Effects of new/future harvesting technologies on supply chain cost for young forest

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Starting point 0:

- **Current annual harvesting potential (on a technical level):**
  - Sweden ca 5-7 M m³ solid
  - Finland ca 5-7 M m³ solid
  - Could be significantly increased, if the trend of keeping the young stands denser (e.g. neglecting PCT), up to the first commercial thinning, continue.

(Routa et al. 2012)
Starting point 1:
How can we reach higher cost efficiency in denser stands?!
Starting point 2:

• "Harvesting work stands for ca 50-60% of the supply cost, of which the cutting work stands for 2/3"
Starting point 3:

- Multi tree handling (MTH) technology for small diameter trees:
  - Felling trees one-by-one by selection
  - Limited accumulation per crane cycle
  → Time consuming crane movements
  → Low accumulation degree per crane cycle
Starting point 4:

- PCT stands
- FT stands

No. of required trees per OD t vs Tree size, dbh (cm)
Starting point 5: Undelimbed trees are bulky
- Only 30-60% of the load-capacity is used!
Conclusions

• Rational handling is required:
  - Area based felling!
  - Higher handling capacity!
  - Bunch- and load compression!
  - Bundling!

• Thus, ”New technology and methods!”
Geometric thinning $\rightarrow$ rational crane movements!

Thinning from below  Perpendicular boom-corridors  Fan-shaped boom-corridors

Working hypothesis!
Effect of work method on productivity

- Conv. techn.:
  - Boom-corridor thinning vs. Selective thinning

\[ \begin{align*}
\text{Corridor thinning} & \quad \text{Thinning from below} \\
\text{Strip road} & \\
\text{Remaining trees} & = \text{Harvested trees}
\end{align*} \]

→ 16-40% increased prod.!
Effect of new techn. + boom-corridor thinning

Conv. techn. (sel och boom-corr.) vs. New techn. and boom-corr.

→ up to 200% increased prod.!!!
Bunch-compression → 80-160% higher bunch density

Load compression → 16-34% higher payloads
Systems analysis

• Objectives:
  – “Study the effect of implementing new harvesting and handling technologies on the supply chain cost and energy efficiency for the early thinning of stands in comparison to conventional systems.” Supply of uncomminuted biomasses are studied.

• Goal:
  – To provide information on possible designs of the future efficient supply chains!
Study design:

- Modeling of conventional and future machines performances
  - Harvesters, forwarders, bundle-harvesters, trucks
- Type stands and treatments
  - Species: pine, spruce, mixed
  - Density: 1700-1150 trees/ha
  - Thinning from below vs. boom-corridor thinning
- Variables
  - Tree size harvested, 5-70 dm³
  - Forwarding distance, 100-500m
  - Trucking distance, 25-250km
Delivered Products

• Pulpwood logs
• Rough-delimbed pulpwood logs
• Rough delimbed tree sections
• Tree sections (whole trees)
• Bundled tree sections
• Bundled rough-delimbed tree sections
## Supply systems (n=14)

<table>
<thead>
<tr>
<th>System</th>
<th>Machine</th>
<th>General description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>I-PL-SEL-A</td>
<td>Conventional pulpwood system</td>
</tr>
<tr>
<td>S2</td>
<td>I-RP-SEL-A</td>
<td>Conventional roughly delimbed pulpwood system</td>
</tr>
<tr>
<td>S3</td>
<td>I-RS-SEL-B</td>
<td>Conventional roughly delimbed tree section system</td>
</tr>
<tr>
<td>S4</td>
<td>II-WS-SEL-B</td>
<td>Conventional tree section system</td>
</tr>
<tr>
<td>S5</td>
<td>II-WS-BC-B</td>
<td>Conventional tree section system combined with boom-corridor thinning method</td>
</tr>
<tr>
<td>S6</td>
<td>V-WS-BC-B</td>
<td>Development of the conventional tree section system combined with boom-corridor thinning method in which an “improved” version of the conventional felling head is implemented</td>
</tr>
<tr>
<td>S7</td>
<td>VI-WS-BC-B</td>
<td>Development of the conventional tree section system combined with boom-corridor thinning method in which an innovative head, especially developed for boom-corridor thinning, is</td>
</tr>
<tr>
<td>S8</td>
<td>III-BWS-SEL-A</td>
<td>Conventional bundle-harvester system for tree sections</td>
</tr>
<tr>
<td>S9</td>
<td>IV-BRS-SEL-A</td>
<td>Conventional bundle-harvester system for roughly delimbed tree sections</td>
</tr>
<tr>
<td>S10</td>
<td>III_{OPT}-BWS-SEL-A</td>
<td>Developed bundle-harvester system for tree sections with no extra time for the bundling work</td>
</tr>
<tr>
<td>S11</td>
<td>III_{OPT}-BWS-BC-A</td>
<td>Developed bundle-harvester system for tree sections combined with boom-corridor thinning</td>
</tr>
<tr>
<td>S12</td>
<td>IV_{OPT}-BRS-SEL-A</td>
<td>Conventional bundle-harvester system for roughly delimbed tree sections with no extra time</td>
</tr>
<tr>
<td>S13</td>
<td>V_{OPT}-BWS-BC-A</td>
<td>Innovative bundle-harvester system: development of the conventional tree section system combined with boom-corridor thinning method in which an “improved” version of the</td>
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<td>S14</td>
<td>VI_{OPT}-BWS-BC-A</td>
<td>Innovative bundle-harvester system: development of the conventional tree section system combined with boom-corridor thinning method in which an innovative head is used</td>
</tr>
</tbody>
</table>
Analysis and comparisons

- Variable time truck
- Terminal time truck (load, unload)
- Variable time forwarder
- Terminal time forwarder (load, unload)
- Harvester time

Graph showing cost-energy efficiency ($/OD t - JOD/t$) vs. distance (km)
Main results: (Values are given for a forwarding distance of 300m and a trucking distance of 75km)

Conventional pulpwood system
"Bending the curve"

- Conventional rough-delimbed pulpwood system
”Keep on bending”: Conventional tree-part system
"Pushing down...":

Optimized conventional tree-part bundling system
"Little bit more bending":

Boom-corridor thinning + new felling technology harvesting tree-parts
"And the final push":

Boom-corridor thinning + new felling technology harvesting tree-parts + optimized bundling unit
Below ca 30 dm³:

Boom-corridor thinning + new felling technology harvesting tree-parts + optimized bundling unit
From ca 30 < ca 70 dm³:

Optimized conventional tree-part bundling system
“Sensitivity analysis”: Effects of compression of tree-parts on forwarders and trucks

- 10% → 1-2% cost reductions
- 20% → 5-6% cost reductions
- 30% → 8-10% cost reductions
Conclusions

• Compaction of biomasses, preferable by the use of bundle-harvesters, render dev. of efficient supply systems!
  – Should be higher if adding the logistical advantages!
  – One trucking fleet – timber trucks!
Conclusions

- Implementation of “simple” load-compression technology for tree-part systems give significant cost reductions
  - (This implementation should been made already!?)}
Conclusions

• The technological development should firstly focus on systems intended for stands with an average tree size < ca 30 dm³
  – High share of the potential, no major competition, PCT is costly
  – New felling technologies are under development!
  – Combination with bundling units!
Finally, ongoing developments...
"Flowcut"!
Prototype!
- MAMA-head
Cintoc
- Dual crane/delivering crane
Why not using two felling cranes?

(Mellberg 2013, Linköpings Universitet)
Simulation of time-consumption of a two-crane system in boom-corridor thinning

The ”history” of fuel wood thinning harvesters productivity development!

<table>
<thead>
<tr>
<th>One-Tree per crane-cycle</th>
<th>Multi-tree handling (MTH)</th>
<th>MTH + boom-corridor (BCT)</th>
<th>BCT-Develop. of current heads</th>
<th>BCT + new techn. (BTCN)</th>
<th>BCTN + two felling-crane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref.</td>
<td>+40%</td>
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<td>Ref.</td>
<td>16-40%</td>
<td>30-100%</td>
<td>200%</td>
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This is left to realize!!!
Thanks,

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