1. Introduction

Motivation

- Significant impacts of transport sector:
  - Energy consumption (→ security of supply)
  - GHG emissions (→ global warming)
  - Local pollutants (→ air quality, health)
  - Accidents (→ injuries, fatalities)
  - Etc.

- Alternative options on urban mobility:
  - Cross-modal electrification
  - Transport system integration coupled with Mobility-as-a-Service (MaaS) to promote modal shift
  - Redesign of transport infrastructure (urban plazas, reduction of speed limits, etc.)
  - Etc.
1. Introduction

Motivation

- Alternative options on urban mobility:
  - Redesign of infrastructure → reduction of speed limits
  - Reduce accident risk
  - Improve the urban environment for pedestrians and bikers
  - Promotion of MaaS products (bike, scooter-sharing, etc.)

Objective

- Assess the impacts of reducing speed limits on a one-vehicle/driver perspective:
  - Using real world driving data (naturalistic driving data)
  - Considering the type of road where the vehicle drives
  - Case study: Lisbon Metropolitan area

2. Data and Methods

2.1. Data collection

- 12 drivers under real world driving conditions
- Data collection in Lisbon metropolitan area
- 1 month of data (September 2016), corresponding to 16412 km and 441 hours of driving
- Vehicles' characteristics

<table>
<thead>
<tr>
<th>GENRE</th>
<th>AGE_GROUP</th>
<th>EXPERIENCE</th>
<th>FUEL_TYPE</th>
<th>DISPLACEMENT</th>
<th>CAR_DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>25-34</td>
<td>10-24</td>
<td>Diesel</td>
<td>1598</td>
<td>2013</td>
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</table>

Using real world driving data (naturalistic driving data)
2. Data and Methods

2.1. Data collection

- Observed monitoring and development within a MAC project: EGI – intelligence to drive
- Differences between the GRID part, coloered 1 Hz driving data, including
  - Vehicle dynamics (speed, acceleration)
  - Engine data (torque, air mass, fuel)
  - Traffic position, etc.
  - Road topography and GPS location

2.2. Quantification of energy consumption

Analysis of 1 Hz driving data to assess:

- Vehicle Specific Power – methodology to correlate vehicle dynamics with fuel use, pollutant emissions

\[
VSP = \frac{d}{dt}(E_{\text{kinetic}} + E_{\text{potential}} + F_{\text{rolling}} \cdot v + F_{\text{aerodynamic}} \cdot v^2)
\]

VSP accounts for driver aggressiveness through speed and acceleration.

Measured drive cycle

Per vehicle
2. Data and Methods

2.2. Quantification of energy consumption

- VSP time distribution
- Fuel consumption per VSP mode

Measured drive cycle
Another drive cycle

7.6 l/100km
6.9 l/100km

2.3. Model development – drive cycle adjustment

Reverse geocoding for each second of driving:
- Level 1 – arterial streets
- Level 2 – minor arterial streets
- Level 3 – distributor and collector streets
- Level 4 – local streets

From GPS → type of road

Level 4 Level 4 Level 3 Level 2
Original drive cycle
Per driver

Second-by-second power requirement (VSP)

Adjustment of speed and acceleration to fulfill criteria by maintaining:
- Total distance
- Stops along road infrastructure
- Power requirements

New drive cycle with modified speed limits
2. Data and Methods

2.4. Definition of scenarios

4 scenarios were considered and compared to the real-world driving cycle (BAU):

<table>
<thead>
<tr>
<th>Speed limit (km/h)</th>
<th>BAU</th>
<th>Sc. 1</th>
<th>Sc. 2</th>
<th>Sc. 3</th>
<th>Sc. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street level</td>
<td></td>
<td></td>
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<tr>
<td>L1</td>
<td>120</td>
<td>50</td>
<td>50</td>
<td>50</td>
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<tr>
<td>L4</td>
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</table>

3. Results

Average of all drivers

- Up to 11 km/h reduction in Scenario 4, with corresponding increase in travel time (44%)

- Very significant reductions in acceleration (connected with driver aggressiveness), mostly noticeable in deceleration events
### 3. Results

**Average of all drivers**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time (h)</th>
<th>Average speed (km/h)</th>
<th>Acceleration / Deceleration</th>
<th>Energy consumption (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>0.21</td>
<td>24.50</td>
<td>0.20</td>
<td>0.20</td>
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<tr>
<td>Scenario 2</td>
<td>0.20</td>
<td>24.75</td>
<td>0.22</td>
<td>0.23</td>
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<tr>
<td>Scenario 3</td>
<td>0.23</td>
<td>25.00</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>0.22</td>
<td>25.25</td>
<td>0.27</td>
<td>0.27</td>
</tr>
</tbody>
</table>

- Scenario 1 presents slight impacts — understandable at urban scale; Scenario 3 and 4 have very similar impacts.

**Distance (km) Difference to BAU (%)**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>0%</th>
<th>0%</th>
<th>0%</th>
<th>0%</th>
</tr>
</thead>
</table>

**Energy impacts per driver**

- This change in drive cycle is reflected in modifications in energy consumption.
- Sc. 1 results in reduction in energy consumption, but speed limitation in Sc 2, 3 and 4 result in up to 15% increases.

**Results per driver**

- D5, 6, 10, 11 and 12 with higher reductions in Avg. Speed.
- Association with the context and conditions of driving.

**Difference in hours**

- 0.30
- 7.57
- 18.13
- 18.90

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**Local pollutants**

- Up to 15% increases (HC, CO, NOx, PM).

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**Opportunity for electric mobility for mitigating impacts**

- Fuel consumption
- Local pollutants (HC, CO, NOx, PM)
3. Results

Connection with risk of injury accidents

- Estimation of risk of injury accidents reduction based on speed\(^1\)

4. Conclusions

and future work

- Assessment of impacts of reducing speed limits on a driver perspective
  - Combination of naturalistic driving data + drive cycle modelling approach
    - Reductions of up to 11 km/h resulting in:
      - Increase of up to 15% in energy consumption
      - Decrease in driver aggressiveness (up to 180%)
3. Results

Results per driver

<table>
<thead>
<tr>
<th>Drivers</th>
<th>D5</th>
<th>D6</th>
<th>D10</th>
<th>D11</th>
<th>D12</th>
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</thead>
<tbody>
<tr>
<td>Avg. Speed (km/h)</td>
<td>72.4</td>
<td>66.4</td>
<td>66.5</td>
<td>65.9</td>
<td>70.8</td>
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<tr>
<td>L1</td>
<td>28.8</td>
<td>24.2</td>
<td>22.7</td>
<td>33.0</td>
<td>28.2</td>
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<tr>
<td>L2</td>
<td>18.9</td>
<td>15.4</td>
<td>15.9</td>
<td>23.7</td>
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<tr>
<td>L3</td>
<td>19.9</td>
<td>11.9</td>
<td>14.2</td>
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<tr>
<td>L4</td>
<td>18.0</td>
<td>11.9</td>
<td>14.2</td>
<td>32.2</td>
<td>29.0</td>
</tr>
</tbody>
</table>

- D5, 6, 10, 11 and 12 with higher reductions in Avg. Speed
- Performance of drivers varies across levels: decreasing speed trend with levels

Connection with accident risk

- Quantification of risk reduction based on Lund, 2005: correlations between reduction in speed and risk of accident