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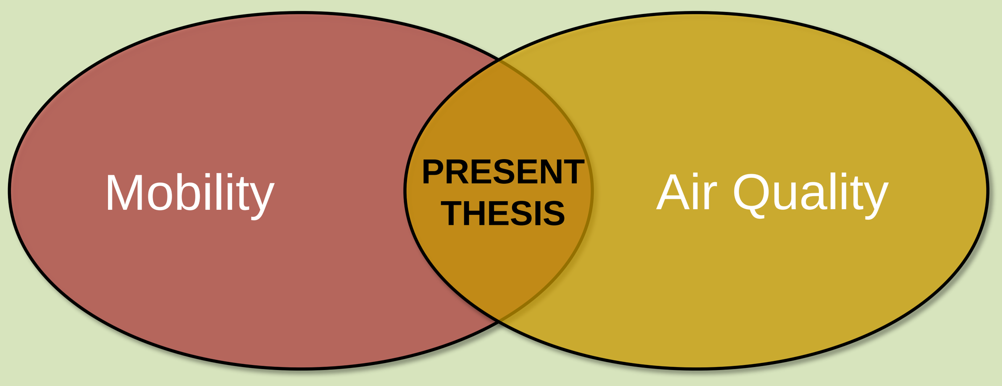
Design and evaluation of mobility policies impact in Barcelona's air quality

Topic: Vehicle emission modelling

Objectives:

Design and evaluate the impact of mobility policies in Barcelona's air quality combining a microscopic traffic simulator, a vehicle emission model and an air quality model.

- Calibration of the microscopic traffic simulator to Barcelona's conditions.
- Select, compare and improve if necessary a vehicle emission model.
- Couple and evaluate the vehicle emission results with CALIOPE-Urban and observed data.
- Evaluate mobility policies related with the improvement of the air quality in Barcelona with the integrated model.



Research process:

Summary

Development of a modeling tool for evaluating the impact of mobility policies on Barcelona's urban air quality

Background:

Barcelona suffers from severe air quality problems, mainly due to the following causes:

- **Vehicles density:** With almost 6000 vehicles/km^2 Barcelona doubles Madrid and triples London vehicle's density.
- **Geographical characteristics:** Sea/land breezes recirculation patterns facilitated by the mountain ranges behind, blocking the air renewal.
- **Meteorological conditions:** Stable mesoscale systems, the Iberian Thermal Low (ITL), strong sun radiation and high temperatures facilitate the formation of secondary pollutants (O_3, PM) and the stagnation of the air masses, while the low precipitation difficult their elimination.

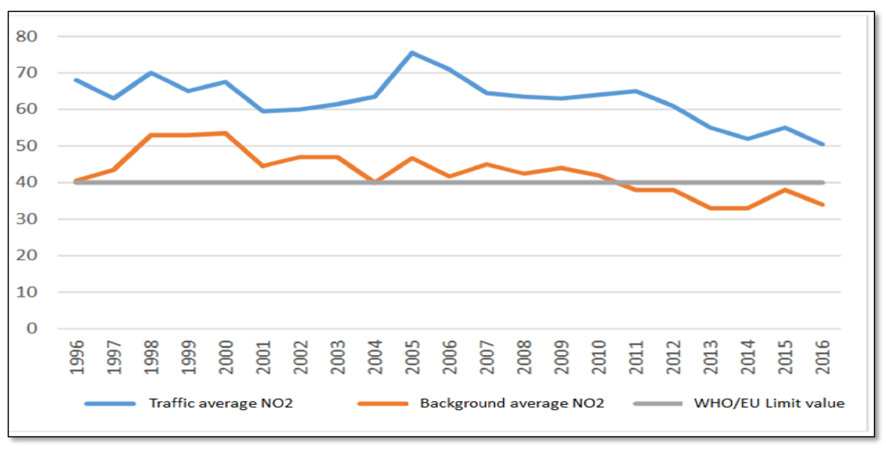


Figure 1: Registered NO_2 results at traffic and background stations from 1996 to 2016 (ASPB, 2016) .

Need in tackling air pollution:

- Air pollution causes every year 44.000 premature deaths in Spain (EEA, 2017).
- Barcelona's NO_2 levels have been steady during the last decade, overpassing the air quality limits imposed by the European Union directive (2008/50/EU) **(Fig. 1)** with traffic emissions as the second overall main contributors and the first in registered NO_2 values at street levels **(Fig. 2)**.
- Ineffective technical improvements in diesel vehicle NOx emissions **(Fig. 3)** (Carslaw et al. 2011; AMB, 2017) focus the attention in mobility and traffic reduction policies to improve air quality.
- **Need in modelling tools capable of estimating the air quality impacts of the different mobility policies applied.**

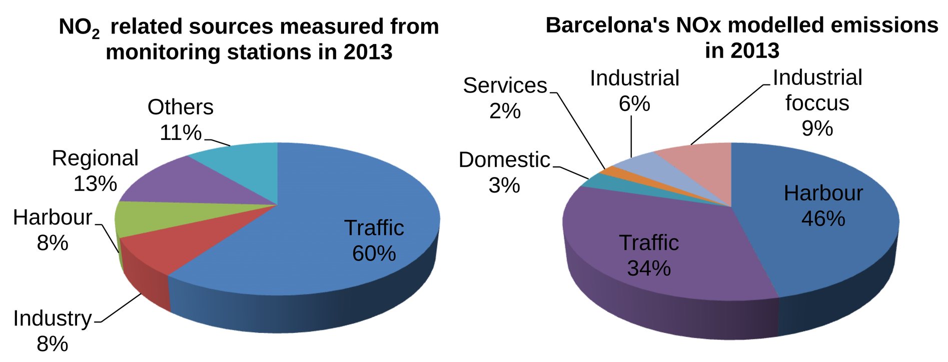


Figure 2: Modelled NO_2 contributors, registered at street level and in total emissions (Ajuntament de Barcelona, 2016).

Current tools

- Observed values measured by the monitoring stations network (XVPCA, **Fig. 4)** which cannot offer an homogeneous distribution of pollutants.
- CALIOPE air quality forecast system (BSC 2017), actual model working over Barcelona with a resolution of 1 x 1 km^2 and 1h, based on COPERT IV methodology **(Fig. 5)**. Composed by the meteorological model WRF-ARW, the emission model HERMES, the chemical transport model CMAQ and the mineral dust atmospheric model BSC-DREAM8b. Estimates the concentration of: NO_2, SO_2, CO, O_3, PM_{10}, $PM_{2.5}$ and C_6H_6.

The current tools lack in flexibility and the microscopic precision needed for the evaluation of mobility plans.

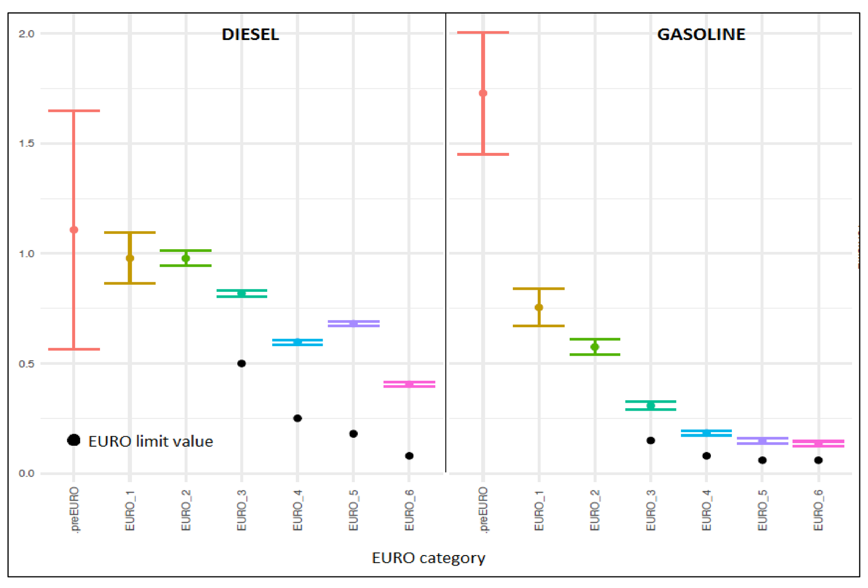


Figure 3: Comparison of observed and EURO emission limits for cars (AMB 2017).

Figure 4: Barcelona's monitoring stations network (XVPCA), (ASPB 2016).

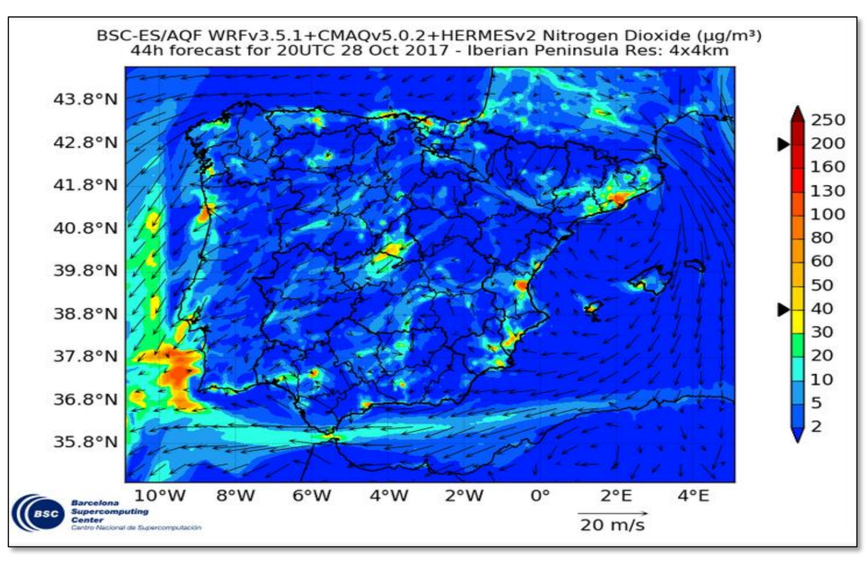


Figure 5: Capture of CALIOPE air quality forecast model (BSC, 2017).

Solution:

AIMSUN microscopic traffic simulator

- Microscopic traffic simulator **(Fig. 6)**.
- Working with Dynamic Traffic Assignment algorithms (DTA).
  - Considers physical relationships, measuring different traffic situations and *how* these propagate on time along the link.
- Composed of the following models:
  - Lane change
  - Gap acceptance for lane changing and yielding
  - Overtaking
  - Car following

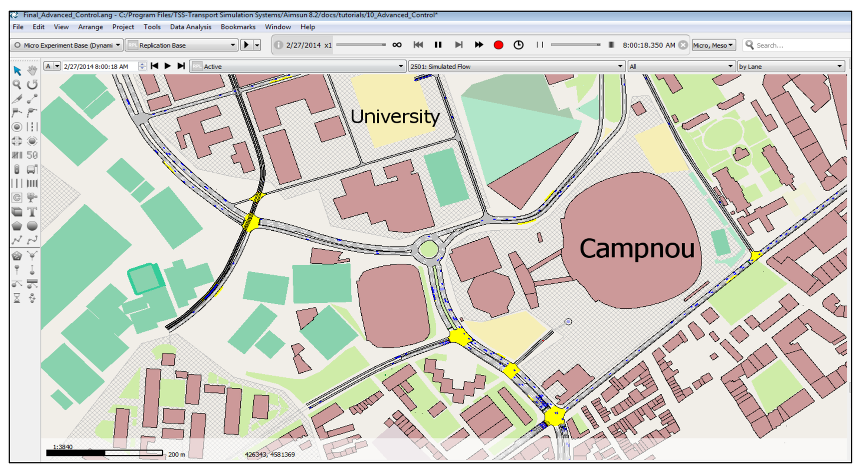


Figure 6: Capture of AIMSUN traffic model over Barcelona.

PHEMlight vehicle emission model

- Microscopic vehicle emission model **(Fig. 7)**.
- Simpler version of PHEM, which originates HBEFA emission factors.
- More than 1000 measures of vehicles for different drive cycles in both laboratory and on road tests from the ERMES group (European Research for Mobile Emission Sources).
- Calculates the emissions for every vehicle estimating the engine power at every second by the longitudinal dynamics and driving resistances (e.g. road grade, air resistance, acceleration power, …).

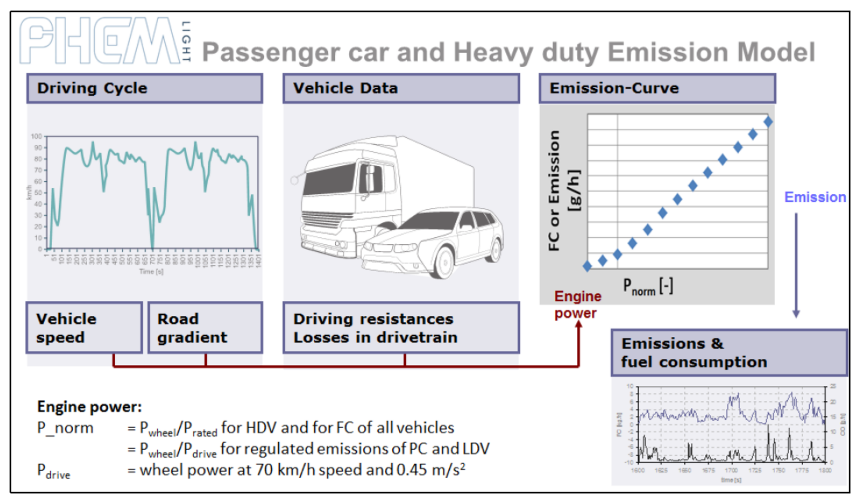


Figure 7: PHEMlight schematic workflow (Hausberger, et al., 2017).

CALIOPE - Urban air quality modelling system

- High resolution air quality modelling system .
- It is currently being upgraded to **CALIOPE-Urban**, which is coupled with the street dispersion model R-line (Snyder et al. 2013), able to quantify pollutant's dispersion along streets **(Fig. 8)**.

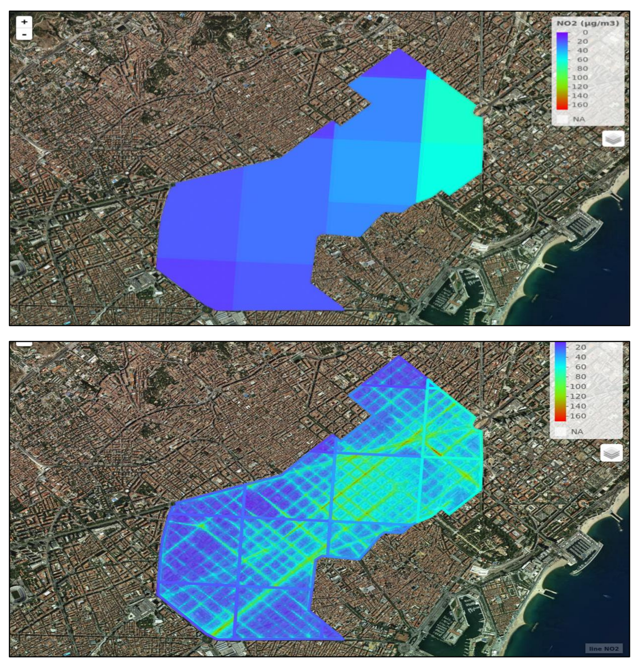


Figure 8: CALIOPE (top) and CALIOPE-Urban (bottom) modelled results (Benavides, 2017).

Present work

The present study aims to integrate a model able to predict vehicle emissions at street level for every vehicle at a time resolution of few seconds. Being able to close specific road lanes, restrict the access to certain types of vehicles, increase the public transport offer or assign different traffic light priorities. This would be done by the flexibility and resolution of the microscopic traffic model, AIMSUN, the accuracy in emissions of an up-to-date vehicle emission model, PHEMlight, over the background of an already stablished air quality model, CALIOPE and its upgraded version CALIOPE-Urban **(Fig. 9)**.

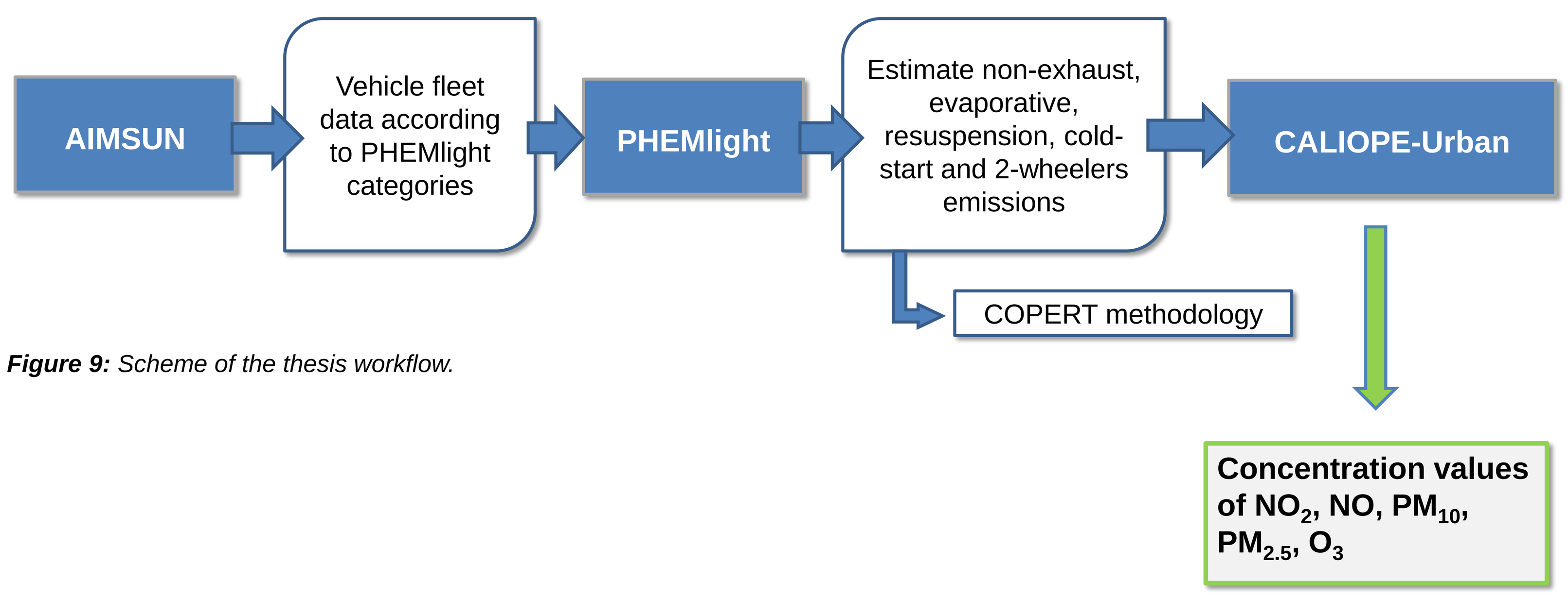


Figure 9: Scheme of the thesis workflow.

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