Modeling multimodal transport in Norwegian wood supply

Dag Fjeld
Dag Skjølaas
Background

Restructuring of pulp mill capacity

Limited rail electrification

spruce pulpwood
pine + spruce pulpwood

electric
diesel
Objective & models

Compare cost levels for varying levels of
- terminal capacity
- demand and electrification

between optimal wood flow solutions using simple transport problem in Excel*

**Model 0:** \( \min \sum \text{truck} + \text{rail costs} \)

...+ terminal-specific costs added after optimization

**Model 1:** \( \min \sum \text{truck} + \text{terminal} + \text{rail costs} \)

given restrictions:
- annual supply per area (45 w/pine, spruce)
- annual demand per market (2 w/pine, spruce)
- terminal transshipment restrictions
- terminal capacity restriction (m\(^3\)/yr)

For an annual transport volume of 1.4 million m\(^3\) pulpwood

*COIN-OR: CBC, Bonmin engines*
Truck transport: area-specific max GVW

74t ➔ 49t load
60t ➔ 38t load
56t ➔ 34t load
50t ➔ 28t load
Rail transport: market-specific train configurations

domestic ≈ 800-1100 m³/train  export ≈ 1700 m³/train

sgnss wagons (3.4 t/m)

laaps wagons (2.7 t/m)

lnps wagons (2.5 t/m)
Cost functions

**Truck transport: NOK/m³ = fixed + variable (km)**

<table>
<thead>
<tr>
<th>Max GVW</th>
<th>50 t</th>
<th>56 t</th>
<th>60 t</th>
</tr>
</thead>
<tbody>
<tr>
<td>fixed NOK/m³</td>
<td>26</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>variable NOK/m³km</td>
<td>0.72</td>
<td>0.67</td>
<td>0.62</td>
</tr>
</tbody>
</table>

**Terminal handling: NOK/m³**

![Terminal handling graph]

**Rail transport: NOK/m³**

![Rail transport graph]
Ranking of factors influencing rail transport costs (NOK/m³)

<table>
<thead>
<tr>
<th>Factor</th>
<th>10% change in cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load/wagon</td>
<td>12.0%</td>
</tr>
<tr>
<td>Wagons/train</td>
<td>10.0%</td>
</tr>
<tr>
<td>Turns/week</td>
<td>6.0%</td>
</tr>
<tr>
<td>Speed</td>
<td>4.0%</td>
</tr>
<tr>
<td>Loading time</td>
<td>2.0%</td>
</tr>
<tr>
<td>Energy price</td>
<td>2.0%</td>
</tr>
<tr>
<td>Operator wages</td>
<td>2.0%</td>
</tr>
<tr>
<td>Locomotive price</td>
<td>2.0%</td>
</tr>
</tbody>
</table>
Cost comparisons with current demand for current (35/65c) vs free (35/65f) terminal capacities.
Solutions: Top three terminals with current demand

35% spruce  0% pine
65% spruce  100% pine
Solutions: Changes in average road and rail distance
Solutions: Top three terminals with increased domestic demand

- Hovemoen: 65% spruce, 65% pine
- Rudshögda: 35% spruce, 35% pine
- Veijmo: 65% spruce, 35% pine

Volume/terminal with increased domestic volume (f)

Model
- Electric + Diesel
- Fully Electrified

Volume/terminal with increased domestic volume (f)

- Hovemoen
- Rudshögda
- Sørfjord
- Haueter
- Veijmo
- Braskerledfoss
- Nærøya
Market-specific cost development* with current capacity/demand/electrification

<table>
<thead>
<tr>
<th></th>
<th>Volume (1000 m³)</th>
<th>w/ current flows «own volumes»</th>
<th>w/optimal flows «all-in»</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>325’</td>
<td>132</td>
<td>132</td>
</tr>
<tr>
<td>Export</td>
<td>275’</td>
<td>149</td>
<td>143</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*spruce pulpwood (sort 102)
In conclusion

«It is always wise to look ahead, but difficult to look further than you can see»

Winston Churchill