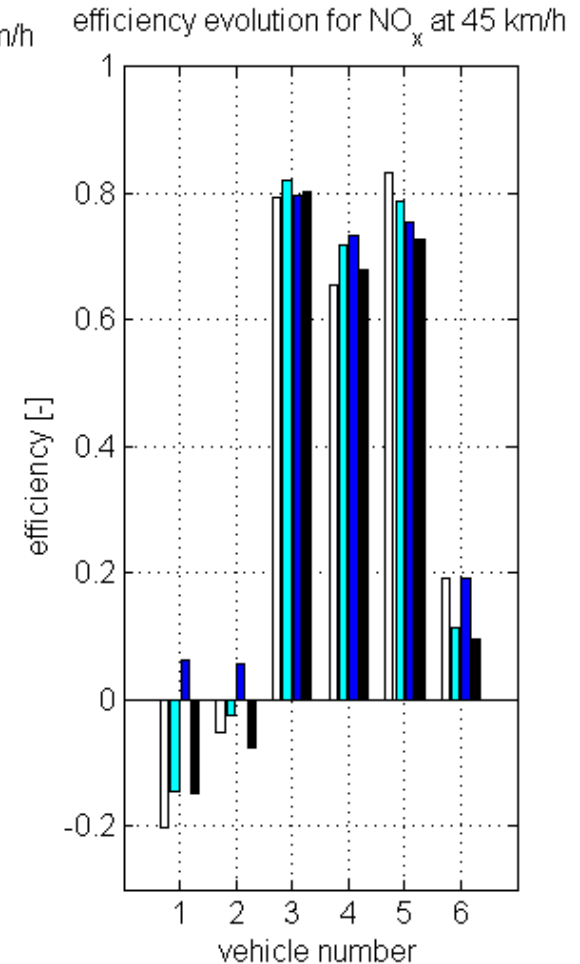
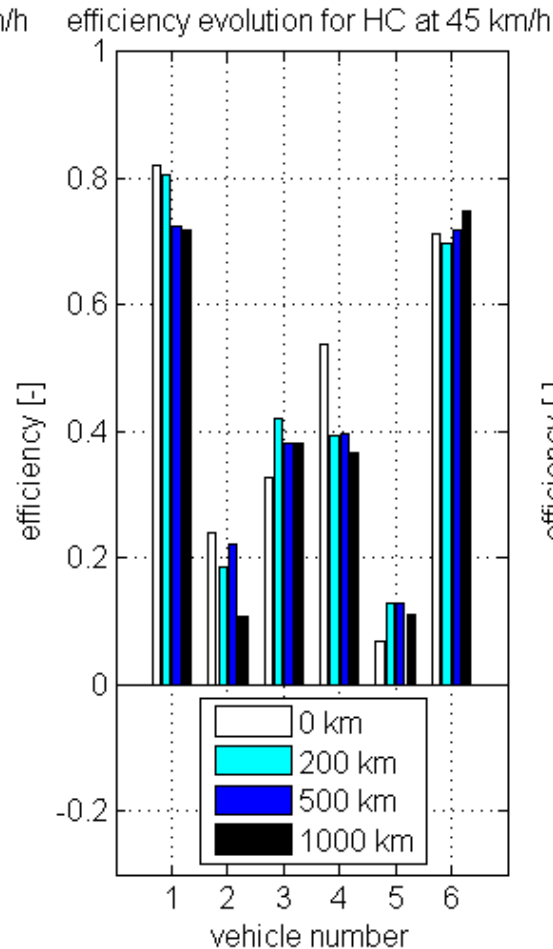
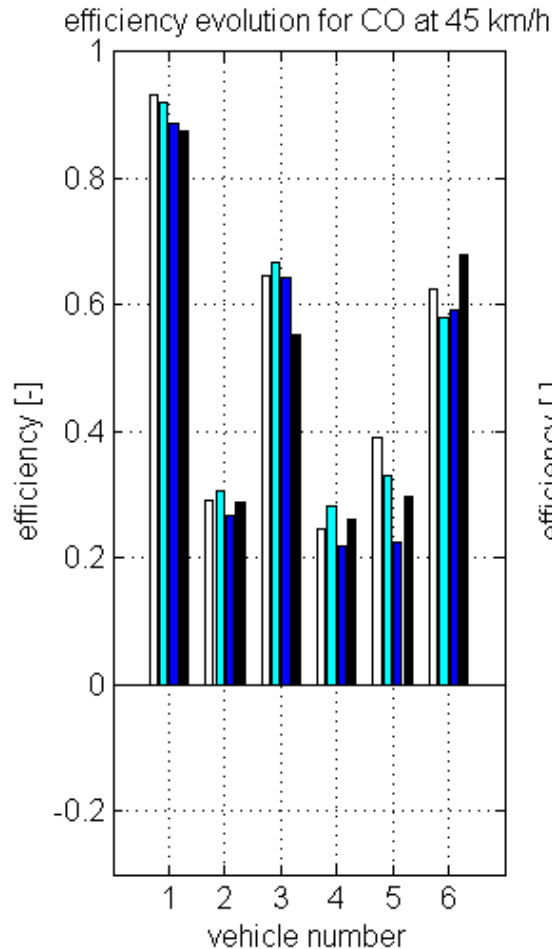
$$\eta = 1 - \frac{\text{Post-OCC}}{\text{Pre-OCC}}$$



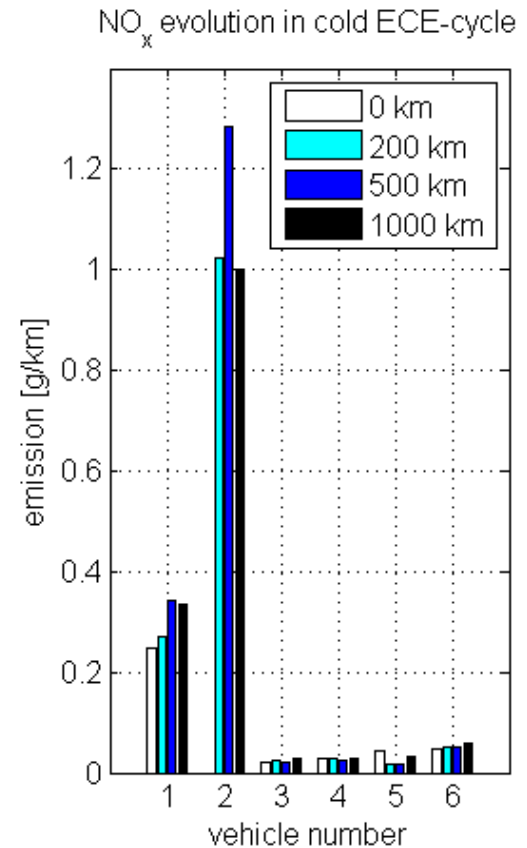
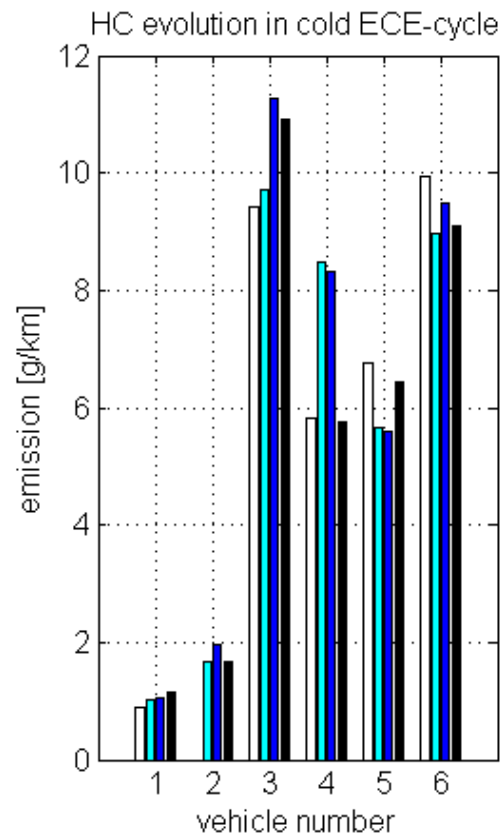
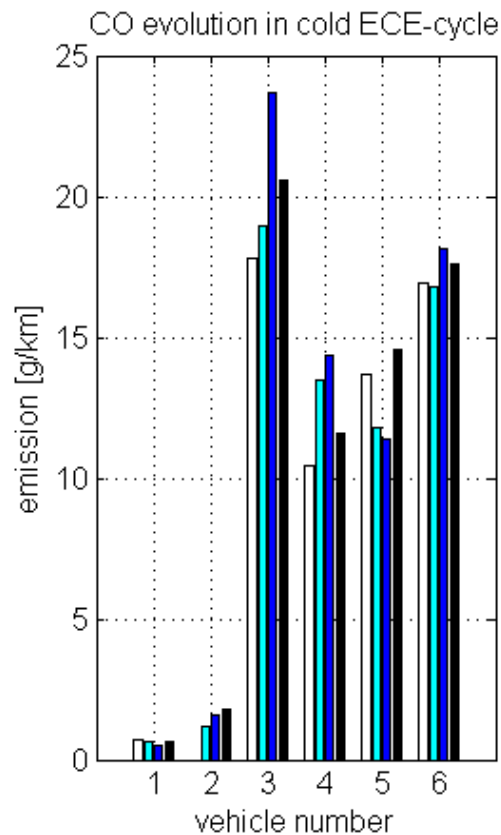
Emission Evolution over 1000 km mileage

OCC Efficiency

$$\eta = 1 - \frac{\text{Post-OCC}}{\text{Pre-OCC}}$$



Cold ECE ('Bag 1' ECE 40m)



Summary

- 4 of 6 scooters fail to comply with Euro-2 emission limits
- Comparable hot emissions in statutory and real-world cycle
- HC conversion efficiencies range from 80% to 10%
- Post-OCC NO_x and especially CO sometimes higher than pre-OCC
- No major deterioration of the OCC visible over 1000km mileage

Thank you for your attention!