



Forest Service

Northeastern Forest
Experiment Station

Research Paper NE-705



Cycle-Time Equation for the Koller K300 Cable Yarder Operating on Steep Slopes in the Northeast

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Abstract

Describes a delay-free-cycle time equation for the Koller K300 skyline yarder operating on steep slopes in the Northeast. Using the equation, we estimated the average delay-free-cycle time was 5.72 minutes. This means that about 420 cubic feet of material per hour can be produced. The important variables used in the equation were slope yarding distance, lateral yarding distance, volume per turn, and stem volume. Cable yarding has an advantage of minimizing the impact on environmentally sensitive areas, especially when complying with Best Management Practices (BMP's) and other forest practices regulations.

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Manuscript received for publication 4 November 1996

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Published by:
USDA FOREST SERVICE
5 RADNOR CORP CTR SUITE 200
RADNOR PA 19087-4585

For additional copies:
USDA Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015

March 1997

Introduction

Interest has mounted in the use of cable yarding in the Northeast to resolve harvesting concerns related to environmentally sensitive areas and for adverse logging conditions. In addition, regulations such as Best Management Practices (BMP's) have impacted the logging industry in recent years. Other regulations such as the Federal Water Quality Acts (Hohenstein 1987) and town logging ordinances (Goodfellow and Lea 1985) have had impacts also. These political and public concerns require new ways of managing forested lands under a sustainable forest concept.

Conventional rubber-tire skidders have been the mainstay for logging in the Northeast. It is a proven method of logging both for efficiency and cost effectiveness, even on moderate slope conditions. On steeper slopes, however, road costs, environmental impacts, and logging costs increase significantly (Cubbage and Gorse 1994). Huyler and LeDoux (1995) estimated the cost of applying Vermont Acceptable Management Practices (AMP's) to logging on moderate slopes and results indicated that the added cost of compliance using conventional rubber-tire skidding makes cable yarding more attractive when logging in environmentally sensitive areas. Cable yarding has the potential to overcome these problems and, therefore, provide an alternative harvesting system to meet the increased demand for wood fiber from the Northeast. This paper summarizes the production attributes, operating condition, and cycle time equation for a study using the Koller K300 yarder on state forest land in Massachusetts.

The Yarding Study

Yarder Description

The Koller K300 is a small cable-yarder system designed for uphill logging. The machine is compact with simple engineering, and designed for small wood logging and residue removal operations (Fig. 1). The yarder can be mounted on a farm tractor with a 3-point hitch or can be placed on a trailer for easy transportation over long distances.

The system components and capabilities are: (1) the tractor engine must have a minimum of 50 hp, (2) approximate weight without the tractor is 3,500 pounds, (3) average mainline speed for the tractor-mounted version is 630 feet per minute, (4) cable capacity is 1,150 feet of 3/8-inch cable for the mainline, 1,150 feet of 5/8-inch cable for the skyline, and 100 feet of 9/16-inch cable for the guyline, (5) uses multispan self-clamping carriage and can be set up with intermediate supports and tailspar, and (6) the tower height is 23 feet.



Figure 1.—Koller K300 operating on steep slopes.

Study Site and Crew

The study site is located in north-central Massachusetts on Beartown State Forest, Region 5. A bid contract for a timber sale was written to harvest using a cable yarder. The bid was for the purchase of approximately 103,700 board feet and 256 cubic feet of standing timber as marked by the state forester on 30 acres of forest land. The preharvest volume was approximately 12.5 Mbf/acre.

The post-harvest volume was approximately 9 Mbf/acre with a residual basal area of 70 square feet. Trees removed were mainly overmature, good-quality red oak (*Quercus rubra*). The remaining stand had a large proportion of large-diameter hemlock (*Tsuga canadensis*), which explains the

Table 1.—Species and volume marked for cutting on steep slopes

Species	Tree quality	Total Mbf	No. of trees
Red oak	Good	78.575	235
Hemlock	Fair	5.475	21
Red maple	Fair	5.166	32
Yellow birch	Good	4.914	24
Other	Fair	9.546	61

higher than normal volume per acre for the region. Table 1 is the tally sheet for the Koller K300 yarder steep-slope study area.

The mean side slope for the entire sale area is 40 to 50 percent. We measured the side slope on six of the mainline corridors and the average was 55 percent with a minimum of 42 percent and a maximum of 65 percent.

The yarding crew included a yarder operator and a choke setter. Trees were cut before yarding using a directional felling technique by a logging contractor. Usually the trees were felled downslope at a 45° angle to the yarding corridor. This facilitates lateral yarding and reduces the chance of residual stand damage. Communications between yarder operator and the choke setter were by two-way radio.

Time Study Methods

A detailed time and motion study was conducted using the continuous-timing method to determine the total yarding cycle times, which is the amount of time it takes the carriage to travel from the landing area to the woods and the return to the landing and unhook the payload. Six yarding elements were identified and timed to determine the total delay-free yarding cycle time.

Outhaul Empty—Begins when the operator is ready to move the carriage from the landing out to the choke setter, and ends when the choke setter touches the choke.

Lateral Out—Begins at the end of outhaul empty and ends when the choke setter is ready to hook a turn. (Choke setter's forward motion has stopped and is ready to begin setting the chokers).

Hookup—Begins at the end of lateral out and ends when the choke setter has completed hooking the chokers and signals to begin yarding.

Lateral In—Begins at the end of hookup and ends when the turn is pulled up to the carriage and the carriage begins to move up the corridor.

In Haul—Begins at the end of lateral in and ends when the turn has reached the position on the deck where it can be directly unhooked at the landing.

Unhook—Begins at the end of in haul when the carriage passes over the tripblock and ends when the chokers have returned to the carriage.

The work cycle elements were recorded to the nearest one-tenth of a minute. The time data were recorded by two forestry technicians who were trained in continuous-timing study techniques. One technician was stationed in the woods at the hookup location and the second technician was stationed at the landing. Communication was maintained by two-way radios. Over the corridors studied, 80 total cycle times were recorded which comprised the data base for the cycle-time equation analysis.

In addition to the total yarding cycle time, delay time must be considered. Delay time is important to the harvesting operation because it has a direct impact on the final cost of production. The delay percentage can be used to adjust the delay-free-cycle time equation and therefore the cost of production. The cause of each delay was recorded and timed to the nearest one-tenth of a minute. Three categories of delays were used in the delay analysis as follows: (1) operational delay, (2) mechanical delay, and (3) nonproductive delay, which represents delays associated with the principal operating functions of the system.

In addition to the yarding delays and cycle elements, the following yarding variables were recorded and summarized:

Skyline Slope Distance—On each corridor, the ground slope distance in feet was measured and marked at regular intervals to aid in recording slope distance that the carriage traveled during the study period.

Lateral Distance—The lateral yarding distance in feet was measured either by pacing the distance or by ocular estimation of the distance to the nearest 10 feet.

Volume—Each piece was measured in the corridor and marked with an identification number and recorded by turn number. The large- and small-end diameters (dib) and length were scaled, and volume was determined by use of Smalian's Formula.

Number of Pieces Per Turn—The number of stems per cycle (payload) were recorded.

Results

Cycle-Time Equation

Regression analysis was performed on the Koller K300 time study data to develop a delay-free-cycle time equation for the machine under the stand conditions stated in the study. The variables included slope yarding distance, lateral yarding distance, volume per turn in cubic feet, and stem volume in cubic feet. The stem volume variable was transformed using the reciprocal to improve the

Table 2.—Mean, standard deviations, and minimum and maximum variable limits, by yarding attributes

Attributes	Mean	Standard deviation	Minimum	Maximum
Slope yarding distance (feet)	425.3	196.82	100.0	675.0
Lateral distance (feet)	27.5	34.50	0.0	150.0
Piece volume per turn (cubic feet)	35.2	14.09	13.0	92.1
Number of pieces per turn	1.5	.38	1.0	2.0

predictability of the equation. The cycle-time equation for the Koller K300 took the form:

$$\text{Cycle time (in minutes)} = .223 + .004 (\text{Syd}) + .024 (\text{Ld}) + .059 (\text{Tv}) + 35.23 (1/\text{Sv}) \quad (1)$$

Where:

Syd = slope yarding distance in feet

Ld = lateral distance in feet

Tv = turn volume in cubic feet

Sv = stem volume in cubic feet

$$R^2 = .67$$

The yarding site attributes given in Table 2 are typical of the cable-yarding operations for the equipment and site and timber sale conditions in the Northeast. The equation is machine specific, and the variable limits (see Table 2) should be observed carefully.

An example of the use of the cycle-time equation follows. If we assume that the harvesting operation has a slope yarding distance of 380 feet, an average lateral yarding distance of 25 feet, a volume per turn of 40 cubic feet, and a stem volume of 35 cubic feet, the delay-free-cycle time would be 5.72 minutes. This represents about 10.5 turns per hour and with an average payload of 40 cubic feet per turn would be about 420 cubic feet per hour or about 2.250 Mbf per productive hour.

In similar studies of the Koller K300 by Rossie (1983), similar results were shown in estimating the cycle-time equation. Testing the same four variables as we did in this study, Rossie also found that slope yarding distance and lateral yarding distance had a significant influence on the outcome of the cycle-time prediction model. Also, in a study that included the Koller K300 integrated with a rubber-tire skidder, McIntire (1981) indicated that slope yarding distance, lateral distance, and tree size were influential on the outcome of the prediction model.

Production vs. Delay Time

The productive time or the machine utilization rate for the Koller K300 in this study was 65 percent of the total on-site time. From Figure 2, the operational delay accounted for 21 percent of the total cycle time. For example, the predominant delays were caused by chokers caught either at the log deck or in the lateral yarding hookup element. Also, waiting for the choke setter and choke release failures at the log landing caused delays. Mechanical delays or mechanical failures of the system accounted for 10 percent of the total cycle time. Examples of these delays were mainline breaks, mechanical failure of the carriage, and hydraulic line failures. The category, nonproductive delays, accounted for 4 percent of the total cycle time. These delays were associated with personal time and talking with either choke setter, the on-site forester, or the research team.

Environmental delay is another category that will more than likely become an important part of the total productive time and therefore cost of production in the future. These would include weather-related delays and delays associated with compliance with Best Management Practices (BMP's) in logging operations. Although these kinds of delays did not occur in our study, they should be considered when estimating the annual scheduled hours of operation for any yarding system. Cable yarding has the distinct advantage over other types of harvesting by reducing the number of skid and haul roads, which minimizes the chance of skid trail erosion and water sedimentation.

As an example of the importance of delay time on the overall cycle time for the yarder, consider the following. We estimated the delay-free cycle time for the Koller K300 to be about 5.72 minutes per cycle. If we adjust the delay-free cycle time with our total delay percentage of 35 percent, it increases our total cycle time to 8.80 minutes per cycle, and this converts to about 6.9 turns per hour.

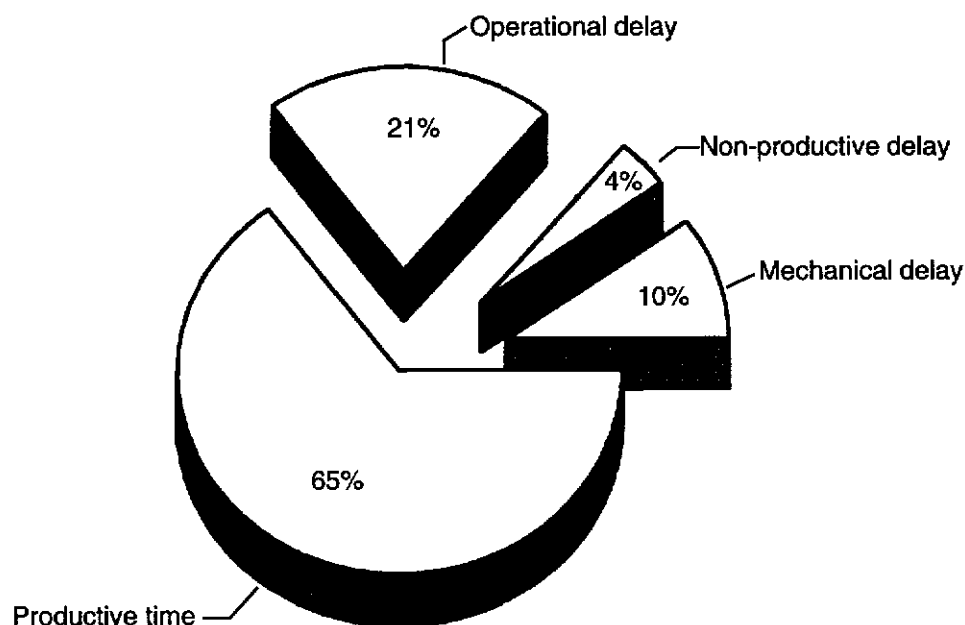


Figure 2.—Delay analysis.

Conclusion

The Koller K300 yarder cycle-time equation is both machine specific and site specific. This yarder, and other similar yarders on different timber sales, may experience different cycle times and therefore different production levels. However, use of the cycle-time equation for the Koller K300 gives forest operators a management tool for use in estimating production levels and cost of production on similar harvesting operations.

Cable yarding is not used much in the Northeast. In general, the reason given is that it takes more time for preplanning the logging operation. However, once in place, the production rate on steep slopes is comparable to the ground-base systems. Most operations using cable yarders are feasible when operating in a high-product-yield stand and when factors affecting production have been carefully evaluated. Cable yarding also has the advantage of minimizing the impact on environmentally sensitive areas, especially when complying with BMP's and other forest practice regulations. Also, it can be integrated into ecosystem management goals and sustainable forestry practices.

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Huyler, Neil K.; LeDoux, Chris B. 1997. **Cycle-time equation for the Koller K300 cable yarder operating on steep slopes in the Northeast.** Res. Pap. NE-705. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.

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Keywords: cable yarder, cycle time, production, equation



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