Daniel Rodríguez Rey[1], Marc Guevara[1], Albert Soret[1], Mª Paz Linares[2]

(1) Barcelona Supercomputing Centre – Centro Nacional de Supercomputación (BSC-CNS) Earth Sciences division, C/Jordi Girona 29, Barcelona, 08034, Spain;
(2) inLab FIB, Universitat Politècnica de Catalunya, Facultat d'Informàtica de Barcelona, C/Jordi Girona 1-3, Barcelona, 08034, Spain.

EVALUATION OF TRAFFIC EMISSION MODELS COUPLED WITH A MICROSCOPIC TRAFFIC SIMULATOR AND REAL DRIVING MEASURES

Introduction

Barcelona suffers from severe air quality problems mainly due to:

- Commuting increase (**Fig. 1)** that raised vehicles density (6.000 veh./km).
- Complex orography: Coastal city surrounded by mountains (**Fig. 2).**
- Meteorological conditions: Strong summer sea breezes and sun radiation with low precipitation.

Need in tackling air pollution:

- Air pollution causes every year 44.000 premature deaths in Spain, 3.000 in Barcelona (EEA, 2017; CREAL, 2007).
- Insufficient NO_2 decrease on the last decades, still above the EU limits (**Fig. 3).**
- Traffic emissions first contributor in registered NO_2 at urban locations (**Fig. 4).**
- Technical improvements in diesel vehicle NOx emissions were ineffective (Carslaw et al. 2011; AMB, 2017), it is then necessary to reduce the traffic activity by mobility policies.
- There were unsatisfactory results after the application of several traffic restriction policies (Holman, 2015; Cantillo & Ortúzar, 2014).
- **The mobility policies applied need to be evaluated with modelling tools capable of estimate their air quality impact.**

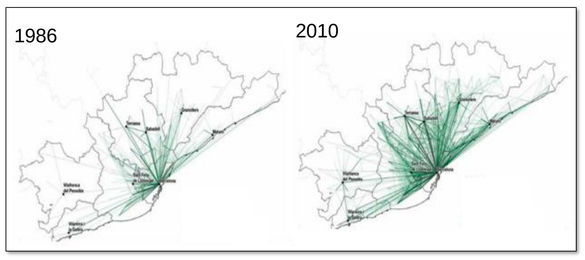

Figure 1: *Evolution of commuters in 1986 and 2010 (AMB, 2014).*

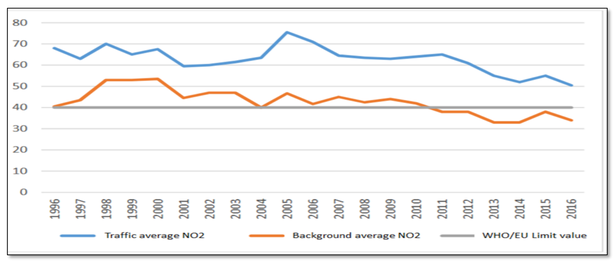

Figure 3*: Registered* NO_2 *results at traffic and background stations from 1996 to 2016 (ASPB, 2016) .*

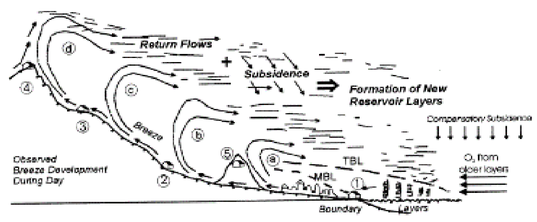

Figure 2*: Daylight perpendicular circulations along the Mediterranean coasts in summer (Millán et al., 2000)*

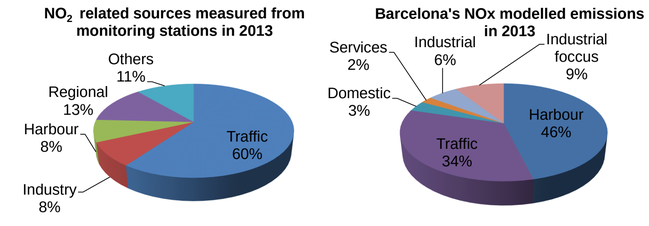

Figure 4: *Modelled* NO_2 *contributors, registered at street level and in total emissions (Ajuntament de Barcelona, 2016).*

Proposed solution:

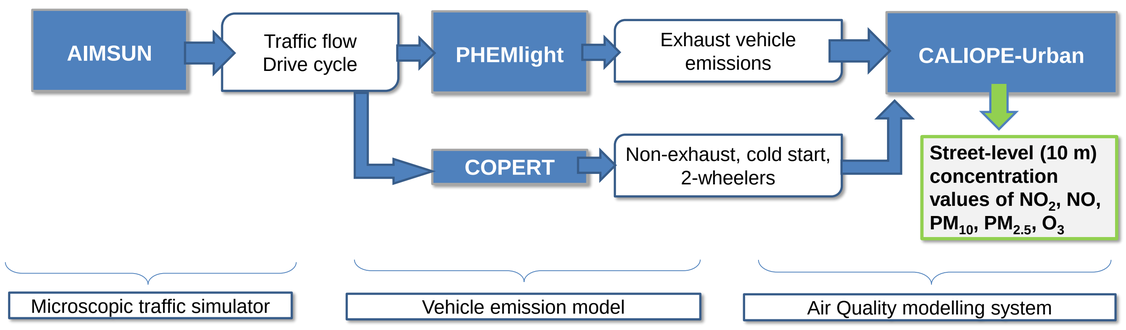

Figure 5: *Scheme of the thesis workflow.*

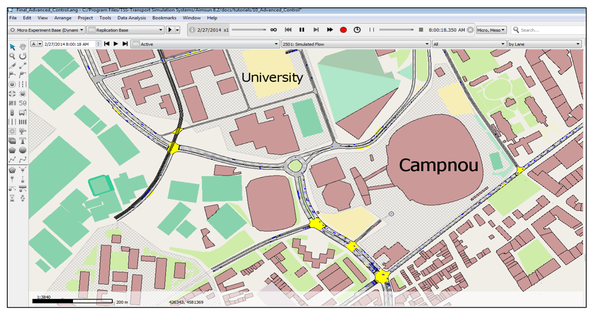

Figure 6: *Screenshot of AIMSUN traffic model over Barcelona.*

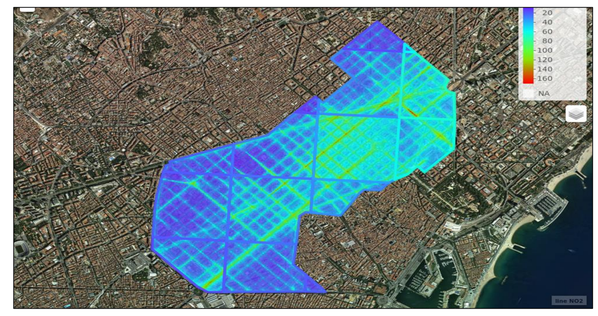

Figure 7: *CALIOPE-Urban (bottom) modelled results (Benavides, 2017).*

First approach to vehicle emission models

Intercomparison between several vehicle emission models: (I) Panis '06 (Panis et al. 2006), (II) PHEMlight (TUG, 2017) coupled with the microscopic traffic simulator AIMSUN **(Fig. 6)** (TSS, 2014), (III) COPERT IV v10.0 (EMEP/EEA, 2012) and (IV) COPERT V (EMEP/EEA, 2017). Additionally, they were compared with the observed results of on-road measurements done by RSD (Remote Sensing Device) on real driving vehicles in Barcelona (AMB, 2017).

Emission factor comparison:

Methodology

- Case study: A 9-blocks area from Barcelona Eixample (**Fig. 8)**
- Traffic simulation: The **drive cycle** was selected from a **passenger car** going around the study area for **99 seconds** with an average speed of **26.7 km/h.**
- The drive cycle was used to estimate the total emissions of Panis '06 and PHEMlight emission models.
- For COPERT, the versions **COPERT IV v10.0** and **COPERT V** were used. Petrol engine degradation factors according to vehicle's age have also been considered and compared. (EMEP/EEA, 2017)
- Emissions simulated: Passenger car **Diesel** and **Petrol Euro 2, 3, 4, 5 and 6**. Pre-Euro and Euro 1 have not been studied since they are disused.
- The average speed of tested vehicles at urban locations during the RSD study was **28.6 km/h**.

Figure 8: *Area used to extract the drive cycle*

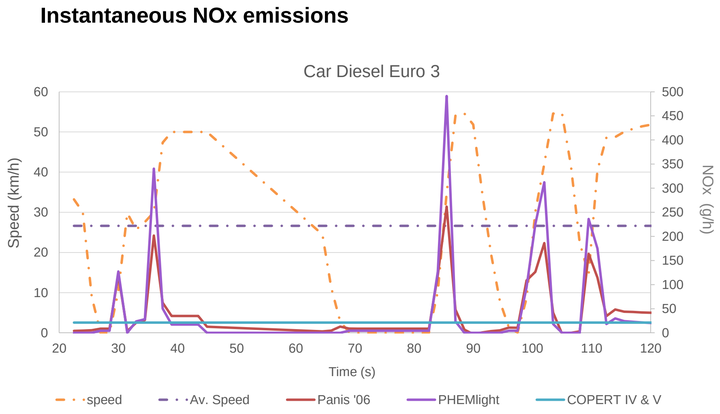

Figure 9: *Speed and NOx emissions in g/h along time with Panis, PHEMlight and COPERT IV and V*

Results

- **Instantaneous NOx emissions (Fig. 9)**
  - Instantaneous emission models (Panis and PHEMlight) agree reasonably well, although PHEMlight present higher peaks during acceleration**.**
  - COPERT represents the average emission during the whole cycle, without considering accelerations.
- **NOx emissions in g/km (Fig. 10).**
  - **DIESEL:**
    - PHEMlight overestimates emissions compared to observations for all EURO categories.
    - Panis '06 agrees well with observations for Euro 2 and 3 (-15% and 4%), but overestimates for Euro 4, 5 and 6 by 30%, 20% and 52%.
    - COPERT V underestimates emissions for EURO 2 by 25% and overestimates for Euro 6 by 28%, but agrees well for the other Euro categories.
  - **PETROL**
    - COPERT V for EURO 2, 3 and 4 with degradation factor underestimates by a factor of 1.2, 2.2 and 1.7 respectively. Without the degradation factor this increases to 3.1, 3.8 and 2.7 in respect with observations. Euro 5 and 6 are underestimated by factors of 4.4 and 3.6.
    - For Euro 3 and newer categories Panis is the closest model to RSD observations.
    - PHEMlight underestimate for all Euro categories, similar to COPERT V with degradation.

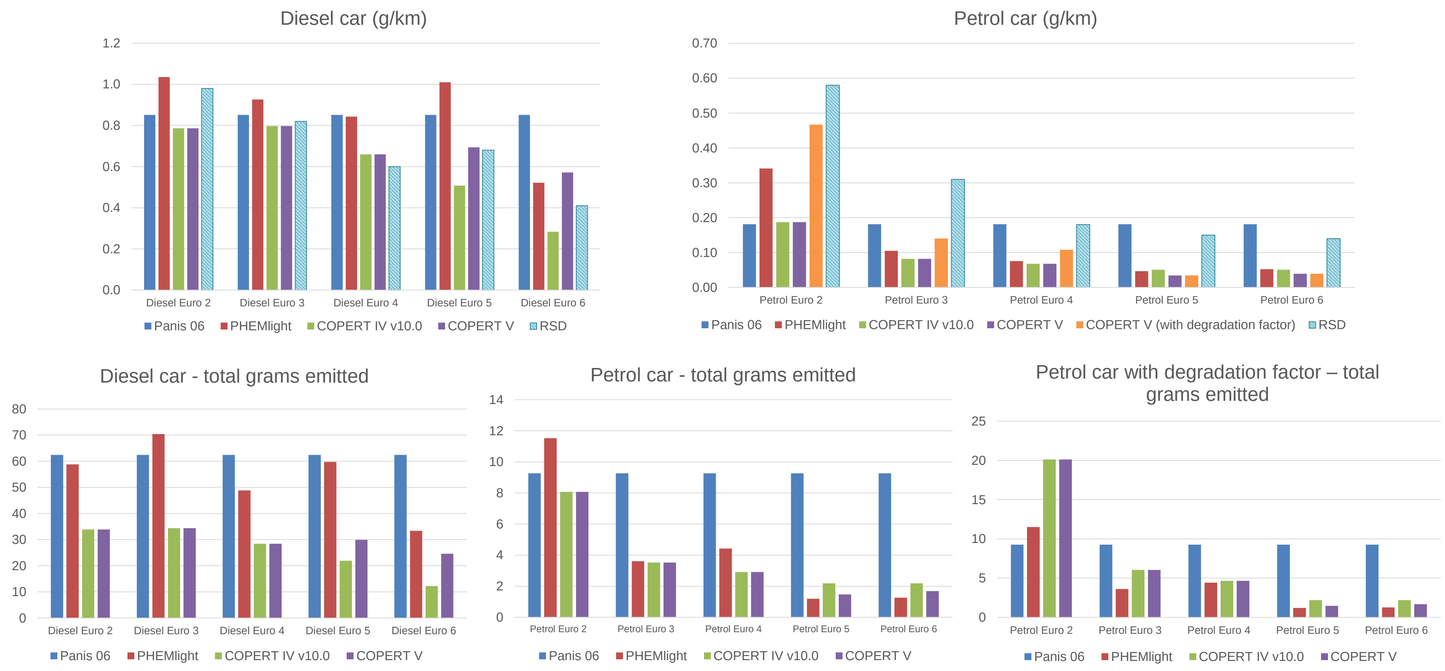

Figure 10: *Diesel and petrol g/km (top) and total grams (bottom) estimated by Panis, PHEMlight, COPERT IV and V models and the observed average of the RSD study for Euro categories from EURO 2 to EURO 6*

Discussion

- The last corrections on COPERT diesel emission factors agree well with the observed RSD results, for petrol however without the application of the degradation factor these result in large underestimations.
- Considering that Panis '06 was a model that only measured emissions until Euro 3 category, its results are closer to observations for Diesel Euro 2, 3, 4 and 5 than PHEMlight, a model with up to date measurements . Being also the most similar to observations for Petrol Euro 3, 4, 5, and 6 (without the degradation factor considered for COPERT models).
- Despite the similar results in g/km for **diesel**, Panis '06 and PHEMlight represent on average total emissions of 52% and 42% more NOx grams than COPERT V, respectively **(Fig. 10).** This might be due to the acceleration peaks that microscopic emission models capture while average speed models do not.

Further research.

- To be able to better observe the benefits of instantaneous emission models a further analysis with the complete range of vehicle emissions at different speeds from the RSD study is needed.
- It will be needed to track the trajectory of the drive cycle analysed.

References

Agència de Salud Pública de Barcelona (ASPB) (2016) *AVALUACIÓ DE LA QUALITAT DE L'AIRE A LA CIUTAT DE BARCELONA*.

Ajuntament de Barcelona (2016) *Mesura de govern: PROGRAMA DE MESURES CONTRA LA CONTAMINACIÓ ATMOSFÈRICA*. Available at: http://governobert.bcn.cat/sites/default/files/MG_Economia_empresa_270112.pdf.

Àrea Metropolitana de Barcelona, 2017. CARACTERITZACIÓ DELS VEHICLES I LES SEVES EMISSIONS A BARCELONA I L'AMB.

Benavides, 2017. CALIOPE-URBAN: Coupling R-Line with CMAQ for urban air quality forecast over Barcelona.

Cantillo, V. & Ortúzar J. de Dios, (2014) "Restricting the use of cars by license plate numbers: A misguided urban transport policy" *DYNA*, 81 (188), pp. 75-82.

Carslaw, D. C., Beevers S. D., Tate, J. E., Westmoreland E. J., Williams M. L. (2011) 'Recent evidence concerning higher NOx emissions from passenger cars and light duty vehicles', *Atmospheric Environment*. Elsevier Ltd, 45(39), pp. 7053–7063.

Centre de Recerca en Epidemiologia Ambiental (CREAL) (2017) Los beneficios para la salud pública de la reducción de la contaminación atmosférica en el área metropolitana de Barcelona

EEA (2017) *Air Quality in Europe - 2017 report*. Environmental European Agency. Available at: https://www.eea.europa.eu//publications/air-quality-in-europe-2017

EMEP/EEA (2017) air pollutant emission inventory guidebook 2016 – Last Update June 2017. Available at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

EMEP/EEA (2012) emission inventory guidebook 2009, updated May 2012. Available at: https://www.eea.europa.eu//publications/emep-eea-emission-inventory-guidebook-2009

Holman, C., Harrison, Roy., Querol, X., (2015) "Review of the efficacy of low emission zones to improve urban air quality in European cities", *Atmospheric Environment*. Elsevier Ltd, 111, pp. 161-169.

Int Panis, L. *et al.* (2011) 'PM, NOx and CO2 emission reductions from speed management policies in Europe', *Transport Policy*. Elsevier, 18(1), pp. 32–37.

Millán, M. *et al.* (2000) 'Ozone cycles in the western Mediterranean basin: Interpretation of monitoring data in complex coastal terrain', *Journal of Applied Meteorology*, 39(4), pp. 487–508.

Transport Simulation Systems, 2014. AIMSUN 8 Dynamic Simulator User's Manual.
Technische Universität Graz, 2017. PHEMlight. User Guide for Version 1.

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