GPS measurement of Swedish car movements for assessment of possible electrification

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Why movement patterns?

Total Cost of Ownership (TCO)

- Operational costs ($/km)
- Investment costs ($/km)
- Isodollar

- Conventional
- Mild etc.
- Full hybrid
- Plug-in hybrid
- Battery electric vehicle

- Technology
- Driving distance
- Battery costs
- Movement pattern
- Electric drive fraction
- Battery size
- Recharging opportunities

Organized by Hosted by In collaboration with Supported by
Travel survey data?

- Track persons, not cars (as in Sweden)
- Short periods, often one day (as in Sweden)

"2/3 of daily driving ≤ 50 km"
Effects of variability in movement patterns

Large variability in real movement patterns =>
Huge differences in opportunities to utilize a specified battery!

Movement patterns matter!
The Swedish car movement data project

The aim has been to collect good and representative data on Swedish car movement patterns by:

- GPS-logging of car movements (time, position, speed) in the current Swedish (conventional) car fleet

=>

- Analyses of PHEV design (battery), viability and potential
The targeted vehicles

- The county of Västra Götaland + Kungsbacka municipality (includes Gothenburg, 2:nd largest city) ≈ 1/6 of Swedish fleet

- Privately driven cars (inclusive of company cars)

- ≤ 100 months old (= most important for economy and purchase)
Stratified random selection from Swedish vehicle register

- ownership: natural person / company cars
- region: Gothenburg area / rest of the region
- model yr: old / new
- fuel: diesel / all other (not electricity)
- weight: light / heavy
• Request by letter
• ≈ 5-10% positive response rate
• Agreement signed – participation – only for specified research
• Commercial equipment
• No connection to the car electronics
• The customer mounts
• Communication via mobile network (2-way)
• Memory card (in case of no coverage)
• 2.5 Hz sampling (as high as possible for simulation)
The measurement campaigns
Perform by Test Site Sweden (TSS)

Time stamp
Position
Velocity
Satellite-id
Dop values

500 ICE

Road type and speed limit data

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Analysis database statistics

**each trip:**
- Distance
- Duration
- Start time
- Stop time
- Start latitude/longitude
- Stop latitude/longitude
- Average velocity
- Pause before

**each device:**
- Total number of trips
- First/last time logged
- Total distance
- Average trip length
- Max trip length
- Total time logged
- Max speed
- Average velocity
- Average velocity squared
- Average velocity cubed
Representativeness

Vehicles, regions and seasons are well or reasonably represented

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average for cars with data</th>
<th>Average* from vehicle register</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model year</td>
<td>2006.37</td>
<td>2006.12</td>
</tr>
<tr>
<td>Maxi. engine power (kW)</td>
<td>98.2</td>
<td>99.5</td>
</tr>
<tr>
<td>Cylinder volume (cm³)</td>
<td>1819</td>
<td>1812</td>
</tr>
<tr>
<td>Kerb weight (kg)</td>
<td>1456</td>
<td>1457</td>
</tr>
<tr>
<td>Fuel use (litre/100km)</td>
<td>7.22</td>
<td>7.26</td>
</tr>
<tr>
<td>CO₂ emission (g CO₂/km)</td>
<td>176</td>
<td>177</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>Distribution subregions over (Data)</th>
<th>Desired distr. over subregions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gothenburg region</td>
<td>220</td>
<td>227</td>
</tr>
<tr>
<td>2 larger cities</td>
<td>80</td>
<td>88</td>
</tr>
<tr>
<td>16 smaller cities</td>
<td>290</td>
<td>260</td>
</tr>
<tr>
<td>29 smallest municipalities</td>
<td>124</td>
<td>138</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>ALL</td>
<td>714</td>
<td>714</td>
</tr>
</tbody>
</table>

Car size
- rank 4+
- rank 3
- rank 2
- rank 1

Number of cars in the household

Logged vehicles

Week of the year
Logged driving

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Data Cars</th>
<th>Data Cars 30d+</th>
<th>Data Cars Corr 30d+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cars with data</td>
<td>714</td>
<td>528</td>
<td>445</td>
</tr>
<tr>
<td>Total distance (km)</td>
<td>1 314 002</td>
<td>1 207 141</td>
<td>1 174 298</td>
</tr>
<tr>
<td>Total travel time (hours)</td>
<td>24 801</td>
<td>22 776</td>
<td>n. a.</td>
</tr>
<tr>
<td>Average distance (km)</td>
<td>1 840</td>
<td>2 286</td>
<td>2 639</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>53</td>
<td>53</td>
<td>n. a.</td>
</tr>
<tr>
<td>Number of trips(^a)</td>
<td>134 425</td>
<td>124 458</td>
<td>113 293</td>
</tr>
<tr>
<td>Average number of trips(^a)</td>
<td>188</td>
<td>236</td>
<td>255</td>
</tr>
<tr>
<td>Average trip length(^a) (km)</td>
<td>9.8</td>
<td>9.6</td>
<td>10.4</td>
</tr>
<tr>
<td>Av. number of trips per day(^a)</td>
<td>3.8</td>
<td>3.7</td>
<td>4.4</td>
</tr>
</tbody>
</table>

After (our) filtering
• Distribution of *daily distance*, *speed* and (normalized) *power need* at the wheels
Various parking times effectively pick out different parking types

- full: share parking
- dotted: charging 2 kW to 10kWh
Examples of use of the data

**Trip level data**

• Assessment of PHEV design, viability, potential and policy
  L-H Kullingsjö, S Karlsson, F Sprei, 2013. Conflicting interests in defining an 'optimal' battery size when introducing the PHEV?, EVS 27

**All data**

• Energy regeneration options
  L-H Kullingsjö, S Karlsson, 2013. The possibility for energy regeneration by electrification in Swedish car driving. EVS 27

• Route identification for energy management
New ongoing logging project

Focusing potentially ‘early adopters’ of BEVs

Logging of both cars in

- 100(?) two-car households
- Gothenburg region
- ≥ two licences, ≤ 65 years old
- MY 2002+, ≤ 2000 kg, 200 kW
- make up ≈ 11 % of private cars
  (no company cars involved)
Conclusions

• Movements patterns matter for vehicle electrification

• GPS-data on Swedish car movement patterns of good representativeness are available and used in research

• Available for research and cooperation
Thank you for your attention!

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