Infrastructure performance viewer

Babak Ebrahimi <babake@chalmers.se>
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Agenda

- Background
- Research topics
- Summary of results
- Outlook and future of research
Norway in a snapshot

Population density in Norway (2017)

Value
High: 5041 (ppl./km²)
Low: 0 (ppl./km²)
Lifecycle of road infrastructure

➢ The NPRA has enforced various climate mitigation measures

Reduction of greenhouse gas emissions by 40% (from the construction of road infrastructure) and 50% (from the maintenance and operation of road infrastructure)
Goal and scope

- Support the Norwegian Public Road Administration to economically and environmentally plan and maintain the open-road network

- How
  - Life cycle assessment (LCA)
  - Life cycle cost analysis (LCCA)
  - Compilation and assessment of data
  - Visualization of assessment
Team

Hrefna Run Vignisdottir
<hrefna.vignisdottir@ntnu.no>

Reyn Joseph O'Born
<reyn.oborn@ui.no>

Gaylord Kabongo Booto
<gaylord.booto@ntnu.no>

Holger Wallbaum
<holger.wallbaum@chalmers.se>

Rolf André Bohne
<rolf.bohne@ntnu.no>
Publications


Evaluation of 3 LCA software tools

- EKA (version 1.0, year 2015)
- EFFEKT (version 6.6, year 2013)
- LICCER (version 2.0, year 2015)

<table>
<thead>
<tr>
<th>LCA Software</th>
<th>Country</th>
<th>Assessment Stage</th>
<th>Elements</th>
<th>Traffic</th>
<th>Assessment Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Early Planning</td>
<td>Construction</td>
<td>Maintenance</td>
<td>Road</td>
</tr>
<tr>
<td>EKA</td>
<td>SE</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>EFFEKT 6.6</td>
<td>NO</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>LICCER</td>
<td>NO, SE, DK, NL</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
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</tbody>
</table>
Designed a case

- AADT 15000, 12% heavy vehicles
- Traffic growth by 1.4%
- Frost amount F100
- Subgrade BC group 7
- Susceptible soil group T4

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material type / thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearing course</td>
<td>4.5 cm asphalt concrete</td>
</tr>
<tr>
<td>Binder course</td>
<td>3.5 cm asphalt concrete</td>
</tr>
<tr>
<td>Base course</td>
<td>13 cm asphalted gravel</td>
</tr>
<tr>
<td>Sub-base</td>
<td>30 cm crushed rock</td>
</tr>
<tr>
<td>Frost protection</td>
<td>130 cm crushed rock</td>
</tr>
</tbody>
</table>

Total thickness: 181 cm
EN Standard 15978

Building Assessment Information

Building Life Cycle Information

Supplementary info.

A1 - 3
Product stage

A4 - 5
Construction Process stage

B1 - 7
Use stage

C1 - 4
End of life stage

D
Potential benefits and loads

A1
Raw materials supply

A2
Transport

A3
Manufacturing

A4
Transport

A5
Construction-installation process

B1
Use

B2
Maintenance

B3
Repair

B4
Replacement

B5
Refurbishment

B6
Operational energy use

B7
Operational water use

C1
Deconstruction demolition

C2
Transport

C3
Waste processing

C4
Disposal

Green box: Mutually covered
Blank box: Mutually not covered

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Results

- Asphalt density and asphalt mixing plan
- Embodied energy for bitumenious binder
  - Feedstock energy

<table>
<thead>
<tr>
<th></th>
<th>EFFEKT 6.6</th>
<th>EKA</th>
<th>LICCER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse gas emissions (ton CO₂.eq)</td>
<td>487</td>
<td>344</td>
<td>296</td>
</tr>
<tr>
<td>Embodied energy (GJ)</td>
<td>28 108</td>
<td>5 786</td>
<td>27 400</td>
</tr>
<tr>
<td>Amount of re-asphalting (ton)</td>
<td>8 330</td>
<td>8 400</td>
<td>7 526</td>
</tr>
</tbody>
</table>
Data compilation (LCI)

i. Aggregates in different sieve sizes

ii. Bituminous binders

iii. Construction machinery
Lifetime of road infrastructure

- ~25% of total maintenance costs is related to asphalt works
- Constant growth of road traffic volume
- Increase in the service levels of road infrastructure
- Effect of maintenance activities on road users
- Unknown technical lifetimes of asphalt surfacing
Selected variables

- Climatic zone
- Signed speed limit
- Asphalt surfacing type
- Annual average daily traffic
- Traveled-way width
- Road condition measurement
Pavement distress

- Transverse uneveness (rutting) used as a response variable

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Approach to estimate asphalt surfacing lifetimes

- Norwegian road database (NVDB)
- Geographic information systems (GIS)
- Cox proportional hazard (PH) model
3 Counties in Norway
Example of results

- AADT 10001-20000
- Sør-Trøndelag
- Signed speed limit 50 km/h
- Aggregate upper sieve size 11 mm
- Administrative bearing-capacity class T10-50

- Median lifetimes of asphalt surfacing
  - Asphalt concrete (paving grade binder): ~ 4.2 yr
  - Stone mastic asphalt (paving grade binder): ~ 4.8 yr
  - Stone mastic asphalt (polymer modified binder): ~ 4.2 yr
Main findings

- Inverse relationship between asphalt surfacing lifetimes and traffic volume
- Asphalt surfacing lifetimes strongly depend on maximum aggregate sieve size
- Shorter lifetimes of asphalt surfacing in colder climate
- Traveled-way widths could influence the longevity of asphalt surfacing
- Determination of the frequency of asphalt surfacing
  - Identification of sections with the highest probability of increase in asphalt surfacing
Operational emissions from construction machinery (NRMM)

- **Aim:** Introduce a screening emission accounting
- **Data**
  - The Norwegian construction machinery database
  - Emission factors from EMEP/EEA guidebook

<table>
<thead>
<tr>
<th></th>
<th>Machine A</th>
<th>Machine B</th>
<th>Machine C</th>
<th>Machine D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. net power (kW)</td>
<td>171</td>
<td>206</td>
<td>288</td>
<td>403</td>
</tr>
<tr>
<td>Operating weight (ton)</td>
<td>20.5</td>
<td>26.5</td>
<td>31</td>
<td>51.5</td>
</tr>
<tr>
<td>Economic lifetime (eh)</td>
<td>7667</td>
<td>8680</td>
<td>9800</td>
<td>13800</td>
</tr>
<tr>
<td>Load capacity (m³/eh)</td>
<td>168</td>
<td>183</td>
<td>198</td>
<td>250</td>
</tr>
<tr>
<td>Fuel consumption (l/eh)</td>
<td>39.5</td>
<td>42</td>
<td>46</td>
<td>60</td>
</tr>
<tr>
<td>Emission standard</td>
<td>EPA Tier 4 final / EU Stage VI</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fuel based emissions per economic lifetime

- Machine A
- Machine B
- Machine C
- Machine D
Load capacity and gaseous emissions
LCA of construction machinery (NRMM)

- **Inputs**
  - Raw material
  - Transpiration
  - Manufacturing

- **Factory**
  - Assembling
  - Transportation

- **Use**
  - Fuel consumption
  - Maintenance
  - Repair/changes/services

- **End of life**
  - Disassembling
  - Transportation
  - Waste management

- **Outputs**
Thank you for your attention