Modeling multimodal transport in Norwegian wood supply

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Background

Restructuring of pulp mill capacity

Spruce pulpwood
Pine + spruce pulpwood

Limited rail electrification

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: \[ \text{min } \sum \text{ truck + rail costs} \]
\[ \text{....+ terminal-specific costs added after optimization} \]

Model 1: \[ \text{min } \sum \text{ truck + terminal + rail costs} \]

given restrictions:
- annual supply per area (45 w/pine, spruce)
- annual demand per market (2 w/pine, spruce)
- terminal transshipment restrictions
- terminal capacity restriction (m³/yr)

For an annual transport volume of 1,4 million m³ pulpwood

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

- 74t ➔ 49t load
- 60t ➔ 38t load
- 56t ➔ 34t load
- 50t ➔ 28t load

(Skogforsk)

(D. Skjølaas)
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)

Inps wagons (2.5 t/m)
**Cost functions**

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

<table>
<thead>
<tr>
<th>Max GVM</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**

**Rail transport: NOK/m³**

- diesel
- electric
Ranking of factors influencing rail transport costs (NOK/m³)
Cost comparisons with current demand for current (35/65c) vs free (35/65f) terminal capacities.
Solutions: Top three terminals with current demand

- 65% spruce
- 0% pine
- 35% spruce
- 100% pine

Volume/terminal with current capacity (c)

Volume/terminal with free capacity (f)

Model: electric + diesel
- fully electrified

Model: electric + diesel
- fully electrified
Solutions: Changes in average road and rail distance
Solutions: Top three terminals with increased domestic demand

Volume/terminal with increased domestic volume (f)

<table>
<thead>
<tr>
<th>Model</th>
<th>65% spruce</th>
<th>65% pine</th>
<th>35% spruce</th>
<th>35% pine</th>
</tr>
</thead>
<tbody>
<tr>
<td>electric + diesel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fully electrified</td>
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</tr>
</tbody>
</table>
Market-specific cost development* with current capacity/demand/electrification

<table>
<thead>
<tr>
<th></th>
<th>Costs (NOK/m3)</th>
<th>Volume (1000 m3)</th>
<th>w/ current flows</th>
<th>w/optimal flows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>«own volumes»</td>
<td>«all-in»</td>
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<tr>
<td>Domestic</td>
<td></td>
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<tr>
<td>Domestic</td>
<td>139</td>
<td>325'</td>
<td>132</td>
<td>132</td>
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<tr>
<td>Export</td>
<td>103</td>
<td>275'</td>
<td>143</td>
<td>149</td>
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<tr>
<td>Sum</td>
<td>122</td>
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<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