COMPARING LONG-SPAN VS. CONVENTIONAL SKYLINE DESIGN OPTIONS: ECONOMICS AND SILVICULTURAL OPTIONS

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ABSTRACT

Production parameters for Long-span yarding systems developed in Central Europe for sled-mounted yarders were compared with similar studies in North America. Cycle times were comparable for a wide range of conditions. Only one study was found, that documented yarding parameters for a large tower yarder for yarding distances from 2 to 4000 ft on the West coast. Rigging times were a significant parameter in yarding productions. Long-span yarding operations were shown to be competitive when used in the proper, silvicultural environment.

Keywords: yarding production, Wyssen, yarding costs, forest operations, harvesting

INTRODUCTION

The Washington Department of Natural Resources (DNR) entered into an agreement with the federal government relating to the compliance with the federal endangered Species Act (16 US>C> 1531 et seq.). As part of that agreement DNR developed a Habitat Conservation Plan (HCP) which would provide the framework for the management activities of its trust lands, (DNR, 1997). Significant changes to timber sales requirements resulted. Rather than commit to a definite, upper limit on road densities DNR agreed to provide for a comprehensive landscape-based road network management process. The major components of that process included among other points the minimization of the active road density and a site specific assessment of alternatives to new road constructions such as extending yarding distances and their use where consistent with conservation objectives (DNR, 1997).

Current road management strategies by DNR are based on average external yarding distances of 1200 ft for cable systems (DNR, 1997). The road management strategy to be followed under the HCP now requires the inclusion of long-span yarding capacity systems when assessing management activities that are part of a larger landscape plan. The ultimate goal is reduction of road densities and their sediment impact on streams and habitat as part of an aggressive roads de-commissioning program.

OBJECTIVES

In this paper we will concentrate on issues that affect production rates for yarding distances >2000ft. We will first review some of the developments of long-span yarding systems both in Central Europe and North America with emphasis on production and cost prediction. Then we will outline the critical issues which play a role in production and cost beyond the conventional range (>2000 ft) and how they apply to PNW forest operations.

LITERATURE REVIEW

General Developments

Most current harvest and road systems are based on a yarding technology with an upper limit of approximately 2000 ft external yarding distance (EYD). A review of a number of recently finished harvest and transportation plans shows that average yarding distances are in the range of 500 -

600 ft that resulted in road densities from 3.35 to 6.13 miles per sq. mile (Schiess, 1993, 1998; Silen and Gratowski, 1953). Most current information shows a wealth of information for the conventional span lengths but very little information exists for the extended spans beyond 2000 ft (Aubuchons, 1982).

Skyline operations began in the U.S. at the turn of the century with the introduction of the steam engine and integral steel tower. Some of those machines yarded up to 4000 ft with a crew of 26 men and a total of 7 miles of wire rope for rigging and yarding lines (Samset, 1985; Lyson, 1971). The long yarding distances were, in part feasible because of cheap labor and expensive transportation systems (railroads). With changes in labor markets (increasing wage rates) and improved technologies that decreased road construction and transportation costs (diesel engines for trucks and road construction) road densities increased and yarding distances decreased.

European Long-span Skylines

Long-span skyline systems developed primarily in Central Europe since the general economic reference frame continued to be comparable to what it was in the U.S. at the turn of the century, relatively cheap labor rates in relation to high-priced timber. A good overview of systems and development can be found in Samset (1985). Numerous authors reported on long-span cable systems (Abegg et al., 1986; Heinimann, 1986; Wettstein, 1971; Pestal, 1961). The Swiss Federal Forest Research Institute developed a series of production and cost tables for the forest districts to be used in their production and cost appraisals based on a data base that covered four years (hereafter referred to as the Swiss appraisal form or method; Abegg et al, 1986). They provided detailed information for corridor layout, system setup (rigging and move times) and production as a function of yarding distance. The cycle time equations were developed from the tabular data provided by Abegg et al. (1986).

1. T_{Uphill} (min.) = 0.0052*AYD + 7.9
2. $T_{Downhill}$ (min.) = 0.0035*AYD + 8.3455

The authors provided detailed time estimating procedures for rigging equipment, set-up/rig-down as well as for intermediate supports and anchoring. Cycle times were considered independent of turn and log sizes, all parameters that are commonly found in North American yarding production equations (Aubuchon, 1982). Heinimann (1986) also provided a production equation with only AYD as the variable.

3. PR = 3.8 + 322 * (1/YD)

Where PR = production (m^3/hour) and YD = yarding distance in meters. He noted that the average turn size was 1.2 m^3. Abegg et al (1986) did provide corrections for lateral yarding distance and turn size, which were applied to the cycle times.

The Swiss appraisal procedure subdivided the rigging time down to flagging and traversing, basic rig-up and rig-down, additional time as related to positioning the yarder, and corrections for corridor changes with either a parallel or fan-shaped setting. All factors mentioned were provided as a function of EYD (ft). The tailholds, headspars, and tailtrees were expected to take eight man-hours to rig-up and two and a half to rig-down. The rig-up time for an intermediate support would take 16.5 man-hours and three hours to rig-down.

Time corrections were afforded once a yarder had been moved to its general location by subtracting five hours from rig-down from each corridor change in a parallel corridor setting. For a fan-shaped setting one could subtract eight hours for rig-up and 12 hours for rig-down for each corridor change. Equation 4 was derived from the data points provided in the Swiss appraisal form.

4. $T = (EYD*0.01454349 + 43.4295714 + 19.5*I + 10.5*(A))*M - 5*(M - 1) + P$

Where I= number of intermediate supports, A = Number of skyline anchors (headspar, tailhold, tailtree), M = number of corridors, and P accounts for rigging time based on yarding direction

5. $P_{uphill} = 0.0063*EYD + 3.5231$
6. $P_{Downhill} = 0.0089*EYD + 5.4176$

North American Experience with Long-Span Skylines

The first long-span, standing skylines (commonly referred to as Wyssen systems) operated in the Maritime province of Canada and the state of New York in 1949 (Hensel, 1977). The first systems showed up in the PNW near Twsip, WA, 1954, and Spillimachem, BC in the early 1950's (Akre, 1967). In all cases a typical system consisted of a 60-80 HP, sled-mounted winch (Wyssen model W-90) with one drum and usually a 3/8 - 5/8 inch mainline with a 5-ton capacity, hydraulically operated carriage riding on a 1 -1-1/4-inch skyline. Malone (1985) provided information on typical equipment costs for such a system based on observations on the Wenatchee National Forest (Table 1).

He reported that about 5 percent of the Forest's harvest volume were yarded with long-span cable systems. Logging costs reported (1985 $) were about $ 144.-/MBF, based on total equipment costs (including loader) of $345,000.-.

Table 1: Typical equipment list and costs for a Wyssen-type cable system (Malone, 1985).

Equipment Item	Cost ($)
Yarder, W-90 4400lbs	65,000
carriage	21,500
skyline, 5000 ft 1-1/4 inch	$14.500
Mainline, 5000ft. 5/8 inch	4,500
Spool truck	20,000
rigging hardware	16,000
radios	6,000
landing cat	37,500
loader, rubber-tired	160,000
Total investment	345,000

In comparison conventional cable yarding costs were $ 116.-/MBF, helicopter yarding were reported as $218.-/MBF and tractor yarding at $ 78.-/MBF. The above costs were based on Forest Service timber appraisal and included stump-to-truck costs including temporary road, soil and stream protection measures. No permanent road construction costs or haul costs were included.

Currently there are no Wyssen systems working on the U.S. West coast. A Wyssen system was used on a Plum Creek Co. timber sale near Cle Elum WA in 1998 . One Wyssen system is currently operating near Boston Bar, BC, Canada (Klossner, pers. comm. 1999).

Waelti (1976) described the operation of a W-90 machine (5-ton capacity) and 4000 ft skyline, near Nelson, B.C in 1975. Crew size was five men, including 2 chokersetters and a foreman. The operation was observed over a period in 1974 and 1975. The total area logged was 70 acres with three corridors yarding about 70 acres. Average daily production was 19 turns per day with an average turn volume of 140 cu.ft (app. 900 BF). Total volume yarded was 2616 cunits. The main time elements for the total operation are shown in Table 2. Total rigging times equaled 19 percent of the total operation. Intermediate support rigging times were about 50 percent higher than reported in the appraisal forms by Abegg et al., (1986). Total rigging times based on the Swiss appraisal form should take 545 man-hours compared to 1008 hours reported by the author. Rigging times were considered high which was attributed to unavailability of a spool truck and crew inexperience. The author observed the need for two sides working side-by-side to share a loader because of the otherwise low utilization.

Table 2 shows average parameters such as cycle times, turn volume in comparison with other studies. Although total average cycle times were high the author also reported that once things were running smoothly, total cycle time was 15 minutes for an AYD of 2000 ft which would agree well with the Swiss appraisal form.

He also observed that although production per man-day appeared low so was equipment operating cost. Still, the high production costs required high timber volumes or values. He also maintained that such a system might be particularly suited in areas of extreme difficult topography. He put the minimum distance at 1500 ft because of the high rigging times required.

Akre (1967) described a Wyssen operation near Twisp. The system was working in a selective cut with a 6 -8 MBF/acre removal. Average log size was about 200 BF (21 inch DBH) with log lengths from 16 to 32 ft. Corridors were from 4 - 5000 ft long. Average cycle times were 18.54 minutes/turn over an AYD of 2566 ft with average turn size of 2.3 logs/turn (Table 3). Crew size was 4 men. Of the total cycle time 6.7 minutes were used for hook time (one choker setter). The author commented on the fact that two choker setters might have increased the production significantly. One comment he made highlights the ambivalence of PNW loggers when confronted with sophisticated equipment. Loggers who visited the side commented on the carriage as being built like a Swiss watch. Rigging time for a 3000 ft corridor required 24 crew hours (96 man-hours). That would appear to be in line with the Swiss appraisal, which reports 92 hours. An average cycle time of 18.5 min. appeared well in line with the Swiss appraisal method (17.1 min.).

Hensel (1977) reported on an operation in Idaho and Eastern Washington. Two operations a downhill and an uphill yarding side were observed. Average turn time for uphill yarding over an AYD of 1990 ft. were 19.3 and 11.8 minutes for a downhill corridor with an AYD of 1470 ft. Average turn size was 4.87 logs/turn and 16 MBF/day for uphill yarding and 19 MBF/day for the downhill yarding operation (Table 3). Hensel provided cycle time equations as noted below.

7. $T_{Uphill} = 5.102 + 0.97*N + 0.00000172*AYD^2 + 0.031*LYD - 0.194*Crew$

8. $T_{Downhill} = 12.304 + 0.385*N + 0.00000062*AYD^2 + 0.0096*LYD + 0.945*Crew$

Turn times differed by about 15 percent from the Swiss appraisal method (18.3 min. and 13.5 min, resp.).

Hensel (1977) reported five days per corridor change with a crew size between four and five individuals for a range of 2000 (est.) to 3100 ft EYD. One example included a headspar and tailtree and for the other a headspar, intermediate support and a tailhold. He noted two days for rock or deadman anchors, but was unclear as to the size of crew required. He did not provide a breakdown of the rigging time. The author's estimate of 191.25 man-hours per corridor for total rigging time matched very well with the Swiss appraisal method of 205 man-hours. However, for multiple corridors, the Swiss appraisal method showed less total rigging time due to corrections for multiple parallel corridors.

Table 2: Comparison of various yarding elements reported by different authors for the Wyssen yarding system in North America.

	Reported Studies					
	Hensel, 1977		Abegg et al., 1986		Akre, 1967	Waelti, 1976
	uphill	Downhill	uphill	downhill	downhill	downhill
Crew size	4.5	4.5	4	4	3	5
Yarding Dist (ft)	1990	1470	2000	2600	2600	2000
cycle time (min)	19.3	11.8	18.3*	15.3*	18.5	23.4 (15.0)**
logs/turn	3.5 - 6	2 - 3.75	N/A	N/A		
(Average)	(4.87)	(3.05)			(2.3)	(3.2)
turn size	96 1.9	0.75 - 0.98	0.22	0.22	0.46	0.90
(MBF/turn)	(0.83)	(0.83)				
slope %	45 - 75	40 - 70	N/A	N/A	50 -60	50-70
# of supports	1	0	N/A	N/A	0	1
Lat yard.dist	50 - 150	50 - 125	30 - 80	30 - 80	150	100-150

*Based on regression equation ** excluding major delays

In summary, the observed North American experiences with Wyssen-type cable systems appeared well correlated with Central European experiences as far as cycle times were concerned. Production was primarily a function of distance and did not vary with silviculture such as clearcut or selective cut (Heinimann, 1984). He also commented that by increasing log lengths yarding production could be increased without impacting cycle times. In most, if not all cases turns were usually fully suspended making the yarding cycle independent of ground or stand conditions.

The effect of suspension on production was well documented by Fieber et al. (1982). One of the requirements for successful long-span operations was full suspension to minimize possible delays caused by dragging turns, especially at the extreme distances.

Several authors in North American studies commented on that fact that yarding distances < 1500- 2000 ft EYD were not economical for Wyssen systems because of the high rigging times (Waeltli, 1976; Hensel, 1977). However, rigging times were not reported to the detail as done in the Swiss appraisal form. Even Hensel (1977) neglected to track rigging time as a variable related to terrain, relative sizes of rigging equipment, and AYD's. Other critical issues were minimum slopes of 40 % to insure gravity transport of the carriage (cord slope > 25%) and timber volumes > 25 MBF/acre, although Akre (1967) reported removal volumes of six to eight MBF/acre. Heinimann (1986) reported a range of 0.7 to 1.2 m3 per meter of skyline as the necessary volume rate for cost efficient operations (or approximately 0.7 to 0.8 MBF per station of skyline), a similar value supported by the Austrian Forests Service.

NORTH AMERICAN TOWER (SLACKLINE) SYSTEMS

Production studies over conventional distances (<2000 ft EYD) are numerous with typical EYD's in the range of 1200 - 1400 ft (Aubuchons, 1982). A 40 - 90 ft tower such as a Thunderbird TTY6160 may characterize typical yarders used in such situations. Engines are rated at > 400 horsepower, and are typically rigged with 2000 feet of 1-1/8 inch skyline. To estimate turn time and eventually production rate a cycle time equation based on work by Peters (1974) was used. Other equations could have been used as reported in Aubuchon (1982).

9. Cycle time $T = 4.443 + 0.00163*AYD$

Production data for slackline operations with yarding distances beyond 2000 ft EYD are rare. Binkley (1965) reports one such study. It includes a three drum yarder (335-horsepower diesel powered BX-185) with large drum capacities (4400 ft of 1-inch mainline and 5700ft of haulback. More modern machines with similar capacities could include, among others, the Thunderbird TY90, Madill yarders (Madill 009 and 046), Skagit BU737, T90 and Washington 137 models. Crew size is usually 5 people and more. Binkley provided cycle time equations based on such variables as crew size (Crew), slope under the skyline (S1), slope perpendicular to the skyline (S2), average number of logs per turn (N), average slope yarding distance (AYD) and lateral slope yarding distance (LYD), and the average volume per turn (V). Binkley provided an additional delay factor as a function of the number of intermediate supports.

10. Cycle time $T = 2.94608 + 0.0819*S1 + 0.8098*I + 0.16345*N + 0.001277*AYD + 0.003839*LYD + 0.000001384*LYD*V + 0.0004127*V + (10\char`^(0.89995 + 0.0020715*LYD))/10 + (10\char`^(0.6147 + 0.3169*S2 + 0.09082*N))/10$

Based on the above cycle time equation an average turn time of 9.02 minutes resulted for an AYD of 1300 ft. The production rates reported were not significantly different for uphill and downhill (gravity) yarding. However, in general practice the downhill yarding was discouraged because of the high level of engineering and field work required to insure full suspension of turns (Binkley, pers. comm., 1999).

Binkley (1965) similarly to Hensel (1977) neglected to track rigging time as a variable despite the rather substantial effect it had on overall production costs. Binkley estimated, for a setup of 1300 feet AYD, a rigging time of 53.7 hrs (crew-hours) per head spar and 26 .7 hrs per tailhold (deadman or multiple stump) respectively. His configuration also required additional 50 man-hours to change corridors (including move in, setup and breakdown) and complete miscellaneous rigging in addition to 22.5 machine hours. Binkley's example included one headspar and tailhold per corridor. It was assumed that the cost of rigging an intermediate support was similar to rigging the head spar. Binkley's time estimates in man-hours seemed high compared to rigging times for modern yarders. However, this time may be appropriate given that extensive and substantial rigging was required to support the extreme forces on the tower and tailhold due to the long spans.

European long-span skylines systems differ from their North American counterpart in horsepower rating and therefore line speeds. The Wyssen W-90 yarder is rated at about 80 to 90 horsepower whereas a North American slackline may range from 400 to 650 horsepower. Line speeds observed for a Wyssen system on an outhaul cycle (under power) may be about 600 ft/min (Akre, 1967). It is not uncommon for slackline yarders to have listed outhaul speeds of up to 2500 ft/min. Binkley (1965) reports a maximum outhaul speed of 2450 ft/min. for the Skagit BX185 yarder.

The effect of line speeds on cycle times is shown in Figure 1. Over comparable distances (< 1000 ft) cycle times for the conventional tower yarders are half the time for the Wyssen systems indicating the effect of line speeds. Cycle times for the Swiss and the Hensel model are very close for the uphill yarding operation and differ by about 15% for the downhill operation. Downhill yarding results in faster cycle times than for uphill yarding for the Wyssen systems because of higher speeds that are attainable with gravity inhaul due to the load. Full suspension, however, is critical. The cycle times for the tower yarder reported by Binkley (1965) are about 60% of the cycle times reported by Abegg et al. (1986) for the downhill direction.

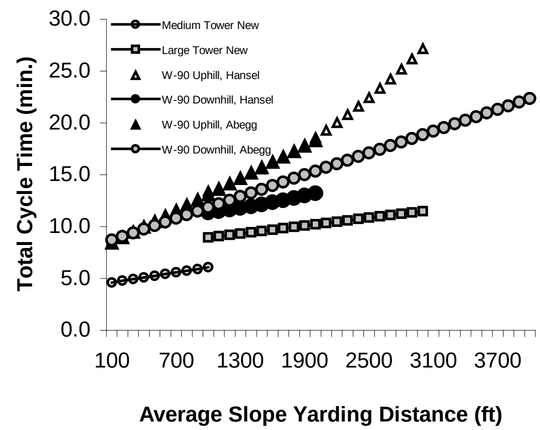

Figure 1: Total cycle times for uphill and downhill yarding for three systems, a conventional tower (EYD<1200 ft), a Wyssen system (Hensel and Abegg) and a large tower (Binkley).

PRODUCTION COST ESTIMATION

The relationship of production cost, (C - $/MBF) with the owning & operating cost rate (R - $/time), production rate (T - MBF/time) and total volume (V - MBF) is summarized in equation 11 and 12 (Peters, 1974).

11 Production cost $C = R*T/V$
12 $C = R*(T_y + T_r) / V$

where T_y = equals yarding time and
T_r = rigging time

For estimation of stump-to-truck production costs, the cost rate (R) and production rate (T) can be sub-divided into rigging and yarding activities (Rr, T_R & Ry, T_Y).

Myata (1982), and Caterpillar (1998) report an in-depth discussion of cost estimation. The total O&O costs reported in Table 3 include rigging and auxiliary equipment, labor, maintenance, fuel, felling, administration, and miscellaneous business costs. The values reported in Table 3 are based on 220 operating days per year, and 8.5 hour operating day, 8.0% interest rate, 1.5% insurance rate, and $1.00 per gallon of #1 diesel fuel.

Table 3: Owning and operating costs for a Wyssen yarder and a conventional yarder based on new and used equipment shown as "depreciated" (World Forestry Institute, 1996).

220 8.5Hr Operating Days	Wyssen*	Depreciated	>70' Tower	Depreciated
Yarder	$179,200	$30,000	$609,250	$71,370
Rigging	$25,000	$25,000	$25,000	$25,000
Carriage	$34,000	$11,827	$43,000	$14,958
Crew	4.5	4.5	5.5	5.5
Total Production Time %	80%	73%	92%	85%
Operating Cost ($/month)	$17,917	$17,136	$20,897	$18,434
Total O&O Cost ($/month)	$35,630	$30,855	$61,891	$51,874

* estimate

Large used tower yarders with pull, line speeds, and drum capacities similar to the Skagit BX-185 yarder are readily available in equipment auctions and advertised in classifieds. The values reported in Table 3 for the depreciated, large tower yarder configuration is based on averages of advertised prices for similar used technologies.

The yarding and rigging times for each of the three systems were estimated over an AYD from 100 feet to 4000 feet, each within its range of observations. Table 4 summarizes the model inputs for the comparison. Corrections were made with regards to the crew size and logs per turn for the conventional tower. An extra crewmember was added as well as one log per turn subtracted. It reflected the shorter time available for hooking a turn when compared to the long-span system where hook time was as high as 6.7 minute (Akre (1967).

Table 4: Variables and their corresponding values used in the production equations to calculate production costs $/MBF for each of the systems for parallel corridors (EYD = 2*AYD)

Slope Under Skyline	45%
Lateral Slope	0%
Harvestable Volume	45 MBF/acre
Average Log Volume	167 BDF/log
Payload	7200 lbs/turn
Intermediate Supports	0
Logs per Turn	4.5
Corridors	4
Lateral Yarding Distance	100 feet
Crew Size	4.5
Daily Operating Hours	8.5
Road Cost	$0 per station

Figure 2a and 2b summarize the results of the inputs provided in Table 4. Figure 2a shows production costs ($/MBF) for uphill yarding (Wyssen systems) and Figure 2b for downhill yarding. In general the Wyssen systems has higher production costs for uphill yarding than for downhill yarding. The reverse is generally true for the tower systems although no correction has been applied to the data presented.

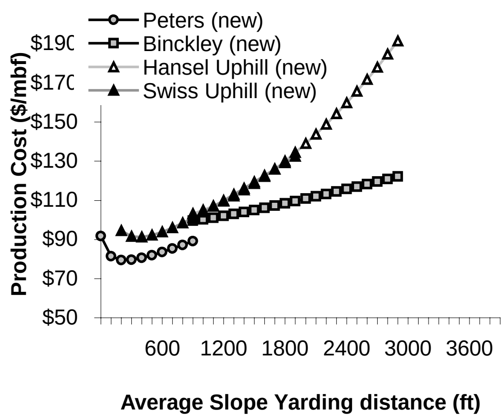

Figure 2a: Up-hill, stump-to-truck production costs for various yarding systems, no intermediate support

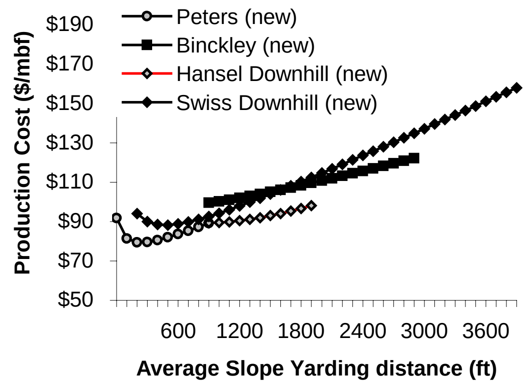

Figure 2b: Down-hill, stump-to-truck production costs for various yarding systems, no intermediate support

The conventional yarding system (Peters) resulted in the lowest production costs and highest production rates over distances from zero to 1000 AYD. The lowest production cost for this example was recorded as $80 per MBF at 350 feet AYD (42.2 MBF/Day). Peters' example ranged from $92 per MBF at 100 feet AYD to $89 per MBF at 1000 feet AYD (37.8 MBF/Day). Overall rigging and yarding times were lowest due to a combination of fast cycle times (high line speeds), short yarding distances and minimal rigging times.

For AYD's exceeding 1000 feet the uphill Wyssen systems showed the highest production costs, ranging from approximately $100 per MBF at 1000 feet AYD to $191 per MBF at 3000 feet AYD (12 MBF/Day). The Swiss downhill production costs from 1000 feet AYD to 1400 feet AYD were actually lower than the example reported by Binkley (1965). The production costs for the Binkley system ranged from $100 per MBF at 1000 feet AYD (33.9 MBF/Day) to $122 per MBF at 3000 feet AYD (27.6 MBF/Day).

DISCUSSION

The results revealed higher production costs for EYD >2000 ft. This is in agreement with surveys of logging contractors who clearly showed a preference for yarding distances less than 1000 ft (Berg and Schiess, 1996). Reasons were increased rigging times and the increased risk for operational delays. In general, optimal AYD increased with increasing rigging times and/or decreasing harvest volumes (MBF/acre) and log/turn size. The optimal AYD is defined as the distance at which the lowest production cost occurs. This observation is in line with Peters (1974) showing that the optimal AYD is proportional to the square root of the rigging time.

Production costs were sensitive to rigging costs (or rigging times). By going from requiring no intermediate support to requiring just one intermediate support (not uncommon for yarding distances >2000 ft as reported by Binkley (1965) and Hensel (1977) yarding costs increased by $10-15.-/MBF for all systems. Depreciated or used equipment provided another opportunity to decrease yarding costs. Typical production costs for used equipment was about $10-15.-/MBF less when compared to new equipment.

Conway (1982) commented on the importance of line speeds. He argued that line speeds were critical to profitability. And high line speeds were only attainable with high-powered, that is, large yarders. It appears that he may be right to a point. Line speeds affect the rate of change of the cost curve. Yarding cost rates for fast machines are not as sensitive to yarding distance as they are for slow machines. For example, the Wyssen systems rigged in an uphill fashion have slower line speeds (higher cycle times) because of the lower power rating of the engines and respond therefore faster to cost increases with increasing distance. When rigged in a downhill fashion gravity increases line speeds the same as for shotgun systems resulting in a lower cost rate increase with increasing distance.

To explore the effect of silviculture on yarding costs two cases were considered. The first case was typical of a regeneration cut of second-growth forests, 50-60 years old with an average volume of 35 MBF/acre and log size of approximately 120 BF/log resulting in a turn size of 6200 lbs. Stump-to-truck cost for a conventional system with an AYD of 600 ft was $103.-/MBF. A comparable large tower system in the same silvicultural situation had stump-to-truck costs of $124.- and $136.-/MBF for AYD's of 1000 and 2000 ft respectively compared with $116.- and $119.-/MBF for a Wyssen system.

The second case was a selection cut in older stands with log sizes of 20 -22 inch (167 BF/log and payload of 9000 lbs. (indicative of east-side condition) and volume removals of 15 MBF/acre. Production costs for a large tower yarder were $116.- and 117.-/MBF for AYD's of 1000 and 2000 ft. Decreasing volumes with increased turn size (such as in selection cuts) had the effect of increasing the optimal AYD. Noticeable was the impact it had on making yarding costs almost independent of distance. Long-span production costs of $116 to 117.-/MBF (AYD's of 1000 – 2000 ft) compared favorably with conventional systems despite higher volume and shorter yarding distances ($103.-/MBF, AYD = 600 ft). Piece or turn size played an important role. With the longer cycle times opportunities exist to maximize payloads in a similar fashion as with helicopter yarding and therefore minimize the impact of distance on yarding costs.

What was not considered were the economics of longer rotation ages and the case of anchor availability for large yarders. However, installations of artificial anchors will have the same affect as intermediate supports, that is increase the optimal AYD.

CONCLUSIONS

Time studies by different authors across a wide range of conditions both silviculturally and geographically agreed surprisingly well. Differences were noted in rigging times reported for long-spans. That may not be as surprising since in most conventional operations (tower and mobile yarders) rigging times and corridor change times were very small and accounted for only a minimal fraction of the overall time required to yard a unit despite several yarder moves.

Long-span systems appeared promising as an appropriate alternative where silvicultural goals included significant dispersed or aggregated retention. In both cases rigging requirements would increase while at the same time reduce the available, total extraction volume but not necessarily the log and turn sizes. Long-span systems had comparable costs to conventional systems, if applied under appropriate silvicultural conditions. Such silvicultural goals might help long-span yarding systems because of the interaction of total volume available, piece size and rigging time requirements as pointed out by Peters (1974).

The interaction of capital cost, line speed and production cost required more attention. The faster line speeds reported by Wyssen for its newest models could alter some of the cost and yarding distance functions.

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