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Yarding Delays for Advanced Logging Systems

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ABSTRACT

Yarding delays add significantly to the time and cost required to obtain a given quantity of timber. In this study, they increased total yarding time by as much as 28 percent. As yarding system complexity increases, the frequency of delays can also be expected to increase. For one balloon yarding system in a clearcutting and for a running skyline in a partial cutting, the frequency of operating delays was positively correlated with yarding distance. Operating delays for cable systems occurred more frequently in partial cuttings than in clearcuttings. Delays on two helicopter operations were caused chiefly by refueling and were not influenced significantly by either yarding distance or silvicultural method.

YARDING DELAYS FOR ADVANCED LOGGING SYSTEMS

INTRODUCTION

This paper describes a study of yarding delays and the factors that influence them.

Nonproductive time is a significant portion of total yarding time for cable, balloon, and helicopter yarding systems (7, 8). In the aggregate, delays for such systems may account for as much as 40 percent of yarding time (4). Surprisingly, this rather large (and expensive) segment of yarding time has been all but ignored by timber harvesting researchers. No formal publications have dealt exclusively with nonproductive time, and any mention of delays in published time studies is usually limited to a listing of total nonproductive time as a percentage of total yarding time. If there were some reason to believe that this percentage is constant for certain yarding systems, that information would be sufficient. A brief review of published yarding-time studies, however, shows that this is not true. Table 1 summarizes nonproductive times that have been reported in selected yarding studies. Differences in delay percentage of the size indicated in the table can have a significant impact on yarding-cost estimates made for timber sale appraisals.

Table 1. Summary of Nonproductive Times Reported for Published Yarding Time Studies.

Reference	Yarding system	Silvicultural method	Nonproductive time as a percentage of total time
			%
Adams (1)	highlead	clearcut	15
Carow (6)	highlead	salvage	48
Dykstra (7)	highlead	clearcut	16
Schillings (10)	highlead, jammer	clearcut	15-20
Tennas <i>et al.</i> (12)	highlead	clearcut	18
Binkley (3)	multi-span skyline	clearcut	14
BLM (14)	standing skyline	clearcut	18-24
Dykstra (7)	Grabinski skyline	clearcut	7
Dykstra (7)	North Bend skyline	clearcut	16
Dykstra (7)	slackline (flyer)	clearcut	9
Aulerich <i>et al.</i> (2)	slackline	thinning	20
Forest Service (13)	slackline	thinning	23
Sinner (11)	slackline	thinning	18-29
Dykstra (8)	running skyline	partial-cut	28
Dykstra (7)	balloon (inverted skyline)	clearcut	16
Dykstra (8)	balloon (haulback)	clearcut	29
Binkley (4)	heavy helicopter	overstory removal	42
Campbell (5)	medium helicopter	clearcut	29
Dykstra (7)	medium helicopter	clearcut	28
Dykstra (8)	heavy helicopter	clearcut, partial-cut	27

DESCRIPTION OF THE STUDY

The analysis described here was part of the Pansy Basin Study on the Mt. Hood National Forest in Oregon (7, 8). Data were gathered during the summers of 1973 and 1974. Terrain ranged from steep and broken to gentle and uniform. The timber was primarily old-growth Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), with a mixture of secondary species. Nine yarding systems were studied:

Cable Systems

Grabinski. A Smith-Berger¹ Planet-Lok L-1 yarder mounted on a Marc I self-propelled tower, rigged as a Grabinski running skyline.

North Bend. A West Coast Falcon mobile yarder-tower, operated as a North Bend standing skyline.

Highlead. The same West Coast yarder as above, but rigged in conventional highlead configuration.

Flyer. A Skagit BU90 yarder on a trailer-mounted T-90 tower, arranged as a gravity-return slacking skyline system.

Running skyline. A trailer-mounted Skagit GT-3 mobile yarder-tower, rigged as a running skyline with a three-drum slackpulling carriage.

Balloon Systems

Inverted skyline. A 530,000-cubic-foot natural-shaped logging balloon tethered to a rebuilt skyline yarder by means of an inverted skyline cableway.

Haulback. The same logging balloon in standard haulback configuration with a Washington Iron Works Model 608 Aero Yarder.

Helicopters

Vertol. A Boeing-Vertol Model 107-II medium-lift helicopter.

S64E. A heavy-lift Sikorsky Skycrane helicopter.

In all of the cable operations yarding was uphill, but on the balloon and helicopter operations yarding was to downhill landings. With the exception of the running skyline, which operated in a first-entry partial cutting, the cable systems were in clearcuttings. Both balloon operations were in clearcuttings, as was the Boeing helicopter operation. The Sikorsky S64E was observed in numerous small clearcuttings and in several heavy, first-entry partial cuttings.

Study teams of two crewmen each timed the yarding operations. One person in each team was stationed at the landing, and the other was positioned near the rigging crew or hooker. Two-way portable radios were provided for communication between the two crewmen. Both cycle and delay times were recorded in minutes, to a precision of one-tenth minute. Timing was continuous. Stopwatches were started synchronously when work began in the morning and were run continuously until work halted for the day. Field records thus indicate the cumulative elapsed time between the beginning of the study period and the beginning of each productive event or delay. Net elapsed times for each event or delay were derived later by subtraction.

¹ The use of trade names or equipment designations in this report is for information only and does not imply endorsement by either Oregon State University or the U.S. Forest Service.

RESULTS AND DISCUSSIONS

Cost of Yarding Delays

The estimated cost of delays for each of the nine systems is listed in Table 2. Estimates are based on equipment and labor costs for direct yarding and include the cost of yarding interruptions but not of extended downtimes, which were not recorded. These costs were obtained by multiplying direct yarding costs (in \$/unit-volume) already reported (7, 8) by the percentage of delay time recorded for each system. As an example, delay costs in dollars per *M* fbm (thousand feet, board measure) for the Grabinski system were computed as follows:

Average direct yarding cost (from Table 2) = \$8.76/*M* fbm.

Percentage of total time in all delays (from Table 3) = 6.6%.

Then, delay cost = (8.76)(6.6/100) = \$0.58/*M* fbm.

Delay costs for the other cable systems and for the two balloon systems were computed in the same way. Conversion of costs per board foot to cubic volume was done with ratios summarized previously (8).

For helicopter logging systems, delay cost calculations are slightly more complex. The costs of helicopter equipment and flight crews are conventionally assessed only against flight time. Therefore, costs had to be computed separately for in-flight delays and nonflight delays, as follows:

	Vertol	S64E
A—Helicopter equipment costs, \$/hr	558.67	1,363.62
B—Cost of flight labor, \$/hr	71.86	95.75
C—Cost of nonflight labor, \$/hr	48.08	54.09
D—Percentage of total time in in-flight delays, %	8.8	7.5
E—Percentage of total time in all delays, %	28.2	26.7
F—Flight time production rate, <i>M</i> fbm/hr	12.7	37.8
G—Total time production rate, <i>M</i> fbm/hr	10.8	29.9

Table 2. Estimated Costs for Direct Yarding and Delays for the Pansy Basin Study.

System	Silvicultural treatment	Average direct yarding cost ¹			Estimated delay costs		
		\$/N fbm	\$/ccf	\$/m ³	\$/N fbm	\$/ccf	\$/m ³
CABLE SYSTEMS							
Grabinski	clearcut	8.76	4.62	1.63	0.58	0.31	0.108
North Bend	clearcut	7.28	4.11	1.45	1.13	0.64	0.225
Highlead	clearcut	16.86	7.22	2.55	2.61	1.12	0.394
Flyer	clearcut	10.43	5.98	2.11	0.96	0.55	0.194
Running skyline	partial-cut	14.66	7.58	2.68	4.05	2.09	0.740
BALLOON SYSTEMS							
Inverted skyline	clearcut	19.02	11.01	3.89	2.95	1.71	0.603
Haulback	clearcut	23.65	13.88	4.90	6.81	4.00	1.410
HELICOPTER							
Vertol	clearcut	58.98	35.28	12.46	5.63	3.35	1.189
S64E	clearcut, partial-cut	42.86	26.35	9.30	3.38	2.08	0.734

¹Sources: Dykstra (7, 8).

These costs do not include downtimes, move-in and setup charges, or the cost of accessory equipment such as spool trucks. Both cubic and board-foot volumes were measured directly, so that conversion ratios vary among the nine systems.

Then,

Cost of in-flight delays:

Flight equipment cost = $(A)(D/100)$, \$/hr	49.16	102.27
Flight labor cost = $(B)(D/100)$, \$/hr	6.32	7.18
H—Subtotal, \$/hr	55.48	109.45
Converting to a volume basis,		
I—Inflight delay cost = $(H)/(F)$, \$/M fbm	4.37	2.90
Allocation of delay time to nonflight labor:		
J—Nonflight labor cost = $(C)(E/100)$, \$/hr	13.56	14.44
Converting to a volume basis,		
K—Nonflight labor delay cost - $(J)/(G)$, \$/M fbm	1.26	0.48
Finally,		
Total estimated delay cost = $I + K$, \$/M fbm	5.63	3.38

These are the costs that appear in Table 2. As with the cable and balloon systems, ratios for conversion from board-foot to cubic measure are derived from a previous publication (8).

Although they are only representative of the specific conditions encountered during the study, the costs summarized in Table 2 do indicate the importance of recognizing delays when yarding costs are estimated. Delay costs for the running skyline, as an example, are nearly as high as total yarding costs for some tractor systems (10).

Nonproductive Event Categories

During the time studies, the cause and duration of each delay were determined and recorded. Later, seven categories of nonproductive time were defined, and each delay was placed into one of these categories. The purpose of this classification was to group the nonproductive events with common characteristics to facilitate their interpretation. The specific categories that were used are arbitrary, and certainly the order in which they are discussed here is of no importance. The percentage of time each system was delayed during the study for each of the seven nonproductive event categories is listed in Table 3. The following discussion summarizes the study results for these categories.

Table 3. Percentage of Total Yarding Time in Each Category of Delay.

System	Delay category							
	Re-fuel	Return chokers	Weath-er	Re-pairs	Per-sonnel	Main-tenance	Oper-ating	Total
	%	%	%	%	%	%	%	%
CABLE SYSTEMS								
Grabinski	--	--	--	0.1	--	0.6	5.9	6.6
North Bend	--	--	--	3.6	--	--	11.9	15.5
Highlead	--	--	--	5.8	--	0.2	9.5	15.5
Flyer	--	--	--	1.5	0.2	1.1	6.4	9.2
Running skyline	--	--	--	6.0	0.3	2.3	19.0	27.6
BALLOON SYSTEMS								
Inverted skyline	--	--	--	12.0	--	--	3.5	15.5
Haulback	--	--	2.6	--	1.0	1.8	23.4	28.8
HELICOPTERS								
Vertol	17.9	2.4	0.1	1.4	--	--	6.4	28.2
S64E	11.8	1.0	5.6	1.8	2.1	--	4.4	26.7

Refueling. This category was of significance only for the helicopter systems (Figure 1). The cable and balloon yarders were usually refueled in the morning, before the start of the 8-hour day. Occasionally, fuel was added during the noon break or during some other lengthy delay. In our observations of five cable systems and two balloon systems, however, only a single delay of 1.5 minutes' duration was attributed to refueling. For the helicopters, on the other hand, refueling was the single most important cause of delay. All helicopters are high consumers of fuel; the Vertol uses fuel at an average rate of 180 gallons per hour, and the S64E consumes about 525 gallons per hour. During the time study, refueling of the Vertol was undertaken every 88.6 minutes on the average and required about 15.9 minutes; for the S64E, the comparable figures are 40.7 and 4.8 minutes.

Return of chokers. This category includes delays related to the handling and return of chokers to the rigging crew on the helicopter operations. A small utility helicopter commonly returned the chokers on the S64E operation. On the Vertol operation, the main aircraft was used for returning chokers more frequently, and these delays consequently occurred more often on that operation.

Weather delays. Only the balloon and helicopter operations were interrupted by weather during the time studies. The primary cause of weather delay on the helicopter operations was fog or other visibility problems, but balloon yarding was interrupted most often because of wind. Note that the study was not designed to gather information on weather shutdowns.



Figure 1. The Sikorsky Skycrane helicopter on the refueling pad. The need for frequent refueling stops proved to be the greatest single cause of delay on the two helicopter operations in this study.

Certainly lengthy downtimes, including both those arising from fire danger and from inclement conditions, have an important impact on logging costs. They are appropriately recognized in cost appraisals by adjusting the number of hours per year that a given system can operate rather than considering them as delays. As an example, cable systems in the Pacific Northwest usually operate about 1,600 hours a year. In contrast, the more weather-sensitive helicopter may only be available for logging about 1,200 hours a year (4). Thus, its fixed costs must be depreciated over a shorter operating season.

Repairs. These delays predominately were for repairs to yarders, except on the running skyline operation where the yarder was new. The most interesting comparison is between the Grabinski and the running skyline. Except for differences between the carriages used on these operations, configurations of the Grabinski and running skyline were essentially identical. The large percentage of repair time for the running skyline (Table 3) was attributed almost entirely to problems with its slackpulling carriage (Figure 2). The Grabinski system, on the other hand, used a simple block carriage that required no repairs during the study. This finding suggests that expected repair time should be increased whenever silvicultural prescriptions require the use of complex cable equipment.

Of the two balloon operations, only the inverted skyline required repair time. The difficulties apparently arose because a rebuilt skyline yarder used on the operation was not capable of fully controlling the lifting force imposed by the balloon. This resulted in a significant amount of wear and tear on the yarder.



Figure 2. A partial-cut silvicultural prescription on the running skyline operation necessitated the use of a carriage capable of lateral yarding. The high frequency of repair and maintenance delays on this operation was largely attributed to problems with this complex carriage.

As mentioned previously for weather delays, we did not collect data on lengthy downtimes. When major breakdowns occurred, the study crew would normally divert to another yarding system because the primary objective of the time study was to obtain information about the systems while they were operating. Data collected as part of a companion study² will provide information on major repair times.

As a final comment on repair delays, our data suggest that breakdowns of yarding equipment are somewhat interdependent. On any days for which repair times were recorded, several such delays almost always occurred, usually with only a few minutes of productive time between them. This kind of dependence is often found in complex industrial systems (9) and usually indicates either that the cause of the initial failure has been incorrectly diagnosed or that corrective action has been insufficient.

Personnel delays. Yarding personnel rarely take breaks that interfere with production. Almost all of the delays recorded in this category were minor interruptions caused by attaching water containers or lunches to the rigging for transport to the rigging crew. Occasionally, yarding was delayed because a crewman was momentarily away from his station. These delays usually involved personnel at the landing (often the yarder operator), were infrequent, and were generally of short duration. Scheduled breaks, such as lunch periods, were not considered delays.

Maintenance. For the cable systems, most of the maintenance delays recorded were related to rigging. These were most significant for the running skyline system (Table 3) and, as with repairs, were primarily related to the slackpulling carriage. Maintenance was also an important source of delay on the flyer and balloon haulback operations. For the flyer, delays in this category were all related to rigging and could be attributed to the large, heavy timber that was encountered on that study area. Maintenance delays on the balloon operation were divided about equally between the yarder and the rigging. For the other systems, most yarder maintenance was performed during breaks or while yarding was interrupted for some other reason. Specially trained personnel were employed on the helicopter operations to perform scheduled maintenance during refueling and lunch breaks.

Operating delays. The majority of yarding interruptions recorded during the Pansy Basin Study were operating delays. They were usually short delays that did not require the yarding crew to be diverted from normal duties. Many of them resulted from what are often called "line-balancing" problems (Figure 3). As an example, several of the yarders were placed on narrow landings with room for only a few logs in the unhooking area. If the loader was unable to keep the unhooking area cleared, yarding would have to be interrupted. Thus, the delay was not specifically related to yarding, but rather to the fact that the yarding and loading systems were temporarily out of balance. Other common operating delays included hangups, broken or snarled chokers, and failures caused by hooking overweight turns. The last were especially important on the helicopter and balloon operations.

Operating delays were substantially higher for the running skyline unit in the partial cutting (Table 3) than for the cable units in clearcuttings. Silvicultural treatment appeared to have no effect on operating delays for the helicopter systems, however. In general, operating delay time was greater for the more complex cable systems (North Bend and running skyline) than for the simpler Grabinski and flyer systems. The frequency of operating delays was also high for the highlead system. Although the highlead is a simple configuration, it is subject to more frequent hangups than comparable skyline systems because it provides less lift to the turn.

²Clarke, E. H. 1973. Summary plan for gross production and time studies on aerial logging systems. Unpublished study plan on file at the Pac. N.W. Forest and Range Expt. Station, Forest Service, U.S. Dept. of Agric., Portland, Oregon. 12 p.



Figure 3. A grapple-equipped skidder was used on the balloon operations to move logs from the unhooking area to the loader. At short yarding distances, the unhooking area occasionally became overcrowded with logs and the yarder was forced to wait until the area had been cleared. In the foreground of this photograph is one of the time-study crewmen, shown measuring log volume.

Operating Delay Correlations

Because most yarding delays in this study were operating delays, it seemed appropriate to study them more closely in the interest of testing their predictability. Field observations suggested two opposing hypotheses that might be appropriate. For line-balancing problems, the frequency of delays apparently was greatest when the loading system was least likely to be able to keep up with the yarding system; that is, at short yarding distances. For other operating delays, the frequency of delays seemed to increase as yarding distance increased.

To test these hypotheses, the category of operating delays was partitioned into "line-balancing" and "other operating" delays, and correlation coefficients were computed for the nine systems in the study (Table 4).

In general, the number of line-balancing delays recorded was too small to provide a definitive result. For the Grabinski and highlead systems, however, the computed statistics do support the stated hypothesis. For the North Bend, the opposite relation is indicated, perhaps because of the short yarding distances at which that system was observed. Correlations for the remaining systems were not statistically distinguishable from zero.

Table 4. Correlation between Operating Delays and Yarding Distance.

System	Correlation coefficient		Average yarding distance ¹	
	Line-balancing delays	Other operating delays	Ft	M
CABLE SYSTEMS				
Grabinski	-0.35*	0.27 NS	450	140
North Bend	0.55*	--	130	40
Highlead	-0.48**	0.10 NS	320	100
Flyer	0.12 NS	-0.16 NS	780	240
Running skyline	0.14 NS	0.09*	280	90
BALLOON SYSTEMS				
Inverted skyline	--	-0.86 NS	850	260
Haulback	0.06 NS	0.09*	1,500	460
HELICOPTERS				
Vertol	--	0.10 NS	3,170	970
S64E	--	0.01 NS	2,280	690

¹Average of the yarding distances at which operating delays were recorded.

** Correlation significant at $p < 0.10$.

* Correlation significant at $p < 0.20$.

NS Correlation not statistically significant.

-- No delays recorded or sample too small for statistical tests.

For operating delays other than those from line-balancing problems, only those recorded for the running skyline and the balloon haulback system were positively correlated with yarding distance (Table 4). For the cable systems, this suggests that operating delays are dependent upon yarding distance in partial cuttings, but not in clearcuttings. The running skyline system was the only one for which a large number of operating delays was timed, however, and therefore this finding should not be considered conclusive. The same is true of the results for the balloon; only a few operating delays were timed on the inverted skyline balloon operation. For the helicopters, the data support a conclusion that no relation exists between operating delays and yarding distance.

CONCLUDING REMARKS

The results reported in this paper should be useful to loggers, forest managers, and appraisal officers for estimating the amount of yarding delay time that would be encountered on logging operations in large timber. The important concept developed in this study is that yarding delays can best be estimated by segregating them into homogeneous classes. Individual estimates can then be made for each of these classes. Such estimates are usually easier to make and more accurate than estimates of total delay time. Admittedly, the method of classifying delays that has been presented here is somewhat rudimentary. We hope further study can refine methods capable of significantly improving the accuracy of delay time estimates for planned logging operations. Although delays may never be eliminated fully, or even reduced substantially, an understanding of the factors that influence delays should permit forest managers to design logging operations more effectively to take advantage of the capabilities, and minimize the limitations, of the yarding systems available to them.

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