Estimation de la consommation de carburant et des émissions de polluant d'un flux de trafic routier

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Objective

Context

One aims to estimate road traffic Fuel Consumption (FC) and Pollutant Emission (PE) from link-agregated traffic dynamics

→ Traffic dynamics (*i.e.* time-dependent flow volume and mean speed) can be directly measured or obtained by a traffic model

Purpose

→ Develop an adapted modelling approach to estimate FC and PE from link-agregated traffic dynamics

Table of contents:

- Review of the modelling approaches of FC and PE estimations
- Presentation of the data used to develop the model
- Estimations obtained
- Conclusion

Main aspects of FC and PE models

Type of emission or consumption (COPERT methodology)

- Exhaust emissions (hot or cold)
- Non-exhaust emissions (tyre, brake or road surface wears)
- Fuel evaporation

Inputs

- Flow composition (mainly the vehicles type, fuel and motor type, or vehicle age)
- Traffic dynamics (time-dependent flow and mean speed)

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Classes of FC and PE models for traffic dynamic

Models classification

- Macroscopic discrete models based on traffic situation (urban, rural or highway)
- Macroscopic continuous models based on vehicles trip mean speed
- Mesoscopic continuous models based on vehicle mean speed distribution
- Microscopic models based on cycle-agregated individual vehicles performances
- Sub-microscopic models based on instanteneous vehicles performances

The two models compared

COPERT 4 – Tier 3 method[b]

[b] L. NTZIACHRISTOS & Z. SAMARAS, 2009, *EMEP/EEA inventory guidebook*

- Macro. continuous model based on trip mean speed
- Scale of application: global, from a country during 1 year to a traffic network of 1 km^2 during a 1 hour
- Emission factor functions of the mean vehicles trip speed

RAPONE *et al.* model[c]

[c] M. RAPONE *et al.*, 2008, *Env. Mod. & Ass.* **13(3)**, 383–392

- Micro. model based on cycle-agregated individual performances
- Scale of application: local, a vehicle trip
- Emission factor functions of a vehicle mean speed, acceleration, running and idle times during a cycle

Data used to compare the emission estimations

Individual vehicles trajectories

- Data obtained by simulation with a basic microscopic car-following model whose parameters are statistically estimated on real data
- Trajectories of vehicles evolving on a ring in stationary state
- Two types of patterns according to the density level:
  - $\longrightarrow$ Free state (for low density levels): vehicle speed is constant
  - $\longrightarrow$ Congested (or interactive) state (for high density levels): presence of kinematic wave, vehicle speed varies
- Simulations are done for different density levels and maximal vehicle speed

Examples of trajectories obtained

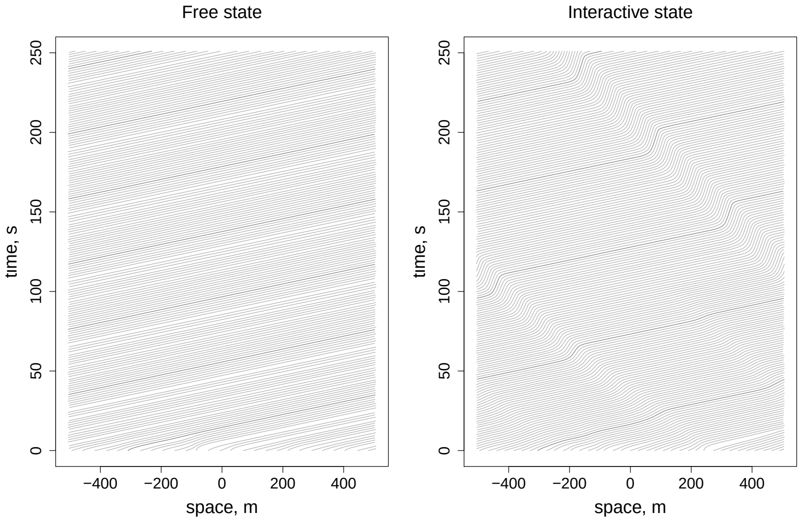


Figure 1: Vehicles trajectories on a ring since random initial conditions

Representation of the data

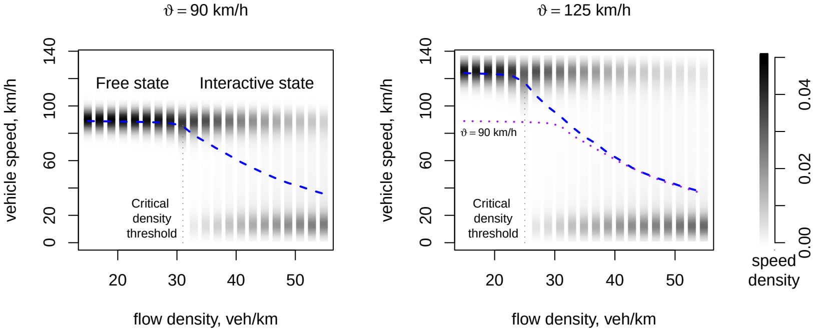


Figure 2: Vehicles speed distributions according to the flow density. Left, 90 km/h maximum speed, and right 125 km/h. Dotted lines are mean value.

FC and PE estimations

Comparison of the Copert models based on mean speed and speed density

We compare the estimations obtained with the COPERT emission factor EF:

$$\mathrm{EF}(v) = \frac{a_1 + a_2 v + a_3 v^2}{1 + a_4 v + a_5 v^2}$$

using the vehicle mean speed:

$$\mathrm{Q}(\mathrm{L}, \mathrm{T}, \varrho) = \varrho\, \mathrm{L}\, \mathrm{T}\, v(\varrho)\, \mathrm{EF}(v(\varrho))$$

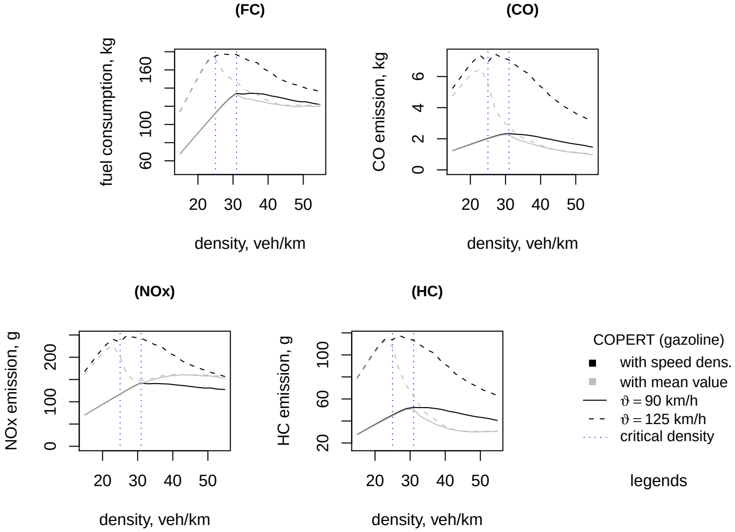
with the estimations obtained using vehicle speed distribution:

$$\mathrm{Q}_1(\mathrm{L}, \mathrm{T}, \varrho) = \varrho\, \mathrm{L}\, \mathrm{T} \int v \mathrm{EF}(v)\, f(v)\, \mathrm{d}v$$

L is the road size considered, T is the observation time and ϱ is the flow density. v is the vehicle mean speed and f is the vehicle speed distribution.

FC and PE estimations

Comparison of the Copert models based on mean speed and speed density



COPERT emission factors functions

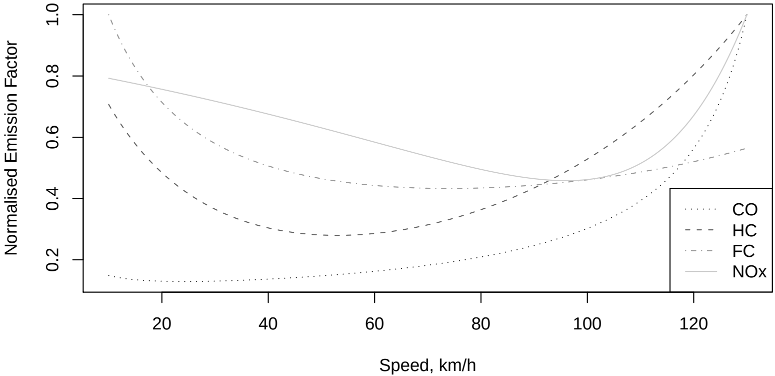


Figure 3: Normalised COPERT emission factors functions for the fuel consumption (FC) and the emission of the monoxyde carbon (CO), the nitrogen oxides (NOx) and the hydrocarbons (HC).

FC and PE estimations

Copert model based on mean speed *vs* the microscopic RAPONE *et al.* model

We compares the estimations obtained using the COPERT model based on vehicle mean speed:

$$\mathrm{Q}(\mathrm{L}, \mathrm{T}, \varrho) = \varrho\, \mathrm{L}\, \mathrm{T}\, v(\varrho)\, \mathrm{EF}(v(\varrho))$$

with the estimations of the RAPONE *et al.* model:

$$\mathrm{Q}_2(\mathrm{L}, \mathrm{T}, \varrho) = \varrho\, \mathrm{L}\, \mathrm{T}\, v(\varrho) \overline{\mathrm{EF}}\big(v(\varrho), w(\varrho), T_{run}(\varrho), T_{idl}(\varrho)\big)$$

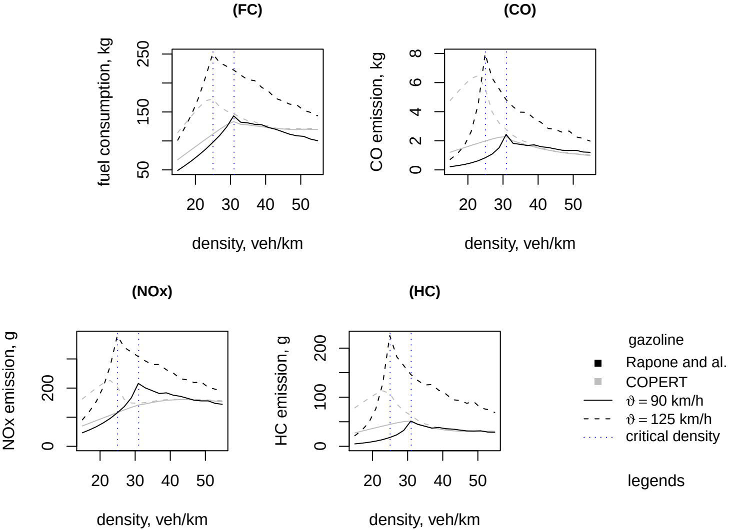
whose emission factor is given by

$$\overline{\mathrm{EF}}(v, w, T_{run}, T_{idl}) = a_0 + a_1 v + a_2 v^2 + a_3 v^3 + a_4 w + a_5 T_{run} + a_6 T_{idl}$$

with w the mean product of the speed by the positive acceleration rate.

FC and PE estimations

Copert model based on mean speed *vs* the microscopic Rapone *et al.* model



FC and PE estimations

Comparison of the Copert models based on speed distribution and bi-modal speed

Lastly, on compare the estimations Q_1 obtained using the COPERT model based on vehicle speed distribution to the one obtained using a bimodal vehicle speed distribution:

$$Q_3(L, T, \varrho) = \varrho \, L \, T \left(\lambda \vartheta \, EF(\vartheta) + (1 - \lambda) u \, EF(u) \right)$$

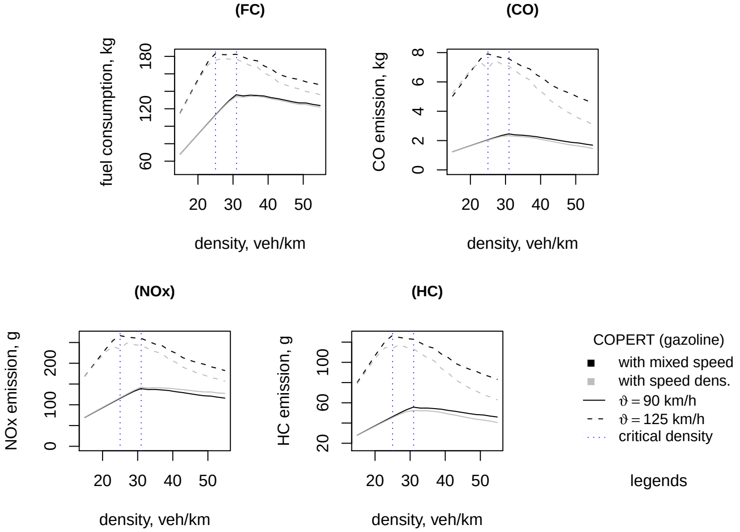
with

$$\lambda = \frac{v - u}{\vartheta - u}$$

where ϑ is the vehicles maximum speed and where u is the vehicle speed into kinematic waves

FC and PE estimations

Comparison of the Copert models based on speed distribution and bi-modal speed



Conclusion

- We propose a emission model assuming bi-modale vehicle speed distributions, based on
  - vehicle mean speed,
  - vehicle maximum speed,
  - vehicle speed into kinematic waves
- The estimations vary only for congested density levels where vehicle mean speed are less to the maximum speed
- The estimations are higher since emission factor are convex functions of the speed
- Even if COPERT emission factor are not estimated for this use, the estimations obtained using bi-modal vehicle speed distribution fit better the ones obtained using the microscopic model