Impact of the penetration rate of ecodriving on fuel consumption and traffic congestion

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Introduction:
What is ecodriving?

- No clear and objective definition exists

- Example: “Ecodriving is a way of driving that reduces fuel consumption, greenhouse gas emissions and accident rates” (www.ecodrive.org)
Ecodriving definition

Using driving rules (Saboohi 2009, Walhberg 2007, Zarcadoula 2007)

• do not drive too fast,
• maintain steady speeds,
• do not accelerate too quickly,
• anticipate traffic flow when accelerating and slowing down,
• shift gears sooner to keep engine speed lower,
• keep the vehicle in good maintenance.
Ecodriving

• In the literature, the benefits of ecodriving are studied for the subject vehicle only.

• Hypothesis 1: ecodriving has an impact on the traffic level and on the fuel consumption on the global network

• Hypothesis 2: this impact depends on the penetration rate of ecodriving.
Aims of this study

Evaluate the impact of ecodriving on fuel consumption and traffic congestion:

• On a whole network

• According to the ecodriving penetration rate

• For different road types and traffic demands
Why are we working on ecdroving?

Light duty vehicles and driver
And the role of passenger cars?

- Fuel consumption US 2004 (IEA)
- In France, Light Duty Vehicles represents 55% of greenhouse gas emissions (source: ministry of sustainable development)
And the role of vehicle, infrastructure and driver?

**Driver:**
- Desired acceleration
- Desired speed
- Engine speed, ... = ecodriving

**Vehicle:**
- Mass
- Engine
- Tires, ...

**Infrastructure:**
- Geometry
- Pavement texture

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Methodology: an ecodriving modelling

Ecodriving parameters

Ecodriven vehicles

Normally driven vehicles

Road network
- Interurban
- Urban

Traffic demand
- Free traffic state
- Intermediate traffic state
- Congested traffic state

Traffic micro simulation
- IDM (Intelligent Driver Model)
  Treiber, 2000
- Gipps model 1981
  (AIMSUN)

Fuel consumption

Traffic indicator (mean speed)

2 types of roads x 3 traffic states x 11 proportions of ecodrivers x 10 replications = 660 numerical tries

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Modelling:
Traffic and fuel consumption
Traffic micro simulation on interurban roads

- Intelligent Driver Model (*Treiber, 2000*):

\[
\dot{v}_\alpha = a \left[ 1 - \left( \frac{v_\alpha}{v_0} \right)^\delta \right] - \left( \frac{s_0 + v_\alpha T + \frac{v_\alpha (\Delta v)}{2 \sqrt{ab}}}{s_\alpha} \right)^2
\]

- Desired acceleration
- Desired speed
- Distance between vehicles
- Minimum gap
- Desired time headway
- Speed difference
- b: desired deceleration

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Fuel consumption on interurban roads

- Energy consumed

\[ dE_{theo} = \left( \frac{1}{2} \rho_{air} S C_x v^2 + C_r r m g + m p + m a \alpha \right) v \alpha dt \]

- Corrected with an efficiency ratio (Wang, 2008)
Traffic micro simulation on urban roads

- Gipps model \((Gipps, 1981)\) with Aimsun (TSS)

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Fuel consumption on urban roads

- Aimsun and Alçelik model (Alçelik, 1982):
  - 4 states are defined:
    - Idling
    - Cruising
    - Accelerating
    - Decelerating
  - 7 parameters from the vehicle are required

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Results:
Interurban roads
Results: interurban road – free traffic

- Fuel consumption
  - Slight and steady decrease
  - Fuel consumption reduces by 7.7%

- Traffic indicator
  - Slight decrease (9.1%)
  - 2 minutes lost on a 20 minutes travel

Optimal proportion of ecodrivers: 100%

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Results: interurban road – intermediate traffic

- Fuel consumption
  - Non linear variation
  - From 0 to 20% of ecodrivers: -8.5%
  - From 0 to 100%: +2.4%

- Traffic indicator
  - Sharp decrease: -38%

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Optimal proportion of ecodrivers: 20%
Results: interurban road – congested traffic

- Fuel consumption:
  - Strong reduction: -35.8%

- Traffic indicator:
  - Sharp decrease: -55%

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Optimal proportion of ecodrivers: 30%
Results:

Urban roads
Results: urban road – free traffic

- Fuel consumption
  - Slow decrease: -9.8%

- Traffic indicator
  - Strong decrease: -19.7%

Optimal proportion of ecodrivers: not defined
Results: urban road – intermediate traffic

- Fuel consumption
  - Non linear variations: -7.6%

- Traffic indicator
  - Non linear variations: -32.3%

Optimal proportion of ecodrivers: not defined but 80% should be avoided
Results: urban road – congested traffic

- Fuel consumption
  - Strong effect: -19.6%

- Traffic indicator
  - Nearly steady

Optimal proportion of ecodrivers: 100%
Proposed solutions for ecodriving

• Short term: promote ecodriving on identified situations

• Middle term: giving real time advice to the driver

• Long term: develop a strategy to manage a whole network
Theoretical and practical implications

• Innovative method to analyze ecodriving.

• It can be applied for several existing or future assistance systems

• Recommendations on ecodriving
## Conclusions and perspectives

### Conclusions

- Ecodriving is efficient at a global point of view
- In some situations, the fuel consumption increases with the % of ecodrivers
- The optimal proportion of ecodrivers varies with the situation

### Study drawbacks

- Current proportion of ecodrivers is unknown
- The engine speed has not been taken into account

### Perspectives

- Refine the modelling
- Experimental validation