Advantage

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Optimizing extraction distance in commercial thinning

Abstract

Because of the low volumes of wood that are harvested in commercial thinning operations, costs must be decreased to improve the economics of the operation. One approach would be to increase extraction distances, thereby decreasing road construction costs. In the present study, the optimal extraction distance ranged from 100 to 250 m for cable skidders and from 250 to 550 m for shortwood forwarders. The optimal distance increases with increasing road construction costs.

Keywords:

Optimization, Extraction distance, Forwarding distance, Skidding distance, Productivity, Cable skidders, Forwarders, Commercial thinning.

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Introduction

Despite the benefits of commercial thinning in terms of improved growth and quality of the residual stand, its high costs impede wide-scale use of this treatment. Because commercial thinning typically harvests only 40 to 60 m³/ha (i.e., less than one-third of the volume harvested in clearcutting operations), opportunities for using this treatment are often limited to stands accessible via an existing road network. Unfortunately, the benefits of commercial thinning would often be greatest when the treatment occurs early enough to promote sufficient growth, and stands that should be harvested in 20 or 30 years (which should receive priority for thinning) generally lack a suitable road network and are often remote. The cost of building roads to reach these areas can thus become a major expense.

Given these problems, FERIC is evaluating various strategies for developing road networks within the context of commercial thinning. One particularly important aspect involves determining the optimal extraction distance for various equipment within a thinning context. The road layout within the stands to be thinned must thus account for the unique characteristics of thinning operations: low removal intensity and lower skidding or forwarding productivity. The analysis in the present report builds on the approach described by Plamondon and Favreau (1994) for clearcutting.

FERIC observed long-distance extraction in the fall of 1998 in the operations of Produits Forestiers Labrieville inc. 100 km north of Forestville (Que.) and the operations of Scierie Saguenay Ltée north of Chicoutimi (Que.) to provide data for the analysis in the present report. The former operations represented a semi-mechanized full-tree commercial thinning system with manual felling; in the latter, a shortwood forwarder was observed working in a fully mechanized operation. The study's goal was to demonstrate that knowing equipment productivity as a function of extraction distance would let planners estimate the optimal extraction distance for various levels of road construction cost.

Description of the operations

At Forestville, the work team comprised two experienced workers and a Timberjack 240 cable skidder (Figure 1). The workers first cleared the extraction trails, which were spaced 40 m apart, by extracting the felled trees to roadside landings. Thereafter, they selectively felled the desired trees so as to prepare half a skidder load on each side of the trail. Each skidder cycle extracted between 10 and 20 stems over an extraction distance that ranged from 280 to 450 m. The commercial thinning operation took place in a stand composed almost entirely of black spruce, with small fir, jack pine, and aspen components. The terrain was rough, with variable ground firmness ranging from low to good and a relatively moderate slope (10 to 20%, CPPA class 2[4].3.2). The thinning treatment reduced the basal area by 31%, with the harvested stems averaging 12.8 cm in diameter.

For the study north of Chicoutimi, in the Monts Valin region, the terrain was rough, the site had good ground firmness, and the slope ranged from moderate to steep (20 to 38%, CPPA class 2.3.3[4]). The spruce stands in this region provided reduced visibility because of their high density. To permit the use of two shifts per day, the contractor used a two-pass approach in which the operators clearcut the trails during an initial night operation and performed selection felling of trees chosen by the operator in the leave strip during the day. The Valmet 901C single-grip harvester felled stems with an average diameter of 12.8 cm working from a network of trails spaced 20 m apart. The harvester produced 2.54- and 3.76-m logs for extraction by a six-wheel-drive Valmet 646 forwarder (Figure 2).

The assumptions used to calculate the direct hourly costs of the equipment appear in Appendix 1. These costs include only the

Figure 1. *(Below, left)* A Timberjack 240 skidder in commercial thinning.

Figure 2. *(Below, right)* A Valmet 646 shortwood forwarder loading 3.76-m logs.

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operating costs, excluding the costs of supervision, transportation, and camps, as well as profits and other overhead. The wood costs were calculated by dividing the hourly rate by the observed productivity. The total combined cost used to determine the optimal extraction distance was calculated using the equations in Appendix 2.

Results

Table 1 summarizes the productivity of the crew observed at Forestville, with a standardized average extraction distance of 150 m. These results combine the productivities for clearcutting of the extraction trails and selective removal in the leave strips. Harvesting the extraction trails accounted for around 25% of the working time. A detailed analysis reveals that the team encountered normal levels of operational delays and downtime, and that travel over this distance (empty and loaded) accounted for 22.4% of the cycle time. Determination of the optimal extraction distance for the full-tree operation considered both the felling and extraction costs (i.e., the thinning cost) since the activities of the two workers were integrated. For example, the skidder operator sometimes helped with felling and the feller sometimes assisted in choking the stems.

Table 2 summarizes our observations of the Valmet 646 forwarder at Chicoutimi. The observed travel speeds were used to calculate the cycle time for a standardized average extraction distance of 150 m. The extraction productivity was relatively low and the costs were higher than those typically observed for this type of equipment in thinning. The types of products being produced and the terrain conditions did not permit loads of 10 or 12 m³, as would have been possible with two packets in the forwarder's bunk in flat terrain. In addition, considerable travel was required during loading because of the irregular trail network; the wood from many short trails had to be

Table 1. Productivity and cycle time elements for the cable skidder at Forestville

Study duration (PMH)	7.1
Number of cycles observed	20
Standardized average distance (m)	150
Average volume (m^3/stem)	0.099
Average load (m^3/trip)	1.7
Productivity	
stems /PMH	45
m^3/PMH	4.5
Direct hourly cost for the crew ($/PMH)	84.00
Direct thinning cost ($/$m^3$)	18.67
Work cycle time elements (%)	
Travelling empty	11.3
Maneuvering skidder	0.7
Loading and winching	56.3
Travelling loaded	11.1
Unloading	18.7
Operational delays and downtime	1.9
Total	100.0

Table 2. Productivity and cycle time for the Valmet 646 forwarder at Chicoutimi

Study duration (PMH)	4.4
Standardized average distance (m)	150
Average load (m^3/trip)	8.0
Average trip time (min)	60
Productivity (m^3/PMH)	8.0
Direct hourly cost ($/PMH)	75.97
Direct extraction cost ($/$m^3$)	9.50
Work cycle time elements (%)	
Travelling empty	3.0
Loading	51.6
Travelling to load	20.1
Maneuvering	1.7
Travelling loaded	3.8
Unloading	18.2
Operational delays	1.6
Total	100.0

gathered during FERIC's observations. However, a detailed examination of the work cycle time elements revealed that a low proportion of the forwarder's travel time was devoted to travelling loaded and empty.

Optimization of extraction distance in commercial thinning

By using the detailed work cycle data for both operations, it was possible to calculate the relationship between productivity and extraction distance (Appendix 2). For the purposes of this exercice, the thinning, extraction and road construction costs were calculated in $/m³. Table 3 presents road construction costs for a removal intensity of 50 m³/ha.

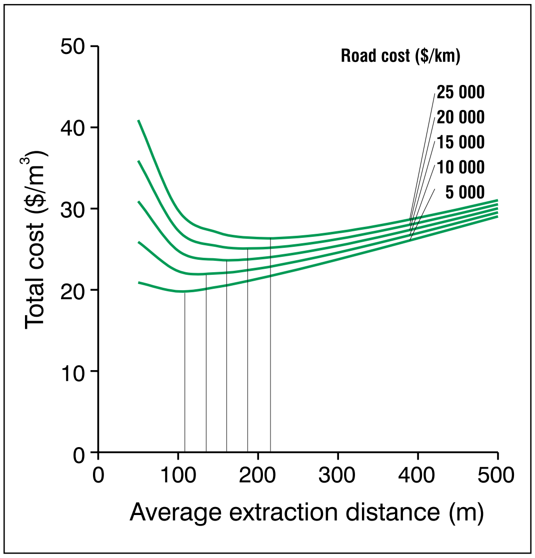


Figure 3. Total costs (thinning plus road) for the cable skidder operation as a function of extraction distance for various road costs. The vertical lines indicate the minimum point on each curve (the optimal average distance).

Semi-mechanized full-tree system

Figure 3 presents the results of our analysis for the cable skidder operation. The curves describe how total cost (thinning plus road construction) changes as a function of average extraction distance for various levels of road construction cost (expressed per kilometre of road). The vertical lines on the graph indicate the minimum value on each curve, and correspond to the optimal distance for each road cost. Each curve has a relatively flat region on either side of the minimum. In this region, the extraction distance can vary without greatly changing the total cost. However, the individual components of this cost (road construction or extraction) nonetheless change in proportion to the distance; it always costs more for longer skidder trips.

When road construction is inexpensive, extraction over short distances clearly provides the lowest cost. In FERIC's study, the optimal average distance for roads with a

Table 3. Road construction costs for a removal intensity of 50 m³/ha

	Road costs ($/m³)				
Road construction cost ($/km)	5 000	10 000	15 000	20 000	25 000
Average extraction distance (m)					
50	5.00	10.00	15.00	20.00	25.00
100	2.50	5.00	7.50	10.00	12.50
150	1.67	3.33	5.00	6.67	8.33
200	1.25	2.50	3.75	5.00	6.25
250	1.00	2.00	3.00	4.00	5.00
300	0.83	1.67	2.50	3.33	4.17
350	0.71	1.43	2.14	2.86	3.57
400	0.63	1.25	1.88	2.50	3.13
450	0.56	1.11	1.67	2.22	2.78
500	0.50	1.00	1.50	2.00	2.50

construction cost of $5000/km was around 100 m, which implies extraction distances ranging from 0 to 200 m. The optimal distance increases as road construction costs increase. However, even with very expensive roads ($25 000/km), the optimal distance does not extend beyond 450 m (i.e., an average of 225 m). These results appear to contradict the expected results, but closer examination of the feller's work cycle provides an explanation: during long-distance extraction, the feller's waiting period increases, and the cost of this lost time contributes to the high thinning cost.

An alternative full-tree system: felling and extraction in two phases

To alleviate the problem of feller waiting times, we simulated a different thinning approach to determine whether it could lower the costs associated with longer skidder travel. This "two phase" method encompasses an initial phase in which the two workers fell and winch groups of trees to the edge of the trail (as described previously) and a second phase in which a second skidder with its own operator extracts this wood to roadside. The feller's waiting time is thus eliminated, thereby reducing the observed increase in thinning costs with increasing extraction distance. The productivity and costs of felling and winching were calculated based on observations of a comparable system being used by Coopérative Laterrière (report in preparation) and using the relevant direct costs in Appendix 1. In this operation, two workers equipped with an inexpensive used skidder felled trees and bunched them at the edge of the trail at a rate of 5.5 m^3/PMH. The work cycle times for the skidder that actually extracted the stems to roadside were estimated using the travel speeds observed at Forestville combined with typical loading and unloading times for extraction of bunched stems in a mechanized full-tree operation.

The curves for this modified system (Figure 4) were calculated by combining the road construction cost and the cost of the two-phase thinning. The first phase, whose cost is unaffected by extraction distance, remains constant and was included in the model for the sake of comparison. The graphs show that the optimal distances for each level of road construction cost increased slightly compared with the results presented in Figure 3. In addition, the total cost at the optimal distance is always lower when extraction to roadside occurs in a separate phase (except when road costs are $5000/km). These results indicate that it's preferable to separate the thinning work into two phases, particularly if the average extraction distance is high. However, this conclusion relies on the results of a simulation, and additional field studies would be required to validate it.

Mechanized cut-to-length system

Figure 5 illustrates the total combined cost (roads plus extraction) for the mechanized cut-to-length system. The curves were created by using the Valmet 646 forwarder's average travel speeds during extraction and an average load volume adjusted to

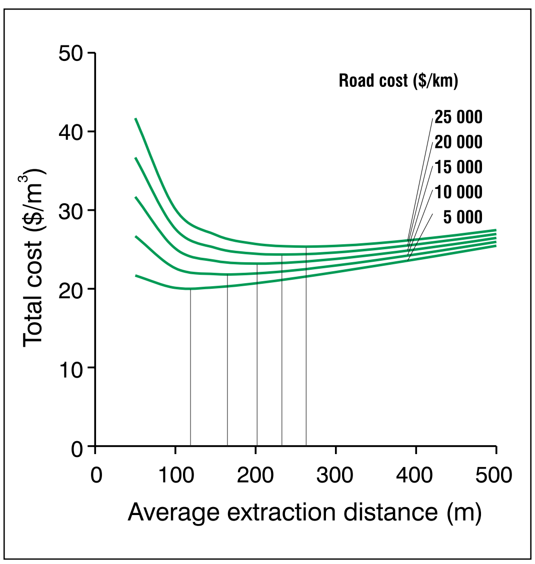
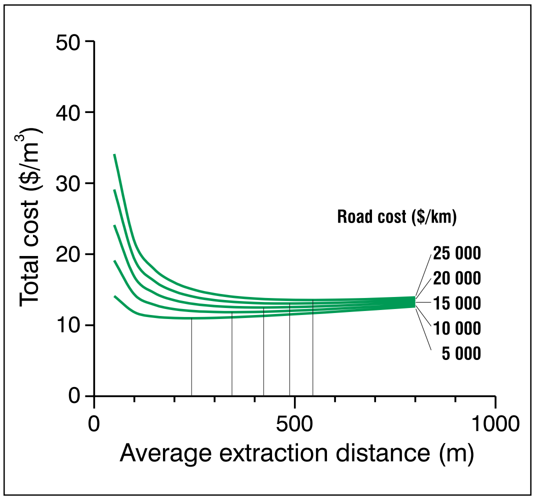


Figure 4. Total cost (thinning plus road) for the system with two cable skidders, working in two phases, as a function of extraction distance. The vertical lines indicate the minimum point on each curve (the optimal average distance).

8 m³ per trip. It's noteworthy that the curves are relatively flat at average extraction distances beyond 200 m. This does not mean that extraction costs are unaffected by distance but rather that decreased road construction costs compensate for the cost increase. A comparison of the shortwood forwarder's performance and that of the skidder shows that increased extraction distances have less effect on costs in the cut-to-length system.

Figure 5. Total road and extraction costs with a shortwood forwarder as a function of extraction distance.



Implementation

To conduct thinning operations in remote areas, where the road network must either be created or restored to usability, managers should:

- Consider that the average distance that minimizes the road and harvesting costs must be analyzed in terms of the specific parameters of the harvesting system being used and the historical costs of road construction for the operating conditions.
- Choose a means of extraction that minimizes changes in total cost as a function of extraction distance; extraction in two phases with the semi-mechanized system is one such example.
- Analyze the skidding or forwarding productivity of the available equipment as a function of the extraction distance to produce curves such as those in Figures 3, 4, and 5. These curves clearly indicate that managers can adjust the layout of the road network where areas to be treated by commercial thinning require the installation of a new network.
- Use variable pay rates for skidding or forwarding as a function of distance to improve the operation's flexibility. Each of the curves is relatively flat around its minimum point, and this indicates that determination of the optimal distance offers considerable maneuvering room. Thus, managers can adapt the road network to suit the terrain. The costs of the extraction operation itself will still depend on the extraction distance.
- Consider using different treatments in an operating area, such as combining commercial thinning operations with clearcutting or precommercial thinning in the same area. This approach also becomes relevant in the context of scattered blocks in clearcutting.
- Analyze the long-term road construction and maintenance costs for a thinning operation in terms of future treatment possibilities. The thinning operation alone cannot generally justify these investments. The road network used for the thinning operations will also serve as the basis of the future road network for the final harvest.

Acknowledgments

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Reference

Plamondon, J.; Favreau, J. 1994. Establishing the optimal skidding or forwarding distance as a function of road cost. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Tech. Note TT-219. 8 p.

APPENDIX 1
Hourly direct costs

	Full-tree			Cut-to-length
	Conventional method	Two phase method		Valmet 646 forwarder
	New skidder + 2 workers	1st phase (used skidder + 2 workers)	2nd phase (new skidder + 1 worker)	
ASSUMPTIONS				
Machine life (years)	10	10	10	5
Scheduled machine hours (SMH)/year	2 000	2 000	2 000	4 000
Purchase price ($)	125 000	95 500	125 000	270 000
Resale value ($)	12 500	9 550	12 500	27 000
Licensing ($/year)	100	100	100	500
Insurance ($/year)	5 000	3 820	5 000	8 100
Interest rate (%)	10	10	10	10
Utilization rate (%)	90	90	90	85
Lifetime repair costs ($)	112 500	85 950	112 500	270 000
Fuel consumption (L/PMH)	15	7,5	15	15
Fuel cost ($/L)	0.50	0.50	0.50	0.50
Oil and lubricants ($/PMH)	1.00	1.00	1.00	1.00
Operator cost ($/SMH)	50.00	50.00	25.00	25.00
FIXED COSTS				
Cost/PMH ($)	13.70	10.48	13.70	22.18
Cost/SMH ($)	12.33	9.43	12.33	18.85
VARIABLE COSTS				
Cost/PMH ($)	14.75	9.53	14.75	24.38
Cost/SMH ($)	13.28	8.57	13.28	20.73
OPERATOR COSTS				
Cost/PMH ($)	55.56	55.56	27.78	29.41
Cost/SMH ($)	50.00	50.00	25.00	25.00
TOTAL COSTS				
Grand total per PMH ($)	84.00	75.56	56.23	75.97
Grand total per SMH ($)	75.60	68.00	50.60	64.58

APPENDIX 2
Variables and equations used

List of variables

C_{tot} = total road construction plus extraction cost ($/m³)
C_{road} = road construction cost ($/m³)
$C_{extraction}$ = average extraction cost ($/m³) = thinning cost
C_{op} = hourly direct cost of the operation ($/PMH, see Appendix 1)
K = cost of road construction ($/km)

V = volume to harvest per hectare (m³/ha)
d = average extraction distance (m)
P = productivity (m³/PMH)

Equations

$$C_{tot} = C_{road} + C_{extraction}$$

$$C_{road} = \frac{10 \times K}{4 \times V \times d}$$

$$C_{extraction} = \frac{C_{op}}{P}$$

Productivity equations

Felling plus extraction: $P = 5.4834\ e^{-0.0013d}$

Extraction (2nd phase): $P = -4.9339 \ln(d) + 35.202$

Shortwood forwarder: $P = 8.4438\ e^{-0.004d}$