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Mechanized processing on steep slopes in winter conditions to produce short logs

Contents

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Abstract

The Forest Engineering Research Institute of Canada (FERIC) studied mechanized processing in cable yarding operations in northern British Columbia. Two danglehead processors were monitored in five cutblocks to determine processing productivity and costs, the amount and cost of loader support required, and the effects of slope and other factors on productivity.

Keywords

Processing, Roadside, Steep slopes, Cable harvesting, Danglehead, Short-wood system, Productivity, Costs, Northern British Columbia.

Introduction

Mechanized processing is the norm for most British Columbia interior operations and is becoming more prevalent in coastal British Columbia (Kosicki and Dyson 2004a). Most mechanized processing takes place on gentle to moderate terrain harvested with ground-based extraction systems. Increasingly, however, companies are trying to find ways to use mechanized processing in steeper areas, often in conjunction with cable yarding. On steep slopes, mechanized processing at the stump is usually not feasible, so processing is performed at roadside after the stems are extracted.

Canadian Forest Products Ltd.'s (Canfor) Mackenzie Operations[1] asked FERIC to study its use of mechanized processing on cable yarding operations. Canfor uses a short-wood harvest system for all of its Mackenzie operations. On steep terrain, a swing yarder, loader, and processor are used in the operation. The yarder usually works independently while the loader usually sorts and piles the processed logs for the processor.

Processing on steep slopes to produce short logs has many challenges not found in more moderate terrain or with a long-wood system. Because the yarder, loader, and processor must often work closely together, conflicts can result. In very steep areas, a loader is required to deck the stems for the yarder, while the processor may require the loader to reposition the stems before processing. As well, the short-wood system generates many logs and sorts with associated sorting and decking challenges. As this combination of equipment is relatively new, little is known about the factors that affect processor productivity and costs when working on steep slopes, or about the amount of loader assistance necessary to support a processor working on steep slopes.

In the winter of 2003/04, FERIC monitored two danglehead processors working in five cutblocks in Canfor's Mackenzie operations. This report presents productivity and cost information, the amount and cost of loader support required, and the effects of slope and other factors on productivity.

Objectives

The objectives of this study were to:

- Determine the overall productivities and costs for processing in winter conditions.

[1] Formerly Slocan Forest Products Ltd.

- Determine the amount and type of assistance that the loader provided to the processor, and calculate the associated costs.
- Determine the effects of slope and other site and stand factors on processor productivity.

Site and stand descriptions

Processing operations were studied in five cutblocks. Blocks 1, 2, 3, and 4 were located approximately 120 km north of Mackenzie, near the Ospika River. Block 5 was located approximately 35 km southwest of Mackenzie, near the south end of Williston Lake. The harvesting prescription in all cases was clearcutting. The first four blocks were classified as the Graham variant of the Engelmann Spruce - Subalpine Fir moist very cold biogeoclimatic subzone (ESSFmv4) (DeLong et al. 1994). The fifth block was classified as the Mossvale variant of the Sub-Boreal Spruce moist cool biogeoclimatic subzone (SBSmk1) (Delong et al. 1993). Elevations ranged from 800 to 1250 m. Table 1 summarizes the site and stand descriptions.

The slopes in the blocks ranged from 0 to 85%. The steepest terrain was in Blocks 1 and 2 (Figure 1) and the gentlest terrain was in Block 4. Forest cover was dominated by mature subalpine fir (*Abies lasiocarpa*), hybrid white spruce (*Picea glauca* x *engelmannii*), and lodgepole pine (*Pinus contorta*), with minor amounts of paper birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides*).

Equipment and system descriptions

Trees were felled and bunched with a feller-buncher on slopes up to 60%. The remaining areas on steeper slopes were handfelled. Bunched and single stems were

Table 1. Site and stand descriptions

	Block				
	1	2	3	4	5
Total area (ha)	150.4	108.1	22.2	29.5	255.2
Cable yarded area (ha)	136.3	101.6	22.2	21.7	8.3
Site characteristics					
Ecological classification	ESSFmv4	ESSFmv4	ESSFmv4	ESSFmv4	SBSmk1
Elevation range (m)	930–1250	940–1240	870–1090	890–980	800–880
Slope					
Range (%)	25–85	25–85	8–71	0–35	5–55
Average (%)	41	45	42	15	18
Stand characteristics					
Species composition (%)					
Subalpine fir	20	32	2	12	17
Spruce	62	49	23	80	41
Lodgepole pine	17	19	71	4	40
Birch, aspen	1	0	4	4	2
Net merchantable volume					
m^3/ha	294	325	377	377	385
m^3/tree	0.65	0.54	0.77	0.51	0.68

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yarded with swing yarders equipped with mechanical slackpulling carriages and radio-controlled chokers. Mobile backspars were used with the swing yarders wherever possible.

All stems were yarded tree length to roadside, then delimbed and cut to length with danglehead processors (Figure 2). The machines processed the stems and sorted them into piles on the road for the loaders to clear away. The heelboom loaders piled the debris (tops and limbs) on the low side of the road to create flat areas where necessary, and then stacked the processed logs on the debris piles (Figure 3). The processors and loaders worked together, and they worked independently of the yarders whenever possible. However, on very steep slopes, the loaders were needed to deck the stems for the yarders and a yarder, loader and processor all worked together. The machines were scheduled to work 12-hour shifts, seven days per week, and were frequently double-shifted during the study period. Specifications for the processors and loaders are presented in Table 2.

During processing, the stems were delimbed, manufactured into short logs, and then sorted by size and species. Generally, pine and spruce were combined into one species group and subalpine fir was placed in a separate sort. Up to 10% subalpine fir could be included in the pine-spruce sorts for the ground-based harvesting, while for cable harvesting the processors were not required to separate the subalpine fir but did so where feasible. Each species group was separated into three colour-coded sorts that were categorized by top diameter (yellow: 10–18 cm, blue: 18–23 cm, and red: 23–36 cm), while the largest logs were placed into a headrig sort (top diameter >36 cm) for a total of seven sorts. The target length was 5.0 m for all logs except for the red sort where it was 6.2 m.

Before settling on this current system for processing stems from steep slopes, Canfor experimented with hauling the stems tree length to a satellite yard for processing into short logs. However, this added approximately $8/m^3 to their logging cost compared to the current system, and proved to be too expensive.[2]

Figure 1. Steep slopes in Block 2.

Figure 2. John Deere 892 ELC/ Waratah HTH624 processor working in Block 4.

Figure 3. Processed logs decked on steep slopes.

Study methods

FERIC observed the processing operation and collected shift-level, detailed-timing, and work sampling data. Shift-level data, consisting of Servis recorder charts and operators' reports about operating time and delays (>10 min/occurrence) were collected for the processing phase over three months in four study blocks (Blocks 1, 2, 3, and 5) for one processor and four operators. Detailed-timing data were

[2] Larry Clark, Operations Superintendent, Canfor, Mackenzie, B.C., personal communication, October 2004.

Table 2. Equipment specifications

Processors			
Carrier	Hyundai 210LC	John Deere 892 ELC	
Engine	Cummins B5.9-C	John Deere 6076A	
Power (kW)	112	164	
Max. boom reach (m)	9.9	11.1	
Lift capacity at 6-m reach (kg)	6 060 [a]	10 422 [b]	
Undercarriage dimensions			
Width (m)	3.40	3.40	
Length (m)	4.44	4.90	
Travel speed (km/h)	up to 5.3	up to 5.5	
Mass (kg)	23 700	30 595	
Processing head	Waratah HTH620	Waratah HTH624	
Maximum delimbing diameter (mm)	560	640	
Maximum diameter saw cut (mm)	620	780	
Mass (kg)	2 210	3 414	
Measuring and control system	LogRite	LogRite	
Loaders			
Carrier	Hitachi EX 220LC	Hyundai 210LC	Hyundai 290LC
Engine	Cummins H07C-TD	Cummins B5.9-C	Cummins QSB5.9-C
Power (kW)	118	112	159
Max. boom reach (m)	10.3	9.9	10.8
Lift capacity at 6-m reach (kg)	6 620 [c]	6 060 [a]	9 550 [d]
Undercarriage dimensions (m)			
Width (m)	2.99	3.40	3.40
Length (m)	4.27	4.44	4.95
Travel speed (km/h)	up to 5.5	up to 5.3	up to 5.2
Mass (kg)	23 800	23 700	33 310
Grapple size (mm)	1 270	1 270	1 524

[a] For an arm length of 2.92 m and a load height of 0 m. [b] For an arm length of 3.20 m and a load height of 0 m. [c] For an arm length of 2.96 m and a load height of 0 m. [d] For an arm length of 3.05 m and a load height of 0 m.

collected on 58 stem decks in the five study blocks for two processors and three operators. Average gross stem volumes were used to calculate gross processing productivity per productive machine hour (PMH) for each stem deck using standard FERIC short-term detailed-timing methods.[3] Net productivity based on processed logs loaded out would be lower. Average processor utilization from the shift-level study was applied to the detailed-timing data to determine the productivity per scheduled machine hour (SMH). Work sampling at 2- and 4-minute intervals was done frequently throughout the study period to determine the loaders' tasks and time spent assisting the processor.

Figure 4. Loader transports logs to decks.

Hourly processor and loader costs were calculated using FERIC's standard costing methods (Appendices I and II) and were applied to the productivity to determine costs per cubic metre. Equipment costs were calculated using a 12-hour shift, with provisions for overtime for time worked over 8 hours. Generic costs were used for the carriers based on the approximate weight classes of the machines used in the study. Although the loaders spent a substantial amount of time travelling back and forth between the processor and the log decks (Figure 4) and therefore undercarriage wear would be higher than in stationary applications, this was not accounted for in the costing.

Correlation analysis and regression analysis (α = .05) were performed on the

[3] More detail on the study methods can be obtained from the author upon request.

detailed-timing data for one operator on one processor to test the effects of ground slope, deck slope, stem size, defects (measured as a percentage of the total number of stems processed that had fork or rot), and branchiness on productivity.

Results

Shift-level study

Shift-level data were collected for 75 shifts totalling 691 hours for the Hyundai 210LC/ Waratah HTH620 processor in four study blocks (Table 3). Shift lengths ranged from 6 to 12 hours and averaged 11.8 hours, with machine availability from 93 to 98%. Machine utilization ranged from 70 to 93% of scheduled time by block and the overall utilization was 78%.

Detailed-timing study

The larger John Deere 892 ELC/Waratah HTH624 processor was 34% more productive in terms of gross m³/PMH than the smaller Hyundai 210LC/Waratah HTH620 processor (51 vs. 38 m³/PMH, respectively) (Table 4). Processing speed for the John Deere/Waratah was 31% faster at

Table 3. Shift-level summary for the Hyundai 210LC/Waratah HTH620 processor

	Block [a]				
	1	2	3	5	Overall
Productive shifts (no.)	10.5	39.5	19	6	75
Productive machine hours (PMH) (h)	99.1	367.8	159.8	64.6	691.3
Mechanical delays (MD) (h) [b,c]	7.6	30.8	14.3	1.7	54.4
Non-mechanical delays (NMD) (h) [b,d]	12.2	39.1	18.3	2.2	71.8
Unknown delays (UD) (h) [b]	5.6	25.4	35.0	1.1	67.1
Total all delays (h) [b]	25.4	95.3	67.6	5.0	193.3
Scheduled machine hours (SMH) (h)	124.5	463.1	227.4	69.6	884.6
Average shift length (h) [e]	11.9	11.7	12.0	11.6	11.8
Utilization (PMH/SMH) (%)	80	79	70	93	78
Availability [(SMH-MD)/SMH] (%)	94	93	94	98	94

[a] The Hyundai 210LC/Waratah HTH620 processor did not work in Block 4. [b] Includes delays ≥10 minutes. [c] Including servicing and fuelling. [d] Examples of non-mechanical delays: waiting for loader, moving, checking log lengths, retrieving lost stems. [e] Scheduled shift length was usually 12 hours with no lunch break (operators would usually eat during their coffee breaks).

Table 4. Detailed-timing summary for the processors

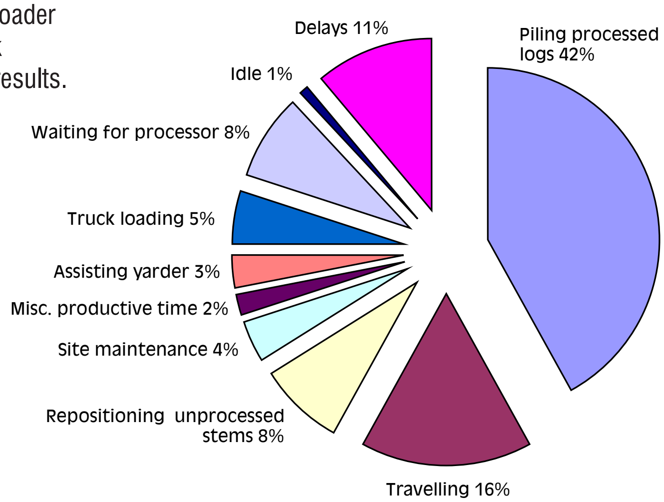
	Hyundai 210LC/ Waratah HTH20 processor Hitachi EX220LC or Hyundai 210LC loader					John Deere 892 ELC/ Waratah HTH624 processor			
						Hyundai 210LC loader	Hyundai 290LCi loader		Both loaders
Block	1	2	3	5	overall	2	3	4	overall
Sample stem decks timed (no.)	3	18	6	12	39	5	1	13	19
Productive time (min)	238	1 445	298	1 196	3 177	373	37	1 196	1 606
Productive machine hours (PMH)	4.0	24.1	5.0	19.9	53.0	6.2	0.6	19.9	26.7
Total stems processed (no.)	170	1301	184	1 000	2 655	297	33	1 595	1 925
Total volume processed (m³)	165	955	226	673	2 019	234	37	1 094	1 365
Total logs produced (no.)	470	3 539	557	2 809	7 375	801	101	4 612	5 514
Average volume (m³/stem)	0.97	0.73	1.23	0.67	0.76	0.79	1.12	0.69	0.71
Average time (min/stem)	1.40	1.11	1.62	1.20	1.20	1.26	1.12	0.75	0.83
Average logs (no./stem)	2.8	2.7	3.0	2.8	2.8	2.7	3.1	2.9	2.9
Productivity									
stems/PMH	43	54	37	50	50	48	55	80	72
m³/PMH[a]	41	40	45	34	38	38	62	55	51

[a] Productivities are based on gross stem volumes with no deductions for stem defects. Actual net productivity based on processed logs loaded out would be lower.

only 0.83 min/stem compared to 1.20 min/stem for the Hyundai/Waratah. The average stem sizes were similar at 0.76 m^3 for the Hyundai/Waratah and 0.71 m^3 for the John Deere/Waratah. The productivity for the Hyundai/Waratah in m^3/PMH was the lowest in Block 5, where the average stem size was the smallest and the processor spent much of the time working with the yarder. Productivity for both processors was highest in Block 3, which had the largest average stem size. Generally, productivity tended to increase as piece size increased. The regular operator of the Hyundai/Waratah considered himself to be average in ability, and he considered the regular operator of the John Deere/Waratah to be above average in ability.

The overall proportion of time spent performing the various elements of the processing cycle was similar for both machines (Table 5). The processors spent between 56 and 90% of the time processing stems. Debris handling, decking, and sorting times were minimal as the loader usually performed these tasks. However, the Hyundai processor spent a substantial amount of time in Block 3 waiting for the loader and the yarder because all three machines worked together on five of the six timing samples. The loader was required to grab the stems from the yarder to prevent them from sliding back down the hill due to steep terrain and icy conditions. The loader that loaded the logging trucks in Block 4 also assisted the processor, because the loader that usually assisted the processor was broken down. The terrain there was quite flat and provided ample room to deck the processed logs. Therefore, the processor did not spend much of its time waiting for the loader.

Figure 5. Loader time, work sampling results.



Work sampling results

The work sampling results for the loaders are shown in Figure 5 and include data for all three loaders. Overall, the loaders spent 72% of their time assisting the processors. These activities consisted of the following:

- piling processed logs
- travelling—moving back and forth between the processor and the log decks

Table 5. Detailed-timing summary of cycle time distribution for the processors

Block	Hyundai 210LC/Waratah HTH620 processor (Hitachi EX220LC or Hyundai 210LC loader) 1	2	3	5	overall	John Deere 892 ELC/Waratah HTH624 processor: Hyundai 210LC loader 2	3	Hyundai 290LC loader 4	Both loaders overall
Distribution of cycle time (%)									
Processing stems	81	75	56	74	74	61	90	80	76
Debris handling	1	4	2	4	4	7	0	3	4
Decking stems	2	5	2	4	4	3	4	4	3
Sorting processed logs	1	5	5	4	4	5	1	5	5
Moving the machine	3	3	7	3	3	5	0	3	3
Waiting for the loader or yarder	0	1	18	5	4	3	0	1	2
Delays ≤10 minutes[a]	12	7	10	6	7	16	5	4	7

[a] Delays >10 minutes were removed from the detailed-timing data.

- repositioning unprocessed stems—breaking the pile apart, straightening and untangling the stems, and pulling the stems up closer to the road
- site maintenance—building up areas to place the processed logs and clearing debris
- other miscellaneous productive time

The loaders spent 8% of their time assisting the yarder or loading trucks, and 9% of their time waiting for the processor and being idle.[4] They spent the remaining 11% of their time in delays.

The amount of decking space available had an influence on loader efficiency. The terrain and the number of log sorts dictated how far the loader had to travel from the processing site to the nearest suitable decking area. Because of the multiple log sorts and the generally steep ground, the loader often had to carry the logs substantial distances to find a decking location (up to 100 m and averaging 25 m).

When the yarded stems were decked farther away from the edge of the road, the loader pulled the stems closer to the road so the processor could reach them. The large processor could reach farther than the small processor and, therefore, required less assistance for this task. However, it was also more productive, so the loader spent more time travelling and piling logs when working with the larger processor. The Hyundai 290LC loader was more powerful and had a larger grapple than the other two loaders. Therefore, it was more efficient when assisting the processor. However, this loader was usually dedicated to loading trucks and was not involved much in the study.

Overall productivity and system costs[5]

Applying the study's overall utilization rate of 78% for the Hyundai/Waratah processor[6] to the detailed-timing results yielded overall productivities of 30 m³/SMH for the Hyundai/Waratah processor and 40 m³/SMH for the John Deere/Waratah processor (Table 6). This resulted in processing costs ranging from \$2.94/m³ to \$4.70/m³. The average cost for the John Deere/Waratah was 10% less than the Hyundai/Waratah, at \$3.52/m³ and \$3.90/m³, respectively. The higher productivity of the John Deere/Waratah offset its higher hourly machine cost. The cost of having a loader working full-time with a processor ranged from \$2.02/m³ to \$3.59/m³. This cost was less when the loader worked with the John Deere/Waratah processor because of this processor's higher productivity. The combined system cost for the processor and loader averaged \$6.30/m³ for the John Deere/Waratah and \$7.13/m³ for the Hyundai/Waratah.

Effects of slope and other factors on processing productivity

The detailed-timing observations for the Hyundai/Waratah processor for one operator (29 stem decks) were analyzed to test the effects of slope and other variables on productivity. When correlation analysis was done on processing time only, processing time was moderately well-correlated with stem size and stem deck slope, and weakly correlated with ground slope. There was no correlation between processing time and branchiness or defects. Regression analysis was then performed to develop a relationship between time and the variables. The only significant variable was stem size ($r^2 = .25$).

Discussion

The processing productivities reported in this study are within the range Kosicki and Dyson (2004a, b) found in a study on Vancouver Island for producing long logs from grapple-yarded decks using a Waratah

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4 During the study, the loaders worked with the yarders on only 12 decks and performed truck loading duties on only 8 decks. For the rest of the time, they were dedicated to the processors.

5 Productivities and costs are based on gross stem volumes with no deductions for stem defects. Actual net productivity based on processed logs loaded out would be lower and costs would be higher.

6 Shift-level data was not available for the John Deere 892 ELC/Waratah HTH624 processor

Table 6. Costs and productivity[a]

	Hyundai 210LC/Waratah HTH620 processor (Hitachi EX220LC or Hyundai 210LC loader)					John Deere 892 ELC/Waratah HTH624 processor			
						Hyundai 210LC loader		Hyundai 290LC loader	Both loaders
Block	1	2	3	5	overall	2	3	4	overall
Productivity (m^3/PMH) [b]	41	40	45	34	38	38	62	55	51
Utilization (%) [c]	78	78	78	78	78	78	78	78	78
Productivity (m^3/SMH)	32	31	35	27	30	30	48	43	40
Hourly machine cost ($/SMH) [d]									
Processor	116.93	116.93	116.93	116.93	116.93	140.99	140.99	140.99	140.99
Loader	96.89	96.89	96.89	96.89	96.89	96.89	96.89	116.20	11.27 [e]
Cost ($/m)									
Processor	3.65	3.77	3.34	4.33	3.90	4.70	2.94	3.28	3.52
Loader assisting	3.03	3.13	2.77	3.59	3.23	3.23	2.02	2.70	2.78
Total	6.68	6.90	6.11	7.92	7.13	7.93	4.96	5.98	6.30

[a] Productivities and costs are based on gross stem volumes with no deductions for stem defects. Actual net productivity based on processed logs loaded out would be lower and costs would be higher. [b] From Table 4. [c] Overall average from shift-level study (Table 3). [d] From Appendix II. [e] Prorated by productive machine hours.

HTH624 processing head mounted on a Madill 3800 carrier. Their study showed productivities of 56 and 38 m^3/PMH for average stem sizes of 1.01 and 0.44 m^3, respectively. The slopes for the blocks in their study ranged from 5 to 80%.

While one of the objectives of this study was to look for a relationship between slope and processor productivity, it became evident that the following factors had a much greater effect on productivity than slope:

- processor size—the larger processor was more productive than the smaller one
- equipment combination—the processors were the most productive when working with just the loader, less productive when working with the loader and the yarder, and least productive when working alone[7]
- stem size—of the variables tested (ground slope, deck slope, stem size, defects, and branchiness), only stem size had a significant effect on processing productivity

Although the natural ground slope at the site occasionally affected processing, the effect was not consistent. On the steepest ground slopes, the stems would be piled either on a landing, in the ditch on the uphill side of the road, or on debris on the downhill side of the road. This meant that the deck slope was a better predictor of productivity. However, the influence of deck slope on productivity could not be isolated because further analysis showed that deck slope was closely correlated with stem size which obscured its influence.

The effect of deck height on processor productivity was not quantified, but FERIC observed that one operator preferred decks to be no higher than the bottom of the machine's cab. Where feasible, the John Deere/Waratah operator would pull stems from the high decks to make a lower pile before he began processing. This seemed to be time well spent as the operator could then process the stems very quickly. Another operator said that he preferred the deck to be no higher than eye level from his position in the machine's cab. If it was higher than the cab, he had to stoop to see the stems. Stems piled on the low side of the road and below the road surface level

[7] Most of the timing samples were conducted when the processor and loader were working together. There were two samples when the processors were working alone because the loader was broken or working with the yarder. In these cases the loader returned later to help deck the processed logs. The average stem size varied in the different machine combinations working together.

were also difficult to see, especially at night, because the machine's lights didn't shine on these stems. The operator had to move the machine to the edge of the slope and sometimes off the road to illuminate these stems. Yarding distance and volume per hectare influence deck height, so the block layout can impact deck height.

The position of the stem deck also affected processing efficiency. The processor needed the loader to clear the logs more frequently when the decks were parallel rather than perpendicular to the road, because the processor needed room to turn these logs during processing. This was more common on steep ground, where the stems were yarded from below the road and decked in the ditch on the high side.

The short-wood system for this study used seven sorts, so finding adequate decking space for all the sorts was difficult on steep terrain. The number of sorts was consistent throughout the study, so it could not be determined whether the number of sorts affected productivity. Another FERIC study[8] has shown that the number of sorts affect processing productivity on steep slopes.

This study occurred in the winter when many of the limbs were removed during yarding. In icy conditions, the stems became very slippery and sometimes slid off the decks, resulting in time lost to retrieve these logs. Productivity may be different during summer conditions

Summary and conclusions

The results of this study show that mechanized processing at roadside can be productive and cost effective when cable harvesting on steep slopes. The larger John Deere/Waratah processor with an above average operator was 34% more productive than the smaller Hyundai/Waratah processor with an average operator. The average cost of processing was $3.52/m³ (gross) for the John Deere/Waratah and $3.90/m³ (gross) for the Hyundai/Waratah. Operations were most productive when the processor and loader were able to work independent of the yarder.

Loaders spent 72% of their time assisting the processors. Most of this time involved piling processed logs and moving back and forth between the processor and the log decks. The combined system cost for a processor and a loader averaged $6.30/m³ for the John Deere/Waratah and $7.13/m³ for the Hyundai/Waratah .

The influence of site and stand conditions on productivity was analyzed. However, a relationship could not be detected for most of the variables tested. Stem deck slope and stem size had the highest correlation with processing time, but stem size was the only variable that had a statistically significant effect.

FERIC is currently studying processors working with cable yarders in summer conditions, and will publish the results in an upcoming report.

Future studies could assess whether decking space and height affect productivity.

Implementation

The following recommendations should improve the efficiency and productivity of processing operations on steep cable-harvested slopes:

- Wherever possible, the processor and loader should work independent of the yarder. Lay out and harvest blocks to minimize situations where a loader is required to assist the yarder with landing the logs. In very steep terrain, yard the stems to a landing instead of to roadside to prevent the decked stems from sliding back down the hill.
- Deck the stems as close to the road edge as possible when yarding so they are within easy reach for the processor. This will reduce the need for a loader to pull the decked stems closer to the road. Also, deck the stems as straight as possible so

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[8] Peter Dyson, Researcher, FERIC, personal communication, October 2004.

the processor or loader does not have to straighten or untangle the logs before processing.

- Yard the stems to areas where there is sufficient decking room nearby for the processed logs. If it is steep on the low side of the road, try to yard to areas with gentle slopes on the high side of the road where the processed logs can be decked.
- Wherever it is possible to do so without compromising yarding chance, locate the haul roads to provide an abundance of adjacent flat areas for decking the processed logs. This will reduce the time required for the loader to travel to the decking areas with the processed logs.
- When the yarder, loader, and processor are working together, more supervision will reduce conflicts and improve efficiency.
- When the loader must work with the yarder, consider if it is more efficient for the processor to process alone in another location and move and sort its own logs, with the loader leaving the yarder periodically to service the processor. Organize the activities to keep the phases separate.
- Reduce loader travel time by estimating which sorts will be the most common in a stem deck and then locate the most common sorts closest to the processor.
- When the yarder is working in an area that has adequate space for it to land its own logs without assistance from a loader, the loader should work elsewhere with the processor, and return periodically to the yarder to clear the logs as necessary.

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Appendix I

Machine costs [a]

	Carrier [b] (20–25 tonne class)	Carrier [b] (30–35 tonne class)	Harvesting head [c] (508-mm capacity)	Harvesting head [d] (610-mm capacity)	Log loading grapple [e] (up to 1 524-mm capacity)
OWNERSHIP COSTS					
Total purchase price (P) $	305 000	410 000	185 000	225 000	22 000
Expected life (Y) y	5	5	5	5	5
Expected life (H) h	15 000	15 000	15 000	15 000	15 000
Scheduled hours/year (h)=(H/Y) h	3 000	3 000	3 000	3000	3 000
Salvage value as % of P (s) %	25	25	25	25	25
Interest rate (Int) %	6.0	6.0	6.0	6.0	6.0
Insurance rate (Ins) %	3.0	3.0	3.0	3.0	3.0
Salvage value (S)=((P•s/100) $	76 250	102 500	46 250	56 250	5 500
Average investment (AVI)=((P+S)/2) $	190 625	256 250	115 625	140 625	13 750
Loss in resale value ((P-S)/H) $/h	15.25	20.50	9.25	11.25	1.10
Interest ((Int•AVI)/h) $/h	3.81	5.13	2.31	2.81	0.28
Insurance ((Ins•AVI)/h) $/h	1.91	2.56	1.16	1.41	0.14
Total ownership costs (OW) $/h	20.97	28.19	12.72	15.47	1.51
OPERATING COSTS					
Fuel consumption (F) L/h	20.0	30.0	0.0	0.0	0.0
Fuel (fc) [f] $/L	0.55	0.55	0.00	0.00	0.00
Lube & oil as % of fuel (fp) %	10	10	0	0	0
Tire replacement (tc) $					
Track & undercarriage replacement (Tc) $	16 000	20 000	0	0	0
Track & undercarriage life (Th) h	5 400	5 400	0	0	0
Annual repair & maintenance (Rp) $	49 000	66 000	30 000	36 000	3 500
Shift length (sl) h	12.0	12.0	0.0	0.0	0.0
Wages [g] $/h					
Operator	25.99	25.99	0.00	0.00	0.00
Total wages (W) $/h	25.99	25.99	0.00	0.00	0.00
Wage benefit loading (WBL) %	38	38	38	38	38
Fuel (F•fc) $/h	11.00	16.50	0.00	0.00	0.00
Lube & oil ((fp/100)•(F•fc)) $/h	1.10	1.65	0.00	0.00	0.00
Track & undercarriage (Tc/H) $/h	1.48	1.85	0.00	0.00	0.00
Repair & maintenance (Rp/h) $/h	16.33	22.00	10.00	12.00	1.17
Wages & benefits (W•(1+WBL/100)) $/h	35.87	35.87	0.00	0.00	0.00
Prorated overtime ((((1.5•W-W)•(11-8)•(1+WBL/100))/sl)+ (((2.0•W-W)•(sl-11)•(1+WBL/100))/sl)) ($/h) [h]	7.46	7.46	0.00	0.00	0.00
Total operating costs (OP) $/h	73.24	85.33	10.00	12.00	1.17
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h	94.21	113.52	22.72	27.47	2.68

[a] These costs are estimated using FERIC's standard costing methodology for determining machine ownership and operating costs for new machines. The costs shown here do not include supervision, travel time, profit, or overhead and are not the actual costs for the contractor. [b] Costs for carriers were calculated using generic machines for each class size. [c] Based on quote from Waratah Distribution for an HTH622B harvesting head. The HTH620 harvesting head is no longer manufactured. [d] Based on a quote from Waratah Distribution for an HTH624 Super harvesting head. [e] Based on quote from IMAC Attachments. [f] Diesel fuel unit price as per a quote from The National Industrial Transport Log for June 2004. [g] Wage rates are as per 2004 rates outlined in the IWA Southern Interior Master Agreement. [h] Prorated overtime rates are as per 2004 rates in the IWA Southern Interior Master Agreement and reflect time and one half for all shift hours in excess of 8.0 hours but not exceeding 11.0 hours. Double time was allotted for all shift hours worked in excess of 11.0 hours.

Appendix II

Equipment carrier and implement combinations and costs

Equipment	Carrier ($/h)	Implement ($/h)	Total ($/h)
Hyundai 210LC carrier with Waratah HTH620 processing head [a]	94.21	22.72	116.93
John Deere 892 ELC carrier with Waratah HTH624 processing head [b]	113.52	27.47	140.99
Hyundai 210LC carrier with 1 270-mm grapple [c]	94.21	2.68	96.89
Hitachi EX220LC loader with 1 270-mm grapple [c]	94.21	2.68	96.89
Hyundai 290LC loader with 1 524-mm grapple [d]	113.52	2.68	116.20

[a] Costs are based on a 20–25 tonne class generic carrier and a 508-mm capacity generic harvesting head.
[b] Costs are based on a 30–35 tonne class generic carrier and a 610-mm capacity generic harvesting head.
[c] Costs are based on a 20–25 class tonne generic carrier with a generic log loading grapple.
[d] Costs are based on a 30–35 tonne class generic carrier with a generic log loading grapple.