Advantage
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Contents



# Grapple yarding under three alternative shift regimes: a case study

**Abstract**

The Forest Engineering Research Institute of Canada (FERIC) conducted a study of grapple yarding under three shift regimes at Canadian Forest Products Ltd.'s Englewood Logging Division on north-central Vancouver Island: single shift, double shift, and four-and-four shift. Six yarders were studied for one calendar year. This report discusses important factors to consider before implementing an alternative shift schedule, and includes productivity and cost results for the three shift regimes.

**Keywords**

Grapple yarding, Shift work, Alternative shift regimes, Single shift, Double shift, Four-and-four shift, Productivity, Costs, Coastal British Columbia.

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## Introduction

Grapple yarding is used to harvest about 50% of the annual volume in coastal British Columbia.[1] Although modern swing yarders equipped with grapples are very productive, they have a high capital cost, and ownership cost is a large component of the total per-cubic-metre cost. Some companies are examining alternatives to the standard 8-hour single shift to increase the hours a yarder works annually, and thus reduce machine ownership costs. However, there is little information available about the effects of alternative shift regimes on yarding productivity, operating costs, and other elements of an operation.

The decision to change to an alternative regime is a complex one with many factors besides yarding productivity and costs requiring consideration. Support services, other logging phases, and crew satisfaction may all be affected by changing the shift regime. This study examines Canadian Forest Products Ltd.'s (Canfor) Englewood Logging Division's experiences with alternative shift regimes and provides information about productivity, costs, and other important factors to consider before implementation.

## Background

The development of grapple yarding resulted in the partial mechanization of cable logging by eliminating the chokersetter. Mechanization was further enhanced with the introduction of mobile backspars to provide greater lift at the back of a setting and very quick road changes. This mechanization, combined with the use of powerful lighting systems, permitted night logging and double shifting of equipment.

The Englewood division began experimenting with alternative regimes many years ago, recognizing that if the yarders could operate more hours per week, machine ownership costs would be reduced and thus make expensive new machines more affordable.

[1] This estimate was derived from information on area harvested in the Vancouver region in 2002, and personal communication with Chuck Rowan, Harvesting Systems Specialist, B.C. Ministry of Forests, January 28, 2003.

Besides reducing ownership costs, alternative shift regimes would also allow Canfor to take advantage of short-term market opportunities by increasing production during these periods. After successful night logging trials, Canfor had operated some of its yarders on a double shift regime for more than twenty years at the time of this study.

Today, compared to twenty years ago, less timber is available on terrain suitable for grapple yarding with mobile backspars. However, the desire remains to continue extending shifts beyond the single shift regime. Therefore, Canfor has experimented with a four-and-four shift regime (one 10-hour shift per day, operating on a four-day rotation with two crews) as a possible replacement for, or supplement to, double or single shift regimes.

At the time of the study, Canfor used the three regimes and had focussed each in the most appropriate location to provide the best overall productivity and costs for the Englewood division. Single shifting was the default regime for all yarders but the alternative regimes were used when an advantage could be realized.

Canfor recognized that the alternative regimes could result in lower productivity compared to single shift operations if not managed carefully. The operating environment included a growing shortage of terrain suitable for yarding with mobile backspars and workers hesitant to adopt new schedules. To provide the best chance of success for the introduction of the four-and-four regime and the continued operation of the double shift regime, Canfor provided certain advantages to the alternative shifts. Advantages included assignment to the gentler terrain where mobile backspars could be used and a guarantee that the four-and-four shift crews' earnings would not decrease compared to those working single shift. The double shift regime was also managed to minimize the amount of time the evening shift spent working in the dark by operating mainly in the summer when daylight duration was longer.

At Canfor's request, FERIC studied Englewood's grapple yarding operations for one calendar year to examine the effects of these shift regimes. Given the advantages provided to the alternative regimes, a result of equal or very similar productivity compared to the single shift would indicate that if all regimes operated in similar terrain conditions, the single shift could be expected to outproduce the other regimes.

## Objectives

The purpose of this study was to determine the benefits and drawbacks of three shifting regimes. The specific objectives were to:

- Determine grapple yarding productivities for single, double, and four-and-four shift regimes.
- Estimate ownership and operating costs of swing yarders used for grapple yarding for each of the three shift regimes.
- Using the productivities and costs developed above, estimate yarding cost per cubic metre ($m^3$) for each shift regime.
- Determine if the differences in productivities and costs for the three regimes are significant considering the differences in operating conditions.
- Identify and discuss key factors other than yarding productivity and costs that influence the feasibility and efficiency of each shift regime.
- Describe Canfor's experiences operating these regimes, including unquantifiable factors affecting a company's choice of shift regime.

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## Description of operation and yarders

The Englewood division, located on north-central Vancouver Island, harvested approximately 600 000 m³ from the company's operations in the year studied. Grapple yarding with swing yarders was the principal harvest method, accounting for 43% of the volume. Loader forwarding (28%), highlead (11%), helicopter (10%), super snorkel (5%), and long-distance skyline (3%) accounted for the remainder. In recent years, the division has operated a fleet of up to six swing yarders on three different shift regimes.

Operations during the study period were conducted in a wide range of stand and terrain types for all regimes. Yarding was performed in both old-growth and second-growth stands with net volumes ranging from 600 to 1200 m³/ha and averaging 800 m³/ha.[2] Tree diameters at breast height ranged from 28 to 59 cm and averaged 47 cm. The average tree height was 39 m. Ground slopes ranged from 10 to 80% and averaged 41%. External yarding distances ranged from 75 to 250 m and averaged 136 m.

Study sites were representative of the variety of conditions present locally. The long study period and large sample size served to reduce the effects of variation in conditions on average productivity by regime. Canfor did, however, favour the alternative shift regimes by applying them in areas where mobile backspars could be used, whenever possible. Mobile backspars were used the most on double shift and the least on single shift.

The division operated up to six swing yarders for grapple yarding on the three shift regimes. The shift regimes were organized as follows:

- The **single shift regime** had one crew per yarder and worked 8 hours per day, 5 days per week, for a total of 40 hours per week. The crew usually worked from 7 a.m. to 3 p.m.
- The **double shift regime** had two crews per yarder. Each crew worked 8 hours per day, 5 days per week, for a total of 80 hours per week. The day-shift crew usually worked from 7 a.m. to 3 p.m. and the evening-shift crew usually worked from 3 p.m. to 11 p.m. Crews alternated weekly between day and evening shifts.
- The **four-and-four shift regime** had two crews per yarder. Each crew worked 10 hours per day for four consecutive days, followed by four days off. Yarders working this regime operated seven days per week for a total of 70 hours per week. The crews usually worked from 7 a.m. to 5 p.m.

The alternative regimes did not operate over the whole year but were used intermittently, mostly in the summer. The six swing yarders studied were two Cypress 7280B yarders, two Cypress 7280C yarders, a Madill 124 yarder, and a Cypress 6280 yarder. These machines ranged in age from new to 15 years old (Table 1). Lighting systems were mounted on the four Cypress 7280 yarders to permit night logging (Figures 1 and 2).[3]

[2] Based on cruise data and logging plan maps for a sample of 23 of the 42 study blocks.

[3] Each lighting system used a 15-kW generator mounted on the deck of the yarder house to power a light set. The light sets consisted of nine 1 000-W lights at the top of the boom; one 1 000-W light at one-third boom height and two 500-W lights on the sides of the yarder to light the landing area; and two 1 000-W lights mounted on the back of the gantry to light the guyline area.

**Table 1. Description of yarders**

| Yarder (no.) | Make & model | Year of manufacture | Age at beginning of of study (yr) | Equipped with lights (yes/no) |
|---|---|---|---|---|
| 1 | Cypress 7280B | 1984 | 15.0 | yes |
| 2 | Cypress 7280B | 1986 | 13.1 | yes |
| 3 | Cypress 7280C | 1988 | 11.3 | yes |
| 4 | Cypress 7280C | 1988 | 11.0 | yes |
| 5 | Cypress 6280 | 1990 | 9.0 | no |
| 6 | Madill 124 | 1999 | new | no |

Figure 1. Cypress 7280 yarder with lights.

Figure 2. Light plant mounted on the deck of the yarder house.

The Madill 124 and Cypress 6280 yarders were not equipped with lights and were not used for night logging. Mobile backspars were also equipped with lights when used for night logging.

During the study period, mechanized falling, mechanized processing, and road building operations at the Englewood division also operated on a four-and-four shift regime but all other harvesting phases in the division operated on a standard single-shift five-day week.

## Study methods

Canfor provided monthly production summaries and daily timecard records for each yarder for the period of January 1 to December 31. The monthly summaries contained the number of scheduled shifts, total hours worked, volume of wood hauled and scaled, and estimated volume of wood remaining in roadside decks at month-end (cold-decked volume). The timecard records included the operating time, mechanical downtime, non-mechanical downtime (idle and other non-productive time), and piece counts recorded by the operator. In Canfor's record-keeping system, shifts were recorded as either day, evening, or four-and-four. For each day on double shift, the yarder was credited with two shifts worked—one day shift and one evening shift. The number of operating days for the single and double shift regimes were determined by matching up dates of day and evening shifts to identify when the double shift regime was used. Day shifts with no corresponding evening shift were considered to be single shifts. This time information was used to calculate productivities, in cubic metres and number of logs, per scheduled machine hour (SMH) and productive machine hour (PMH). Analysis of variance ($\propto = 0.05$) was applied to the data to test for significant differences.

FERIC supplemented Canfor's production records by interviewing logging crews, and by having yarder operators complete daily forms for each scheduled shift from late July to early December. This information was used to obtain a clearer view of practices related to the different shift regimes. It also provided information on daily time distribution, piece and turn counts, number of yarding road changes, crew breaks, other delays longer than 15 minutes, and hours of use of the lighting systems. During the four-month period, FERIC visited the division twice each month to collect the forms, observe yarding operations, and discuss progress with the logging crews.

The cost analysis used a Cypress 7280 yarder as the base machine to compare three scenarios, one for each shift regime. For each scenario, the yarder was assumed to work under only one shift regime for its entire life. Canfor provided machine records and costs for these analyses, including the make, model, year of manufacture, original purchase price, fuel consumed, fuel cost, wire rope cost, and repair and maintenance cost records for each yarder. Labour rates were based on the current

IWA-Canada contract where applicable. Hourly yarder ownership and operating costs were calculated according to FERIC's standard costing methods (Appendix I) and adjusted using Canfor's cost records. These operating costs could not be separated by shift regime and therefore were applied equally to the three scenarios. Fuel usage for each yarder was calculated from Canfor's records (Appendix II). The average fuel usage for the Cypress 7280 yarders was also applied equally to the three scenarios. Light usage from FERIC's daily report forms was combined with Canfor's cost records to determine lighting system operating costs. Assumptions used to determine hourly yarder ownership and operating costs for each shift regime are summarized in Appendix III. The estimated hourly cost for the Cypress 7280 yarders for each shift regime was then applied to the average productivity for that shift regime to determine unit costs. Sensitivity analyses were performed to examine the effects of changes in productivity rate and operating hours per year on unit costs.

Extensive discussions were conducted with the logging supervisors and the shop foreman to gain knowledge about important aspects of operating alternative shift regimes that could not be determined by analyzing the productivity and cost data. These discussions, combined with FERIC's on-site observations, served to identify other key factors that influenced the feasibility and efficiency of each regime. The unquantifiable factors were weighed with the productivity and cost results, and discussed as part of the input into a company decision whether to convert operations to another shift regime.

## Results

### Shifts worked by regime

Overall, the six yarders were scheduled to work a total of 1 428 shifts during the year. Of this total, 172 shifts were non-operating due to weather and miscellaneous causes, and 1 256 shifts were operating shifts. A shift was considered to be an operating shift if the yarder operated for a minimum of 0.5 hours during the scheduled time. The six yarders logged 42 cutblocks and produced 270 405 $m^3$ and 187 394 pieces during the 1 256 operating shifts.

The 1 256 operating shifts represented 620 days for the single shift regime (i.e., 620 day shifts), 108 days for the double shift regime (i.e., 101 day shifts and 115 evening shifts, or 216 total shifts—there were 14 evening shifts without corresponding day shifts recorded), and 420 days for the four-and-four shift regime. Figure 3 shows the distribution of operating days by shift regime for each yarder. The six yarders operated from 52 to 241 calendar days per year (419 to 2449 h/yr). The four Cypress 7280 yarders were all equipped with lights and worked under all three shift regimes. The Madill 124 yarder, which was not equipped with lights, worked both single and four-and-four shifts. The Cypress 6280 yarder, also not equipped with lights, was acquired by the division in October of the year studied and only worked the single shift regime.

Figure 4 shows the distribution of operating days by shift regime for each quarter. The single shift regime was used from early January to mid-December on 1–4 yarders. Most of the yarders worked single shifts in the first and fourth quarters when daylight

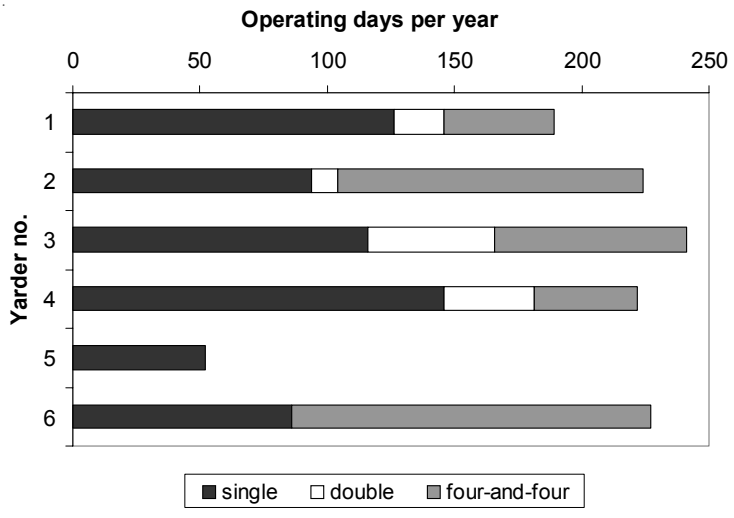


Figure 3. Distribution of operating days by shift regime and by yarder.

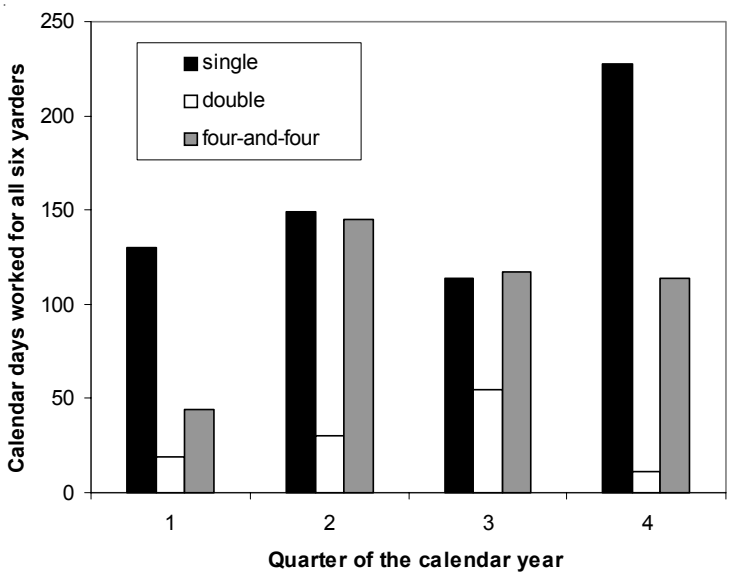


Figure 4. Distribution of operating days by shift regime and by quarter.

duration was shortest. In the spring and summer, however, several yarders switched to the double shift or four-and-four shift regimes. The spike in single shifts in the fourth quarter was due mostly to the acquisition of the Cypress 6280 yarder in October. The double shift regime was used intermittently throughout the year, mostly from June to September to take advantage of long daylight duration, but also at other times of the year to take advantage of favourable market and stumpage fluctuations. During the summer, when most of the double shifting occurred, it remained light until late in the evening so only a small part of the evening shift was dark enough to require the use of lights. The equivalent of at least one yarder operated on the four-and-four regime from mid-February through April, and the equivalent of two yarders worked this regime from May until November.

Only 10% of the scheduled double shift operating days were in the winter while 41% were in the summer to take advantage of the longer days. Better weather in the spring, summer, and fall also improved visibility when operating at night compared to winter logging. The four-and-four regime was also given seasonal favourability with only 8% of its scheduled shifts in the winter, compared to 18% for the single shift regime.

## Machine availability and utilization

Table 2 presents the distributions of scheduled yarder time for the single, double,

**Table 2. Distribution of scheduled machine hours by shift regime**

| | Single | | Double | | Four-and-four | | Total | |
|---|---|---|---|---|---|---|---|---|
| | (SMH) | (%) | (SMH) | (%) | (SMH) | (%) | (SMH) | (%) |
| Productive time (SMH) | 4 256 | 85 | 1 416 | 82 | 3 447 | 85 | 9 119 | 84 |
| Non-productive time | | | | | | | | |
| Mechanical (SMH) | 333 | 7 | 138 | 8 | 171 | 4 | 642 | 6 |
| Non-mechanical (SMH) | 438 | 9 | 168 | 10 | 453 | 11 | 1 059 | 10 |
| Sub total non-productive time (SMH) | 771 | 15 [a] | 306 | 18 | 624 | 15 | 1 701 | 16 |
| Total time (SMH) | 5 027 | | 1 722 | | 4 071 | | 10 820 | |
| Total shifts (no.) | 620 | | 216 | | 420 | | 1 256 | |
| Average shift length (h) | 8.1 | | 8.0 | | 9.7 | | 8.6 | |
| Availability (%) | 93 | | 92 | | 96 | | 94 | |
| Utilization (%) | 85 | | 82 | | 85 | | 84 | |

[a] Totals do not add exactly due to rounding.

and four-and-four shift regimes. Average shift lengths were 8.1 h for the single shift regime, 16.0 h for the double shift regime (8.0 h for each of two shifts), and 9.7 h for the four-and-four shift regime. Yarders experienced their highest mechanical downtime rates when working on the second (i.e., evening) shift of the double shift regime. Overall, machine availability was 96% for the four-and-four shift regime, 93% for the single shift regime, and 92% for the double shift regime (91% on the second shift). Non-productive operating time (mostly moving and rigging) was similar for all shift regimes, between 9 and 11%. Machine utilization was 85% on the single and four-and-four shift regimes and 82% for the double shift regime (80% on the second shift).

Proactive management by Canfor improved machine availability on the alternative shift regimes. Road changes and machine moves were done on the day shift portion of the double shift whenever possible. On evenings and weekends when a machine on an alternative regime broke down, its crew had the flexibility to switch to a machine operating on the single shift regime. Because machine availability was determined from crew timecards and not shop records, when crews switched yarders, no mechanical downtime was recorded. While this practice increased production, it distorted machine availability on these regimes. Machines working the four-and-four shift regime also received special treatment with a higher level of mechanical support during the week compared to machines on other regimes. This practice was instituted to ensure that the yarders could work on the weekend when little mechanical support was available. The extensive use of the new Madill yarder on the four-and-four shift regime also contributed to higher machine availability. This one yarder worked 34% of the total four-and-four shifts (Figure 3). When only the Cypress 7280 yarders were considered, the machine utilization dropped to 83% for the four-and-four regime. These circumstances underestimated mechanical downtime compared to what might be expected on an operation where all machines worked the same alternative shift regime.

## Yarding productivity

Table 3 compares average yarding productivities by shift regime, for all yarders. Overall, the day shift out-produced the evening shift in the double shift regime. Productivities for the three shift regimes were similar, and none of the observed differences were significant. The single shift and double shift regimes averaged 24.3 m³/SMH and the four-and-four shift regime averaged 26.1 m³/SMH. When only the four Cypress 7280 yarders are considered (Table 4), average yarding productivities by shift regime are essentially the same as with all yarders included.[4] Productivities were 25.9 m³/SMH

[4] This comparison restricts the productivity analysis to a group of similar yarders, all of which operated under all three shift regimes, and removes the potential productivity differences that are related to the make and model of yarder (in particular, the Madill 124 yarder).

**Table 3. Summary of productivity results, all yarders**

| | Operating time (shifts) | Scheduled machine time (h) | Productivity | | | |
|---|---|---|---|---|---|---|
| | | | m³/PMH | m³/SMH | pieces/PMH | pieces/SMH |
| Single shift regime | 620 | 5 026 | 28.7 | 24.3 | 20.6 | 17.4 |
| Double shift regime | | | | | | |
| day shift | 101 | 804 | 30.6 | 25.9 | 19.6 | 16.5 |
| evening shift | 115 | 919 | 28.3 | 22.7 | 18.2 | 14.6 |
| average | - | - | 29.5 | 24.3 | 18.9 | 15.6 |
| Four-and-four shift regime | 420 | 4 072 | 30.9 | 26.1 | 21.2 | 18.0 |

**Table 4. Productivity results, Cypress 7280 yarders**

| | Operating time (shifts) | Scheduled machine time (h) | Productivity | | | |
|---|---|---|---|---|---|---|
| | | | m³/PMH | m³/SMH | pieces/PMH | pieces/SMH |
| Single shift regime | 482 | 3 910 | 30.0 | 25.4 | 20.6 | 17.4 |
| Double shift regime | | | | | | |
| day shift | 101 | 804 | 30.6 | 25.9 | 19.6 | 16.5 |
| evening shift | 115 | 919 | 28.3 | 22.7 | 18.2 | 14.6 |
| average | - | - | 29.5 | 24.3 | 18.9 | 15.6 |
| Four-and-four shift regime | 279 | 2 719 | 31.0 | 25.9 | 20.8 | 17.4 |

with the four-and-four shift, 25.4 m³/SMH with the single shift, and 24.3 m³/SMH with the double shift. Differences between shift regimes were not significant. Productivity differences between day and evening shifts for the double shift regime were not significant either. However, the overall productivity trends were not consistent between individual yarders. Two of the six yarders achieved their highest productivities while operating on single shift and one yarder achieved its lowest productivity while working on four-and-four shift.

The data were stratified into three piece-size classes (smaller than 1.25 m³, 1.25 to 1.75 m³, and larger than 1.75 m³) to determine if average piece size influenced shift regime productivities. No effect due to shift regimes was found within the same piece-size class.

Canfor's assignment of settings to favour the alternative regimes likely allowed machines on these shifts to maintain higher productivity than would have been possible under conditions similar to those for the single shift yarders. Double shift yarders, and to a lesser extent, the four-and-four shift machines, were assigned to gentler terrain where mobile backspars could make operations easier and more productive. The other regimes, especially the single shift, were assigned to the steeper, more difficult terrain requiring stump-rigging or tailtrees. This assignment improved productivity on both evening and day shifts compared to the other regimes. While it is very difficult to accurately quantify the effect of mobile backspars on productivity, Canfor estimated a 25 to 30% increase may be achieved compared to stump-rigging. When grapple yarding bunched wood with a mobile backspar, a yarder could produce 1000 m³/day or more.

Proactive management of repairs on double shift machines by Canfor also influenced productivity by scheduling repairs for the evening shift when productivity tended to be lower. In Canfor's experience, this practice weighted the average productivity on double shift regime towards higher production day shift.

Considering that the differences in productivity between regimes are very small and that Canfor placed the alternative regimes in more favourable conditions compared to the single shift, one could expect productivity to be higher on a single shift regime if all circumstances were equal.

## Estimated yarding cost by shift regime

Because all yarders except one[5] worked a variety of shift regimes throughout the study period, actual costs by shift regime could not be compared. Therefore a theoretical analysis was performed for three scenarios, assuming for each scenario that the yarder was dedicated to one shift regime only. A Cypress 7280 yarder was chosen as the base machine for this analysis. Hourly cost calculations for

[5] The Cypress 6280 (yarder 5) worked only a single shift regime.

the Cypress 7280 yarder are shown in Appendix I. The assumptions used to estimate costs are summarized in Appendix III. The most important difference between the scenarios and the way Canfor operated was a large increase in the scheduled machine hours per year for the alternative shift regimes in the scenarios compared to actual shifts worked by Canfor.

The costs for the single shift, double shift, and four-and-four shift regimes were estimated at $336/SMH, $315/SMH, and $336/SMH, respectively. The purchase prices for the double and four-and-four shift yarders were $41 000 more than the single shift yarder, reflecting the additional cost of the lighting systems. However, in the scenarios the yarders used in the double and four-and-four shift regimes were scheduled to work 95% and 70% more hours per year, respectively, than the single shift regime, which reduced interest and insurance costs.

Operating costs for the yarders working in the double and four-and-four shifts were higher compared to those working in the day shift due to the lighting system and higher wage and benefits costs. Based on light usage recorded by operators and from Canfor's cost records, the operating cost for a lighting system was $9.99/h. If the lighting systems operated 243 h/yr for the four-and-four scenario and 872 h/yr for the double shift scenario, operating costs would be $0.83/SMH and $2.63/SMH, respectively.[6] With overtime and shift differential premiums taken into consideration, the hourly costs for crew wages and benefits were $122.08 for the single shift regime, $122.84 for the double shift regime, and $141.76 for the four-and-four shift regime.

Because Canfor's yarders did not work exclusively on one regime, the effect of shift regime on repair and maintenance could not be determined and average costs were applied equally to the three scenarios. However, alternative shifts had detrimental effects on repair, maintenance, and line costs, and these effects were not captured by the study. The sharing of yarders by crews made it difficult for supervisors to assign responsibility for maintenance and determine accountability for breakdowns. Operators could incorrectly assume that machine greasing had been performed. Respooling and upending of running lines could be postponed in the hope that the other crew would do the work. Increasing operating hours between machine services and line maintenance increases wear, reduces component life, and increases costs.

On the alternative shift regimes, less time was available for scheduling repairs and maintenance. Therefore, more repairs were done outside regular shop operating time when shop personnel were paid overtime rates, which would increase repair costs compared to the single shift regime. This situation could not be factored into FERIC's cost estimates for the scenarios.

The average productivities calculated for the Cypress 7280 yarders for each shift regime were used to calculate the unit costs, and the resulting unit costs for each shift regime are summarized in Table 5.

There was negligible difference in unit costs for the three regimes. Double shifting year-round and four-and-four shifting had the lowest unit costs at $12.95/m$^3$ and $12.98/m$^3$, respectively, or 2.1% and 1.9% less than for single shifting at $13.23/m$^3$.

Care should be taken when interpreting these cost results if an operation's productivity is likely to drop when an alternative shift regime is implemented full-time, for instance if working without a mobile backspar or if working in less favourable light and weather conditions. During the study, the alternative regimes worked only during the part of the year when daylight conditions favoured longer working hours. The cost calculations assumed that the productivities observed during the study would be maintained when the alternative shift regimes were extended to the same operating months as the single shift regime. This increase in scheduled operating time requires a higher proportion of working time in the dark and unfavourable

[6] Total annual costs were rounded to the nearest $100 in this calculation.

**Table 5. Productivity, production, and costs by shift regime for the Cypress 7280 yarders**

| Shift regime | Productivity ($m^3$/SMH) | Production: Daily production ($m^3$) | Production: Weekly production ($m^3$) | Production: Daily production ratio compared to single shift | Production: Weekly production ratio compared to single shift | Costs: Machine cost ($/SMH) | Costs: Unit cost ($/$m^3$) | Costs: Unit cost savings compared to single shift (%) |
|---|---|---|---|---|---|---|---|---|
| Single shift | 25.4 | 203 | 1 016 | 1.00 | 1.00 | 336.07 | 13.23 | 0.0 |
| Double shift | 24.3 | 389 | 1 944 | 1.91 | 1.91 | 314.61 | 12.95 | 2.1 |
| Four-and-four shift | 25.9 | 259 | 1 813 | 1.28 | 1.78 | 336.06 | 12.98 | 1.9 |

weather conditions, which may reduce productivity and increase costs on the alternative regimes.

## Sensitivity analysis for costs

A sensitivity analysis was conducted to determine the effects of changes in productivity (Figure 5). For the double shift regime, productivity was held constant for the day shifts and changed only during the evening shifts. For example, a 10% drop in productivity during the evening shifts (for instance, if double shifting was extended into the winter months with no daylight during the evening shifts) resulted in a 3% rise in costs to $13.58/$m^3$, negating any cost savings realized by lower machine costs. However, for a four-and-four shift regime the same 10% drop in productivity produced a 9% increase in costs compared to single shift regime costs, resulting in a cost of $14.42/$m^3$. The effects of productivity drops are more severe on costs per cubic metre for the four-and-four shift regime than for the double shift regime because the evening shift contributes only one half of the average productivity to the double shift regime. The spread between the double shift and four-and-four shift regimes increases as the drop in productivity increases. For example, a 50% productivity drop results in cost increases of 28% for the double shift and 96% for the four-and-four shift.

The number of calendar days/year that a yarder works on an alternative shift regime will also affect costs (Figure 6). Analysis was conducted to determine the affect of

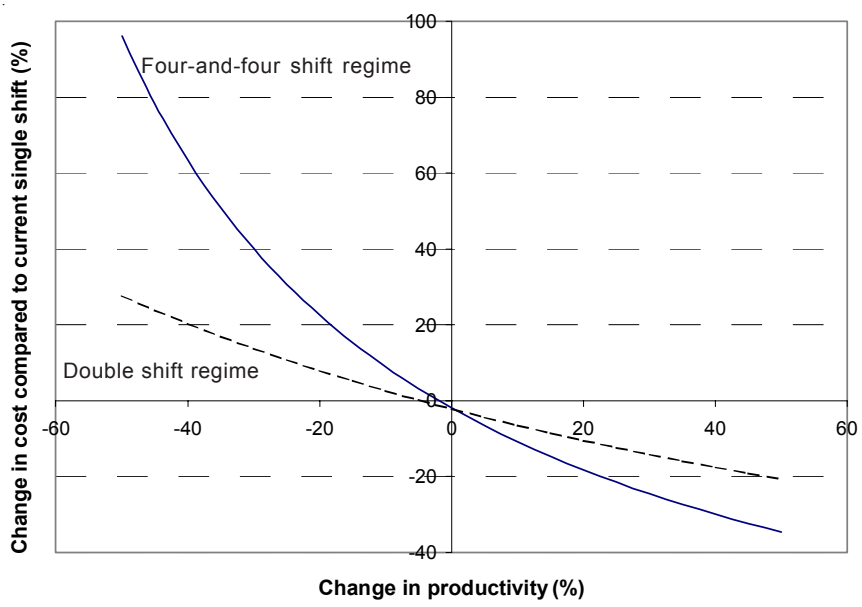


Figure 5. Projected effect of changes in productivity on costs.

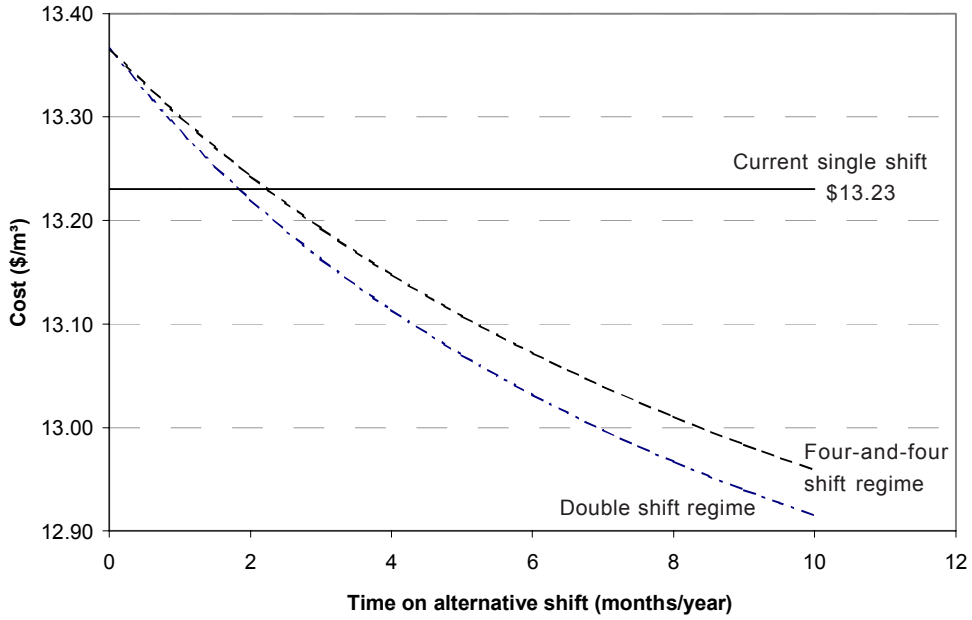


Figure 6. Projected cost versus time on alternative shift.

increasing the time per year from 0 to 10 months, with the yarder shutdown for two months per year as in the scenarios. Productivity/SMH and light usage/shift remained constant, by regime, throughout the year in the analysis.[7] Light system operating costs, wage costs, and productivity were weighted to reflect the amount of time the yarder spent working on the alternative regime compared to the single shift regime. Results showed that the total yarding costs/m³ decreased as the time spent on alternative shifts increased. However, costs were higher than the single shift regime for alternative shift usage of less than two months/year due to light system purchase costs. There was more of an advantage increasing the months/year for the double shift regime than for the four-and-four regime because more hours are worked on double shift. However, the maximum decrease in costs for both alternative regimes was only about 2%.

The differences in costs for the three scenarios are very small and slight changes in productivity would change their ranking. When the probable effects of changed circumstances such as less favourable terrain and light conditions for the alternative regimes and differences in costs that were not captured by the study are taken into account, yarding costs for the alternative regimes can be expected to be equal to or higher than those for the single shift regime. Because results show little difference in yarding costs between regimes, strong consideration should be given to other items when determining the overall suitability of alternative regimes to an operation.

## Other considerations

There are many factors to consider when contemplating the implementation of an alternative shift regime. When differences in productivity are not significant and the costs per m³ are very similar for different regimes, other factors become the major components in a decision. While difficult to quantify, these components had a large effect on operational efficiency and were instrumental in Canfor's decision to discontinue the alternative shift regimes.

### Lights and working in low light conditions

- In general, yarding crews tended to use lights if their yarders were equipped with them, regardless of the shift regime. When working day or four-and-four

[7] In actuality productivity/SMH could be expected to decrease and light usage/shift could be expected to increase as the months/year on alternative shifts increases.

shifts, lights were used mostly in the early morning but also in late afternoon or in poor weather to improve visibility. During the evening shifts, the lights were turned on at dusk. Between July 26 and December 6, yarder operator records indicated that the lights were used on 56% of day shifts, 39% of four-and-four shifts, and all of the evening shifts. If there was high fire hazard, then the day shift started earlier and for all these early shifts the lights were used. For the days when the lights were used, day shifts averaged 1.3 h of light use, evening shifts averaged 2.8 h, and four-and-four shifts averaged 0.8 h.

- Yarder operators reported they could adjust more easily to working in the dark if they worked from daylight through to darkness rather than starting work in the dark.
- Operators also commented that shadows produced by the lights occasionally made the logs more visible than in daylight.
- Rigging crews found the lights hard on their eyes and occasionally wore sunglasses when working in the dark.
- Yarder moves and set-ups were avoided on evening shifts and on weekends. If necessary, the crew would move to another yarder to work.
- Double shift operations were usually assigned to gentle terrain where mobile backspars could be used, and single shift and four-and-four shifts were preferred for more difficult terrain.

## Effects of alternative shift regimes on workers' annual hours worked and income

A theoretical analysis was performed to compare workers' annual hours and wages for the three shift regimes using the assumptions in Appendix III (Table 6). The analysis indicated that workers on the double shift and four-and-four shift regimes worked 47 to 368 hours less per year, respectively, than workers on single shift, including travel time. Double shift workers worked less than single shift workers because double shifting was not possible during periods of high fire hazard when early shift operation was required. Similarly, despite the yarder working 10 hours per day and seven days per week, four-and-

**Table 6. Annual crew hours and wages**

| | Single shift | Double shift, both crews | Four-and-four shift 1st crew | Four-and-four shift 2nd crew |
|---|---|---|---|---|
| Day shifts [a] (no.) | 212 | 106 | 5 | 5 |
| Evening shifts (no.) | - | 101 | - | - |
| Four-and-four shifts (no.) | - | - | 142 | 139 |
| Total shifts (no.) | 212 | 207 | 147 | 144 |
| Working time (SMH) | 1 696 | 1 656 | 1 460 | 1 430 |
| Travel time (h) | 318 | 311 | 221 | 216 |
| Total time (h) | 2 014 | 1 967 | 1 681 | 1 646 |
| Wages [b] ($) | 43 689 | 42 909 | 43 225 | 42 684 |
| Travel time [c] ($) | 8 192 | 8 045 | 8 424 | 8 250 |
| Total salary [d] ($) | 51 881 | 50 954 | 51 649 | 50 934 |
| Average rate ($/h) | 25.76 | 25.90 | 30.73 | 30.94 |

[a] Includes early shifts.
[b] For machine operator, coastal B.C. IWA rate, effective June 15, 2000.
[c] Based on 1.5 h/shift. See assumptions in Appendix III for more details.
[d] Does not include service time, driving time, statutory holiday pay, vacation pay, or overtime other than scheduled Sunday work and hours worked in excess of 8 h/day for the four-and-four shift.

four shift crews worked fewer hours per year than single shift crews because the available operating days per year had to be shared between two crews and two sets of statutory holidays had to be fitted into the calendar. However, the average hourly rate paid to the four-and-four crews was higher than to the single and double shift crews due to overtime paid for Sunday work and for hours worked in excess of eight hours per day. The average hourly rate paid to the double shift crew was slightly higher than to the single shift crew due to the shift differential premium paid to the evening shift.

For the theoretical year studied, the second four-and-four shift crew worked three less shifts than the first due to shutdown periods and the odd number of total days available. Because four-and-four shift crews worked fewer days per year, total annual travel time was about 31% less for the four-and-four crews compared to the single and double shift crews. In summary, compared to single shift crews and considering travel time and working time wages, double shift crews earned 2% less per year while the first and second four-and-four shift crews earned the same or 2% less per year, respectively. However, the average hourly rate was 19 to 20% higher for the four-and-four shift regime compared to the single shift and double shift regimes due to overtime paid, and the "no loss, no gain"[8] provision in the coastal B.C. IWA master agreement.

## Workers' views on alternative shift regimes

- Workers' opinions of the alternative shift regimes were mixed. In general, workers who lived farther away preferred the four-and-four shift schedule because it allowed them to spend more time at home with their families. However, workers who lived locally preferred to have more free time in the evenings and the weekends off, and therefore disliked the four-and-four shift regime. Finally, some workers preferred working the evening shift during the summer because they enjoyed having free time during the day for personal activities.
- Conflicts occurred between crews working on the same machine, for example, when one crew's plans for yarding an area differed from the other crew's plans, or when the yarder was moved or rigged differently than the other crew had planned. Sometimes workers believed the other crew intentionally yarded the easier terrain. Operators mentioned that occasionally equipment was lost when yarders were shared.

## Other crew-related items

- Absenteeism cost more on the alternative shift schedules because day-shift workers filled in for absent workers at overtime rates.
- More operators were required to operate the alternative regimes and this strained Canfor's pool of experienced operators. The additional operators were less experienced and therefore less productive and harder on the machines and the lines than the experienced operators.
- Workers switching to different machines could result in non-productive time when the workers' gear was located in a different part of the division.
- Because four-and-four shift workers' schedules were often out of synchrony with those of their family members and friends, requests for time off were concentrated on weekends. These were harder to accommodate compared to the single shift regime workers' requests which were less frequent and more evenly spread over the Monday to Friday work

[8] The Memorandum of Agreement between Canadian Forest Products Ltd. Englewood Logging Division and IWA - Canada, Local 2171, May 19, 1999, Section 4 states: "When this alternate shift schedule is in effect, other provisions of the Master Agreement will be administered on the principle that an employee 'will not lose or gain' any benefits over his historical work schedule. The hours to be included in the averaging will be amended to reflect each individual's current hours of work."

schedule. Denials of time off requests or crew shortages on the weekends resulted with the four-and-four shifts.

## Overhead and supervision

- A lower ratio of supervisors to machines and a greater geographic spread of equipment for the alternative regimes compared to the single shift regime resulted in a lower level of supervision. Under the single shift regime, three foremen oversaw all logging in the division. However, no foremen were on duty during evening shifts and weekend four-and-four shifts when grapple yarding was the only activity.
- Camp costs per cubic metre may be lower on alternative shift regimes if the volume available is fixed and the camp can be operated for fewer days per year.
- Two crew transportation vehicles are required for a double shift regime.
- Supervision, repair and maintenance, first aid, and camp costs may be higher for alternative shift regimes if the entire operation is not working on the same schedule and extra coverage is required.

## Maintenance and repairs

### Scheduled downtime

Because yarders are utilized more hours per week on alternative shift regimes, maintenance and repairs are more difficult to schedule. If more repairs are done outside regular shop operating time, the shop staff have to be paid overtime rates which increases repair costs compared to the single shift regime. For example, emergency off-shift repairs for the double shift regime required paying mechanics at overtime rates for late night repairs after the evening shift was completed.

Although the four-and-four regime had no scheduled down days available for machine repairs and maintenance, Canfor's shop operated an evening shift to stay current with the single shift machinery and this time was also available for the four-and-four machines. However, Canfor's master mechanic preferred double shifts to four-and-four shifts because repair and maintenance could be done on the weekend. He noted that if the shop went to a full four-and-four shift schedule, his preference may change and the shop would require four more mechanics.

### Outside support

Canfor's external support network of equipment manufacturers and suppliers did not work weekends and nights, which made it difficult or impossible to get parts, advice, and other support when the alternative shifts had problems during these times.

### Lighting systems

The yarders operating in the dark required extra repairs and maintenance to sustain their lighting systems.

### Monday and Friday crises

Repair and maintenance crises often occurred on Fridays and Mondays on the four-and-four regime. On Fridays, machine operators reported mechanical problems that could prevent the machine from working through the weekend, reduce productivity, or damage the machine if not repaired immediately. The problem may have been a new development or one that had been getting worse all week, and the operator just realized that it must be repaired if the machine was to work over the weekend with little or no mechanical support. Supervisors and mechanical staff would then have to scramble to complete the repair before the weekend.

On Mondays, operators reported problems that developed over the weekend but were not repaired properly because of the low level of mechanical support. The crew may have managed to keep working over the weekend but at the expense of damage to the machine and/or lower productivity. On Mondays, when full support was available, there was urgency to get the machine repaired and operating optimally again.

These situations occurred frequently and resulted in high supervisor stress and

frustration due to constant crisis management. Crew dissatisfaction resulted from the inability to produce at optimum level.

**Mechanical support**

Machines working the four-and-four shift regime received special treatment with a higher level of mechanical support during the week compared to the machines on other regimes. This strategy was to ensure the equipment could work through the weekend with little mechanical support.

**Machine changes**

When a machine on an alternative regime broke down on evenings or weekends, the crew had the flexibility to switch to a machine operating on the single shift regime. This change of machine usually occurred because servicing alternative shift yarders in need of repairs was not considered a priority for mechanics during evenings and weekends. The practice of moving to another yarder underestimated the mechanical downtime in the study. If all machines in an operation worked the same alternative shift regime, other machines would not be available.

## Responsibility for machines

- There was a serious lack of operator and crew assuming responsibility for machines and equipment when these items were shared. Weekly greasing, respooling of lines, upending of lines (regular respooling and upending of lines helped to reduce line costs significantly), reporting and attendance to safety related items, and general cleanliness and housekeeping were all improved when all machines were switched to single shift regime.
- Machine damage was higher during the four-and-four shift regimes compared to the other regimes.
- Workers who were the sole operator of a machine took more pride in its upkeep and operation than those sharing machines. The sole operator becomes intimately familiar with the machine and brings small problems to the attention of maintenance staff before damage occurs or expensive repairs are required.

## Fewer yarders

- Fewer yarders are needed to harvest the same volume of wood on alternative shift regimes if the regimes are operated year round and are able to maintain their productivity level. For example, to harvest 270 000 $m^3$/year at 26 $m^3$/SMH, the single shift regime would require 6.1 machines, the double shift would require 3.1 machines, and the four-and-four shift would require 3.6 machines.
- More volume per yarder can be harvested in a given time period on alternative shift regimes. This can be useful when operating in the narrow time windows caused by fluctuating markets or weather constraints. Small blocks with room for only one yarder can be logged more quickly.
- More jobs can be provided for the same capital investment on alternative shift regimes, provided sufficient volume is available to harvest throughout the year.

## Costs

- Ownership costs are lower for alternative shift regimes due to savings on interest and insurance.
- Alternative shift regimes can reduce capital investment, thus maximizing return on investment for a given time period.
- Labour costs are higher for alternative shifts due to overtime rates for the four-and-four shifts and the shift differential paid for evening shifts on the double shift regime.
- The double shift regime can operate more hours per day for each yarder without incurring overtime costs, compared to a single shift regime.

## Fibre delivery flows

- Fibre delivery can be controlled better by operating alternative regimes intermittently.

Volume can easily be adjusted by adding or subtracting a shift. Increased regulation of fibre flow may benefit other parts of a company's operations as well.
- An operation can adapt to higher or lower yarding requirements by running an alternative shift schedule for part of the year if there is insufficient volume for another full-time yarder.

### Terrain

- Because the double shift regime was assigned to gentle terrain, mobile backspars could be used and productivity was higher when yarding in the dark compared to if stump-rigging had to be used.
- The four-and-four shift regime has an advantage over the double shift regime in rough terrain because acceptable productivity can be achieved more easily without a mobile backspar if working in daylight.
- In suitable terrain, a swing yarder can cold deck logs and work independently of a loader. This practice is preferred because a loader is usually underutilized when working full time with only one yarder. On a double shift, savings can be realized if the yarder can cold deck the wood during the evening shift and the loader operates only during the day shift. If a loader is required to deck wood during the evening shift, loading costs will make the double shift regime less attractive. There is a similar cost disadvantage for loading for the four-and-four shift regime if the loader is required during weekends. However, during the study a loader rarely worked during the evening or weekend shifts.

### Season

- Canfor operated the alternative regimes mainly in the spring, summer, and fall when the days were longer to reduce operation in darkness. Only 10% of the scheduled double shift operating days were in the winter while 41% were in the summer. Better weather in the spring, summer, and fall also improved visibility when operating at night compared to winter logging. The four-and-four shift regime was also given seasonal favourability, as only 8% of its scheduled shifts were in the winter.
- In the fall, fog was common which resulted in reduced visibility during evening shifts.

### Effect on other harvesting phases

- Efficiencies may be realized in other harvesting phases such as loading, hauling, secondary transportation,[9] sorting, and scaling. Alternative shifting of grapple yarding provides additional volume to later phases and can reduce those costs if the equipment and facilities are underutilized, or increase costs if they are already operating at capacity.

## Canfor's decision to end alternative shift regimes

Canfor experienced many challenges while operating the alternative shift regimes and these eventually convinced the company to return to the single shift regime for all grapple yarding operations. It is a credit to Canfor's staff that the potentially adverse effects of the alternative regimes did not significantly reduce productivity compared to the single shift regime. Favoured operating conditions on alternative shifts allowed these regimes to maintain higher productivity and lower costs than would have been possible if they had worked in conditions similar to the single shift regime. Canfor recognized that even though productivities for the different regimes were similar, the preferential treatment given to the alternative shifts was reducing productivity of the single shift regime. Also, if the alternative shift regimes were operated

[9] Trains are used for secondary transportation in this operation.

year round or if all machines operated on only one regime, it would not be possible to favour them with these advantages and lower productivity could be expected.

Canfor's decision to end the double shift regime was also influenced by the division's changing timber profile. Much less timber is now available on terrain suitable for yarding with mobile backspars compared to when Canfor started double shifting in the Englewood Logging Division over twenty years ago. Currently only 35–40% of Canfor's grapple yarding is done using mobile backspars while the majority must be done with stump rigging. The available grapple yarding for mobile backspars is mainly in the low elevation areas reserved for winter logging and therefore less suitable for the double shift regime. There is also less terrain available now where a swing yarder can cold deck logs and work independently of a loader.

Although not quantified, Canfor perceived that its machine repair and maintenance costs and line costs were much higher on the alternative shift regimes for the reasons discussed previously. Canfor staff also found the alternative shifts extremely frustrating to manage. The repair and maintenance crises on Fridays and Mondays for the four and four regime and the difficulties related to machine sharing and crew responsibility were particularly trying. The combination of these factors influenced Canfor's decision to stop operating the alternative regimes.

Although Canfor decided that alternative shifts were not appropriate for its operations at the present time, the company noted that these regimes may be reconsidered in the future, and that they could be very effective in other operations. The high capital costs of new swing yarders had been a driving force to try alternative shift regimes, and Canfor suggested that the need to purchase new machines might again bring these regimes into consideration. Changes in labour costs and labour relations may also affect future plans.

The Englewood division continues to successfully operate a four-and-four shift regime for other harvesting phases, notably road construction and mechanized ground-based logging. While reasons for this difference in success compared to grapple yarding were not investigated, differences in crew size per machine and phase connectivity may be factors. A feller-buncher or an excavator require only one worker whereas grapple yarding requires three, and therefore has potentially more crew-related problems. Also, grapple yarding is connected more closely to other phases of the operation compared to road construction and mechanical felling, and therefore cannot work as independently.

Canfor staff have learned techniques from alternative shift regimes that have resulted in a more productive single shift operation. A large buffer of decked wood, approximately one month of yarding, is maintained and provides the flexibility to yard blocks in the most efficient way. By de-coupling grapple yarding from later phases, extra moves to accommodate loading and hauling have been eliminated. Yarding can now be done more productively instead of ensuring that decked wood in an active block is always accessible for loading.

## Conclusions

There was very little difference in average productivity between the three shift regimes. The average productivity was the same for the single shift and double shift regimes (24.3 $m^3$/SMH), and slightly higher for the four-and-four shift regime (26.1 $m^3$/SMH).

When only the Cypress 7280 yarders were considered, the spread was even less. Productivity with the four-and-four shift regime (25.9 $m^3$/SMH) was almost the same as the single shift regime (25.4 $m^3$/SMH), and the double shift regime (24.3 $m^3$/SMH) was only slightly lower than the single shift regime. These overall productivity trends were inconsistent between individual yarders and the differences between shift regimes were not significant.

The ownership and operating costs of the Cypress 7280 yarder for the three regimes were very similar at $336/SMH for the single shift regime, $315/SMH for the double shift regime, and $336/SMH for the four-and-four shift regime. When the Cypress 7280 yarder productivities for the three shift regimes were used to calculate costs per cubic metre, a yarder working a double shift regime had only a 2.1% lower cost than a yarder working a single shift regime, while a yarder working a four-and-four shift regime had only a 1.9% lower cost. The unit costs were all very similar at $13.23/m³ for the single shift regime, $12.95/m³ for the double shift regime, and $12.98/m³ for the four-and-four shift regime. Small changes in productivity or hours worked per year would change the cost per cubic metre ranking of the regimes.

Because the differences in productivity between the three shift regimes are not significant and the costs per cubic metre are very similar, other factors play a major role when considering the alternative shift regimes. The ability to harvest more volume per machine within a given time period, the flexibility to control fibre delivery flows by adding or reducing shifts, and possible economies of scale in other phases of an operation may support the choice of alternative shift regime. Other concerns such as crew preference, supervision requirements, scheduling of machine service and repairs, and effects on other parts of the operation also influence the decision.

Workers' opinions of the different shift regimes varied. Some preferred the traditional single shift and others preferred the alternative regimes. A theoretical analysis of workers' wages showed the alternative regimes had little effect on workers' total annual earnings when including travel time, even though the workers' total hours per year were lower on the alternative shift regimes than the single shift regime. Workers' annual earnings were 2% less for the double shift regime than for the single shift regime, while workers on the four-and-four shift regime earned the same or 2% less. However, the average hourly rate was 19 to 20% higher for the four-and-four shift regime compared to the single shift and double shift regimes due to overtime paid.

At the end of this trial, Canfor concluded that the alternative shift regimes resulted in no cost savings and were not appropriate for its operations. Canfor has since reverted to a 100% single shift operation for grapple yarding.

## Implementation

When deciding if alternative shifts are appropriate for an operation, the following questions should be considered:

- Is the terrain suitable for mobile backspars that may enhance productivity when working in darkness?
- Does the terrain require a loader to work with the yarder on all shifts?
- Will the company culture support alternative shifts?
- Does the location support alternative shifts (e.g., isolated camp vs. daily commute)?
- Are sufficient skilled and experienced workers available to adequately staff all shifts with backup for absenteeism?
- Will the hours of work for equipment suppliers and other outside support adequately meet the requirements of alternative shifts?
- What will be the interaction with other parts of the operation (e.g., shop, first aid, supervision, and later phases such as loading, hauling, and sorting)? How will these departments handle the extra work that will result from alternative shifts?
- Will alternative shifts result in shorter work years for workers or affect their income in other ways?

When implementing an alternative shift schedule, the following items should be addressed:

- Ensure adequate supervision, mechanical support, and first aid coverage for all shifts.

- Ensure adequate time is scheduled for yarder maintenance and parts replacement.
- Provide an avenue for effective communication between shifts and ensure each shift has daily contact with supervisors.
- Select workers who are suited to shift work.
- Cross-train personnel for other positions to reduce overtime costs when covering worker absence.
- Make sure alternative shift policies are fair to all employees.
- Maintain a balance of skill levels on each shift by rotating schedules or incentives.
- Consider the costs and benefits of extra volume on the other phases of the operation, and take advantage of any opportunities offered.
- If operating a mix of regimes, consider how season and location can be used to enhance overall productivity.

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# Appendix I

## Cypress 7280 machine costs [a] ($/scheduled machine hour (SMH))

| | Single shift | Double shift | Four-and-four shift |
|---|---|---|---|
| OWNERSHIP COSTS | | | |
| Total purchase price [b] (P) $ | 1 400 000 | 1 441 000 | 1 441 000 |
| Expected life (Y) y | 9.4 | 4.8 | 5.5 |
| Expected life (H) h | 16 000 | 16 000 | 16 000 |
| Scheduled hours/year (h)=(H/Y) [c] h | 1 696 | 3 312 | 2 890 |
| Salvage value as % of P (s) % | 30 | 30 | 30 |
| Interest rate (Int) % | 8.5 | 8.5 | 8.5 |
| Insurance rate (Ins) % | 2.0 | 2.0 | 2.0 |
| Salvage value (S)=((P*s/100) $ | 420 000 | 432 300 | 432 300 |
| Average investment (AVI)=((P+S)/2) $ | 910 000 | 936 650 | 936 650 |
| Loss in resale value ((P-S)/H) $/h | 61.25 | 63.04 | 63.04 |
| Interest ((Int•AVI)/h) $/h | 45.61 | 24.04 | 27.55 |
| Insurance ((Ins•AVI)/h) $/h | 10.73 | 5.66 | 6.48 |
| Total ownership costs (OW) $/h | 117.59 | 92.74 | 97.07 |
| OPERATING COSTS | | | |
| Wire rope (wc) $ | 33 400 | 33 400 | 33 400 |
| Wire rope life (wh) h | 2 150 | 2 150 | 2 150 |
| Radio (rc) $ | 9 500 | 9 500 | 9 500 |
| Radio life (rh) h | 5 760 | 5 760 | 5 760 |
| Fuel consumption (F) [d] L/h | 22.6 | 22.6 | 22.6 |
| Fuel (fc) [e] $/L | 0.44 | 0.44 | 0.44 |
| Lube & oil as % of fuel (fp) % | 10 | 10 | 10 |
| Annual operating supplies (Oc) [f] $ | 7 700 | 15 000 | 13 100 |
| Annual repair & maintenance (Rp) [g] $ | 108 100 | 211 100 | 184 200 |
| Annual lights operating costs (Lc) [h] $ | 0 | 8 700 | 2 400 |
| Wages [i] $/h | | | |
| Operator | 25.76 | 25.92 | 29.73 |
| Hooktender | 25.09 | 25.25 | 28.95 |
| Utility man | 22.58 | 22.74 | 26.06 |
| Crew travel time [j] | 13.77 | 13.86 | 16.52 |
| Total wages (W) $/h | 87.20 | 87.75 | 101.26 |
| Wage benefit loading (WBL) % | 40 | 40 | 40 |
| Wire rope (wc/wh) $/h | 15.53 | 15.53 | 15.53 |
| Radio (rc/rh) $/h | 1.65 | 1.65 | 1.65 |
| Fuel (F•fc) $/h | 9.94 | 9.94 | 9.94 |
| Lube & oil ((fp/100)•(F•fc)) $/h | 0.99 | 0.99 | 0.99 |
| Operating supplies (Oc/h) $/h | 4.54 | 4.53 | 4.53 |
| Repair & maintenance (Rp/h) $/h | 63.74 | 63.74 | 63.74 |
| Lights operating cost (Lc/h) $/h | 0.00 | 2.63 | 0.83 |
| Wages & benefits (W•(1+WBL/100)) $/h | 122.08 | 122.85 | 141.77 |
| Total operating costs (OP) $/SMH | 218.48 | 221.87 | 238.99 |
| TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/SMH | 336.07 | 314.61 | 336.06 |

[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, profit and overhead, and are not the actual costs for the contractor or the company studied. [b] Yarder purchase price was estimated by FERIC based on past information from Madill Equipment Canada. Double shift and four-and-four shift regimes includes $41 000 for lighting systems based on $15 000 for the light plant, $18 000 for the lights, $6 000 for the wiring, and $2 000 for the structure construction. (Lighting system costs from personal communication, Rick Bitten, Master Mechanic, Canfor, January 24, 2003.) [c] See assumptions about scheduled hours by regime in Appendix III. [d] Fuel consumption is based on Canfor's machine records. See Appendix II. [e] Fuel costs are based on Canfor's costs for the study year which ranged from $0.39 to $0.49/L, averaging $0.44/L. [f] Annual costs for operating supplies were estimated by FERIC based on Canfor's machine records. [g] Annual costs for repairs and maintenance were estimated by FERIC based on Canfor's machine records. [h] Annual costs for lighting systems were estimated by FERIC based on Canfor's machine records, light usage reported by operators, and assumed light usage by regime described in Appendix III. [i] Coastal B.C. IWA wage rates, effective June 15, 2000. Blended rate for four-and-four regime included overtime paid at 1.5 times straight time rate for Sunday work and for hours worked in excess of 8 h/day. Blended rate for double shift regime includes $0.31 shift differential premium for evening shift. [j] Travel time costs (not usually included in FERIC studies) were included because these varied by shift regime. See assumptions in Appendix III.

# Appendix II

## Yarder fuel consumption

| Yarder (no.) | Machine type | Fuel [a] (L) | Productive time (h) | Fuel consumption (L/PMH) | Fuel consumption (L/SMH) |
|---|---|---|---|---|---|
| 1 | Cypress 7280B | 41 260 | 1 439 | 28.7 | 23.4 |
| 2 | Cypress 7280B | 46 233 | 1 740 | 26.6 | 22.8 |
| 3 | Cypress 7280C | 56 732 | 2 014 | 28.2 | 23.3 |
| 4 | Cypress 7280C | 43 749 | 1 742 | 25.1 | 21.0 |
| 5 | Cypress 6280 | 6 231 | 325 | 19.2 | 15.3 |
| 6 | Madill 124 | 30 495 | 1 772 | 17.2 | 15.0 |
| All [b] | | 224 700 | 9 032 | 24.9 | 20.9 |

[a] In addition to this fuel, 6 mobile backspar machines used with the yarders burned 19 152 litres during the year for 2.1 L/yarder-PMH.

[b] Average fuel consumption for the Cypress 7280 yarders was 27.1 L/PMH or 22.6 L/SMH.

# Appendix III

## Assumptions used to detemine machine costs for the three shift regimes

**All shifts**

- 10 statutory holidays with no work, including 3 during shutdown periods
- 5.5 week winter shutdown
- 3 week summer shutdown
- 2 weeks of early shift operation
- it is not a leap year

**Single shift regime**

- 212 calendar days available, 1696 SMH
- 8 h/day worked on all available days
- no weekends worked
- no lights installed on the machine
- while on early shift, the machine will operate one 8-h shift/day
- workers will receive 1.5 h/shift travel time paid at straight time rate

**Double shift regime**

- 212 calendar days available, 3312 SMH
- 16 h/day (two 8-h shifts) worked on all available days except early shift days
- while on early shift, the machine will operate one 8-h shift/day
- crews will alternate between day shift and evening shift each week
- no weekends worked
- lights used 1.3 h/day on day shift and 2.8 h/day on evening shift during all operating days
- workers will receive a shift differential premium of $0.31/h paid when working evening shift
- workers will receive 1.5 h/shift travel time paid at straight time rate

**Four-and-four shift regime**

- 291 calendar days available, 2890 SMH
- 10 h/day worked on all available days except early shift days
- while on early shift the machine will operate one 8-h shift/day
- weekends worked
- two sets of statutory holidays (one for each crew) except when holidays fall during a shutdown
- weekends at the end and beginning of shutdown periods are not worked
- overtime for work >8 h/day Monday to Saturday paid at 1.5 times the hourly rate
- overtime for Sunday work paid at 1.5 times the hourly rate
- lights used 0.8 h/day during all operating days
- workers will receive 1.5 h/shift travel time paid at 1.5 times the hourly rate