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

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Abstract:
In conventional ground based mechanized cut-to-length systems a harvester fells and cuts trees into logs that are stored on the ground until a forwarder picks them up and carries them to landing sites. A proposed improvement is to place logs directly into the load spaces of transporting machines as they are cut. Such integrated loading could result in cost reductions, shorter lead times from stump to landing, cleaner logs and lower fuel consumption. However, it might also create waiting times for the machines involved, whereas multifunctional machines are likely to be expensive. Thus, it is important to analyze whether or not the advantages of any changes outweigh the disadvantages. The conventional system was compared with four potential systems, including two with autonomous forwarders, using discrete event simulation with stochastic elements in which harvests of more than 1000 final felling stands (containing in total 1.6 million m³) were simulated 35 times per system. The results indicate that harwarders have substantial potential, and may become competitive if key innovations are developed. Systems with co-operating machines have considerably less potential, limited to very specific stand conditions. The results conform with expected difficulties in integrating processing and transporting machines' work in variable environments.

Keywords: Integration, harvester, forwarder, harwarder, Beast, simulation

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1 Introduction

In the conventional mechanized cut-to-length (CTL) system a harvester fells and cuts trees into logs that are stored on the ground until a forwarder picks them up and carries them to landing sites. A proposed improvement is to place logs in the load space of the transporting machine as they are cut. Besides possible cost reductions, integrated loading should also result in shorter lead times from stump to landing, in cleaner logs and lower fuel consumption. In this paper four potential systems for future CTL harvesting are considered:

- Harwarder; a manned machine does the work of both harvester and forwarder.

- Autonomous load-changing (ALC) system; a harwarder load logs directly into its bunk. When full, the bunk is switched with the systems' autonomous forwarder, which transports, unloads and returns it.

- Autonomous direct-loading (ADL) system; a harvester cuts and processes trees directly into the bunk of one of the system's two autonomous forwarders that transports and unload automatically.

- Remote-controlled direct-loading (RDL) system In principle, the same as the ADL system outlined above, but with two manned forwarders taking turns to remotely control one unmanned harvester (as in the Besten system (e.g. Bergkvist 2006)).

When referring to methodology in which harvesters load directly into forwarder bunks in ADL and RDL, these two systems will here be called Integrated Forwarder Loading (IFL) (cf. Lindroos (in press)).

Integration of work elements might create waiting and blocking times for the machines involved, whereas multifunctional machines are likely to be expensive. Thus, it is important to analyze whether or not the advantages of considered options outweigh the disadvantages. This can be done by applying theoretical comparisons, in which idealized suggested systems are analyzed to estimate their maximal potential. However, since machine interactions are likely to create queuing, the analysis would benefit from dynamic and stochastic approaches to fully evaluate the potential of different systems. The objective of this study was to evaluate the potential of possible future systems for CTL harvests by: i) building a discrete event simulator to capture the dynamic and random character of interactions between machines used for integrated loading of logs, ii) comparing the economic performance of four potential systems for integrated CTL harvesting and a conventional harvester-forwarder system in final felling.

2 Material and Methods

To fully evaluate the impact of the analyzed work methods, a discrete-event simulator was implemented in Matlab to simulate the time consumptions of the involved machines. Two general assumptions are made concerning the similarity of the five investigated systems. First, the outcomes of all systems' work are assumed to be equal, in terms of both output quality and impact on the stand environment (e.g. rutting). Second, it is assumed that the same type of work is done equally rapidly by all systems. Hence, the potential of integrated loading as a work method is addressed without considering possible differences in specific technical implementations between systems. This is justified by the fact that if technical advances make one system faster than another (e.g. by use of a stronger crane), those advances could also be applied to other systems, unless there are fundamental restrictions (e.g. being enabled due to the lack of operator). The following factors were considered crucial to implement in a dynamic manner to make the simulations realistic and relevant:

1. Random delay occurrence and duration during work, due to e.g. machine breakdowns and operator needs.

2. Variation in forwarding distance within stands, since the distance depends on where in a stand a load is collected, which affects the occurrence of queuing and waiting times.

3. Queuing due to random delays and mismatches between the work of interdependent machines. For instance, a harvester may have to wait for a forwarder to be available before loading or switching of loads can commence in the IFL and ALC systems, respectively.

To avoid the simulator being too complex, other parts were applied in a static and deterministic manner. The simulator was applied to data from more than 1000 Swedish final felling stands (containing in total 1.6 million m^3), and each simulation was repeated 35 times to allow for random delay effects. The computations for time consumptions, costs and fuel consumptions were based on Nurminen et al. (2009); Nurminen et al. (2006) and Lindroos (in press).

3 Results and Discussion

Based on the conducted simulation it can be concluded that harwarders have considerable theoretical potential to compete with the conventional system under most of the tested stand conditions, and quite minor technical innovations appear to be required to realize the system's potential. The other tested systems had, if any, potentials under very specific stand conditions, making them viable only as complements to the conventional system. For the ADL system the situation is the opposite to that of the

harwarder, having low potential due to a combination of limitations in its work organization and the technical challenges associated with autonomizing machines. A prototype RDL system (Besten) is already available, but the system suffers from the limitations in its work organization and high system costs. The ALC system represents a compromise between the harwarder and IFL systems, in terms of being less limited by the work organization but requiring autonomous forwarders to be viable.

This study indicates that future focus should be on developing harwarders when aiming for direct loading of logs in mechanized CTL operations. When the ongoing development towards autonomous forwarders (e.g. Ringdahl et al. (2011)) results in machines available on the market, they should be used either in the conventional system or with a load-changing harwarder, but not with a direct-loading harvester.

As the possible integrated loading systems emerge further, future analysis could focus on mimicking the specific characteristics and limitations of the suggested innovations. Hence, expected potentials when they are introduced could be estimated instead of the theoretical maximal potentials addressed here.

4 References

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