Potentials of possible machine systems for directly loading logs in cut-to-length harvesting

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Outline

- Integration approaches
- Analytical objective
- Methods & assumptions
- Results: system potentials
- Conclusions
Work tasks in CTL harvest

Harvester
- Felling and processing

Forwarder
- Empty transport
- Loading
- Full transport
- Unloading

- Stem size
- Distance, speed
- Stand density, speed
- Distance, speed
- Assortments

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Direct loading of logs -
Integration of work tasks

• Work tasks combined to be done at the same time and place:
in sequence or simultaneously

• Results
  – Reduction of work tasks
  – Shorter lead time
  – Reduction of stocks (buffers)

• Technical or organizational
Direct loading = logs are processed directly to load space of transporting vehicle

Technical approach: 1 machine (*harwarder*)

Organizational approach: Co-operating machines (*Besten*)
Harwarder

- 1 machine harvests and forwards
- Tested from 1950:ies
- Potentials
  - Lower relocation costs
  - Simple planning
  - Faster production
  - Clean lumber
Co-operating machines

• Harvester process directly to forwarders’ bunk
• Potentials:
  – Faster production
  – Clean lumber
Forest stand

Conventional

Manned harvester

Roundwood on ground

Manned forwarder

Harwarder

Manned harwarder

Manned harwarder

Manned harvester

Integrated Forwarder Loading (IFL)

Autonomous Load Change (ALC)

Unmanned forwarder

Remote controlled Direct Loading (RDL)

Autonomous Direct Loading (ADL)

Unmanned harvester

Manned harvester

Manned harvester

Unmanned forwarder

Unmanned forwarder

Unmanned forwarder

Manned forwarder

Road side

Roundwood on ground
Gain, machine time = \textit{loading}

Gain, calendar time = \textit{loading} + \textit{buffer time}

\textit{Calendar time} = \textit{machine time} + \textit{buffer time}
**Time gain**

### Conventional CTL

- Felling & processing
- Driving empty
- Loading
- Driving full
- Unloading

**Buffer time**

**Calendar time = machine time + buffer time**

### Harwarder

- Driving empty
- Felling & processing
- Driving full
- Unloading

**Gain, machine time = **loading**

**Gain, calendar time = loading + buffer time**

### Co-operating machines

- Driving empty
- Loading
- Loss
- Driving full
- Unloading

**Loss, machine time = **fell & process** – loading**

**Gain, calendar time = loading + buffer time**
Co-operating machines

- Balance (suitable distance)
Co-operating machines

- Too short distance
Co-operating machines

• Too long distance
Objective

• Analyze the theoretical potentials of the four direct loading machine systems in final felling

• What machine system should be prioritized?
Methodology

• Discrete event simulation of time consumption for harvest of >1000 stands (ca 1.6 million m³)
• Required productive machine time defined by stand characteristics
• Random delay occurrence and duration during work
• Variation in forwarding distance within stands
• Queuing due to random delays and mismatches between the work of interdependent machines
Simulation example – time in different states

[Graph with time on the x-axis and states (Delay, Wait, Unload, Load) on the y-axis, showing different states for Harvester, Forwarder 1, and Forwarder 2 over time.]
Results 1: Time consumption
(Mean of 35 simulation runs)
Cost assumptions:

- Fixed cost harwarder: is +17% than a conv. harvester (*harvester head-grapple, rotatable bunk*)
- Fixed cost ALC harwarder: +20% than a conv. harvester (*harvester head-grapple, rotatable and switchable bunk*)
- Fixed cost autonomous forwarder: +5% than a conv. forwarder (*requires rotatable or switchable bunk, but no cabin*)
- Fixed cost RDL harvester: -20% than a conv. harvester (no cabin).
- Fixed cost RDL forwarder: +17% than a conv. forwarder (requires remote control gear and rotatable bunk).
- Fuel consumption when idling is 21% of the consumption in normal operation (idle when being loaded, delay & waiting)
- Relocation cost per machine
Results 2: Costs

Cost difference (€/m³)
Conclusions

- High potential in technical integration
  - Technical limitations

- Low potential in organizational integration
  - Organizational limitations

Further reading:
Ringdahl, O., Hellström, T. and Lindroos, O. Potentials of possible machine systems for directly loading logs in cut-to-length harvesting. (resubmitted manuscript).


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