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# TB10: A Comparison of Arch-yarding and Ground-skidding of Pine Sawlogs in the University of Maine Forest

Henry A. Plummer

Roger F. Taylor

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**A comparison of  
Arch-yarding and Ground-skidding of  
pine sawlogs in the University of Maine forest**

**A case study by Thomas J. Corcoran  
Henry A. Plummer  
Roger F. Taylor**



## LIST OF FORESTRY PUBLICATIONS

- Bulletin 554. Marketing forest products from small woodland areas in Maine. Gregory Baker and Frank Beyer. 1956.
- Misc. Pub. 651. How Maine sawmills market their lumber. Gregory Baker. 1961
- Bulletin 601. Forest plantations in Maine. Robert I. Ashman. 1962
- Bulletin 614. A plan for the recreational development of the Machias Lakes region in Washington County, Maine. A Temple Bowen, Jr. 1963
- Bulletin 616. The integration of year round recreation and timberland management of the Passadumkeag Mountain region of eastern Maine. Robert Greenleaf. 1963
- Bulletin 615. Marketing Maine lumber to the northeastern building construction industry. Samuel M. Brock. 1963 (available in libraries only)
- Bulletin 620. The relationship of maximum peat depth to some environmental factors in bogs and swamps in Maine. Richard A. Kennedy. 1963
- Misc. Pub. 658. Recreational use of private land in a portion of eastern Maine. Bruce E. Stewart. 1963
- Misc. Pub. 659. A plan for the recreational development of the University of Maine Forest. Bruce E. Stewart. 1964
- Tech. Bul T-7. Scheduling of pallet trucks in pulpwood operations. Thomas J. Corcoran. 1964
- Bulletin 621. The market for lumber in Maine manufacturing industries. Samuel M. Brock. 1964
- Tech. Bul T-10. A comparison of arch-yarding and ground-skidding of pine sawlogs on the University Forest. Thomas J. Corcoran, Henry A. Plummer and Roger F. Taylor.
- Tech. Bul T-12. Preliminary fresh and dry weight tables for seven tree species in Maine. Harold E. Young, Lars Strand and Russell Alterberger. 1964

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## SUMMARY

The decision whether to use a trailing-arch or operate by ground-skidding methods may face many a sawlog producer. This case study attempted to determine statistically whether there existed significant differences between the two methods of operation by examining the various activities performed by a crawler-type tractor within the arch-yarding and ground-skidding phases of a harvesting system. These activities, defined as components of the skidding or yarding phase, were related to a set of variables describing some of the physical conditions encountered. The components included return trip, positioning for bunching, bunching, load trip, unloading, decking, and delay.

Study data were collected from pine sawlog operations on the University Forest over a two-year period. Based solely upon cycle time comparisons, expressed as a linear function of distance and load size, there appeared to be no significant advantages attributable to either method of operation. However, differences were noted in some specific activities such as decking time.

Since cycle time proved to be an incomplete basis for selection, suggestions of other factors on which to base judgments were advanced.

# A COMPARISON OF ARCH-YARDING AND GROUND-SKIDDING OF PINE SAWLOGS ON UNIVERSITY FOREST

## A CASE STUDY

Thomas J. Corcoran, Henry A. Plummer, Roger F. Taylor<sup>1</sup>

### INTRODUCTION

A harvesting system in sawlog operations can usually be subdivided into a number of phases such as felling, bucking, skidding, loading, and hauling. Each of these phases can be said to be dependent upon the successful completion of the preceding phase. While a balance between these phases is essential for the overall efficiency of the harvesting system, it is also important that specific activities within each phase be recognized and evaluated. In this way, the effectiveness of any phase can be more thoroughly understood when compared with alternative methods or related to the other phases of the harvesting operation. The study of intra-phaseal activities or phase components provides, for example, as much insight into the skidding process as does the study of the afore-mentioned phases into the entire logging system.

The costs associated with the skidding or varding process are generally assigned on a unit-volume basis as a function of the time spent in these operations by the men and equipment involved. Quite often these costs are developed as a combination of fixed charges as well as operating charges, both placed on an hourly basis. Since production rates and costs quite naturally vary with the region or the locality of interest, investigation into phases of harvesting operations have been widely conducted in North America.<sup>2</sup> Consequently,

<sup>1</sup>Assistant Professor of Forestry, Associate Professor of Forestry, and Superintendent of University Forest, respectively.

Campbell, R.A. 1953. *Logging methods and costs in the Southern Appalachians*. U.S.F.S. Southeastern For. Exp. Sta. Paper No. 30. 29 pp.

Jiles, R. A. and J. W. Lehman 1960. *Hardwood logging methods and costs in the Tennessee Valley*. T.V.A. Div. Forestry Rel., Report No. 232-60. 40 pp.

Doyle, J. A. and W. W. Calvert 1961. *Effect of tree size of jack pine on harvesting and conversion to lumber in Northern Ontario*. Forest Products Research Branch (Ottawa) Tech. Note No. 19. 26 pp.

Schnell, Robert L. 1961. *Harvesting pine pulpwood in the Tennessee Valley*. T.V.A. Div. Forestry Rel., Rept. 238-61. 20 pp.

Boe, Kenneth N. 1963. *Tractor-logging costs and production in old-growth redwood forests*. Pacific S. W. Forest & Range Expt. Sta. Res. Paper PSW-8. pp. 16.

their results are subject to operating conditions, wage and other cost structures, and equipment arrangements encountered in the particular areas. Unlike the cited studies, which are broad in scope in that they consider many harvesting phases and represent aggregate data from a varying number of commercial sites, this investigation attempts to isolate the specific activities of a tractor operating as a single unit on pine sawlogs under some controlled conditions for the purpose of comparing two methods of its use. More specifically this study's objectives can be enumerated as follows:

- a) subdivide the activities of a medium-size tractor, engaged as a single unit in the activities of ground-skidding or arch-yarding pine sawlogs, into similar phase components and define these components for evaluation by time-study;
- b) determine and relate the degree of effect that selected variables have on the times required to accomplish the phase components; and
- c) establish whether real differences exist between ground-skidding and arch-yarding methods under the conditions proposed.

## STUDY METHODS

The University Forest, a property of the University of Maine under control of the School of Forestry, is comprised of approximately 1600 forested acres. This tract serves as a field laboratory and as a research area for forestry, wildlife management, and related fields of study. Concurrent with the above uses the forest produces an annual harvest of various primary forest products. A sizable proportion of the annual cut can be attributed to forestry students working on a part-time basis under the direction of the forest superintendent.

### **Study Area**

The study was conducted on a 33.3-acre area of the University Forest known as "The Sewall Pines" which supports a white pine volume of approximately 14,500 board feet per acre. This area is well-drained and quite level. Approximately 20,000 board feet of white pine were harvested under the shelterwood method from a total area of 14 acres during the two study years (1962 and 1963). In each of these years investigations were confined to a period in April and May during which time, weather and ground conditions were considered to have a constant but negligible effect on production rates.

### **Study Equipment**

The crawler-type tractor utilized throughout the study was powered by a 40-engine-horsepower, 4-cylinder, high torque, gasoline

engine. This unit was equipped with a 4-roller track frame and 14-inch snow-type track shoes, as well as full length bottom plate and a direction reverser. Additional tractor equipment included an inside-mounted bulldozer blade and a PTO-driven, integral, rear mounted winch. A rubber-tired trailing arch was used for the arch-yarding portion of the study.

The above-mentioned equipment is part of the regular operating facilities of the University Forest and was not acquired specifically for purposes of this investigation.

### **Phase Components**

A tractor, when functioning in skidding or yarding, performs a sequence or cycle of activities. The focal point of this cycle in a sawlog operation is the sawlogs themselves. The subdivision of the tractor cycle into recognizable intra-phaseal activities or phase components requires judgment as to the degree of delineation. For purposes of this study, seven phase components were defined for time-study measurement. These include:

*Return trip* — the forward movement of the tractor from a log-decking landing after the last log is in position on the deck to the vicinity of the next logs awaiting pick-up.

*Positioning for bunching* — any tractor movement, other than the direct forward movement of the return trip, occurring in the vicinity of the logs ready for pick-up that results in the tractor being in a better position for bunching. Normally this implies a backing motion from a stop position of the return trip. Positioning for bunching need not necessarily occur in every cycle.

*Bunching* — the bundling of logs into a position behind the tractor or raised on the arch for subsequent movement to the decking area. This is accomplished by repeated winching by cable of individual logs or small groups of logs that have been prechoked and that will in aggregate form a bundle or load to be carried by the tractor. The capacity of each load is left to the judgment of the choker-setter and the tractor operator.

*Load trip* — the forward movement from the position of load make-up of the tractor and its load toward and to the landing area.

*Unloading* — the separation of individual logs from the bundle of logs by releasing the cable-chokers, or choker-tongs, from both the main cable hook and from the logs themselves.

*Decking* — the action by which the tractor stacks logs upon each other to form a deck of logs in the landing area. Any backing or forward motion which results in logs being decked or from logs having been decked is chargeable to the decking component.





LOAD TRIP



DECKING

Figure 1. The crawler performing the activities associated with two of the phase components.

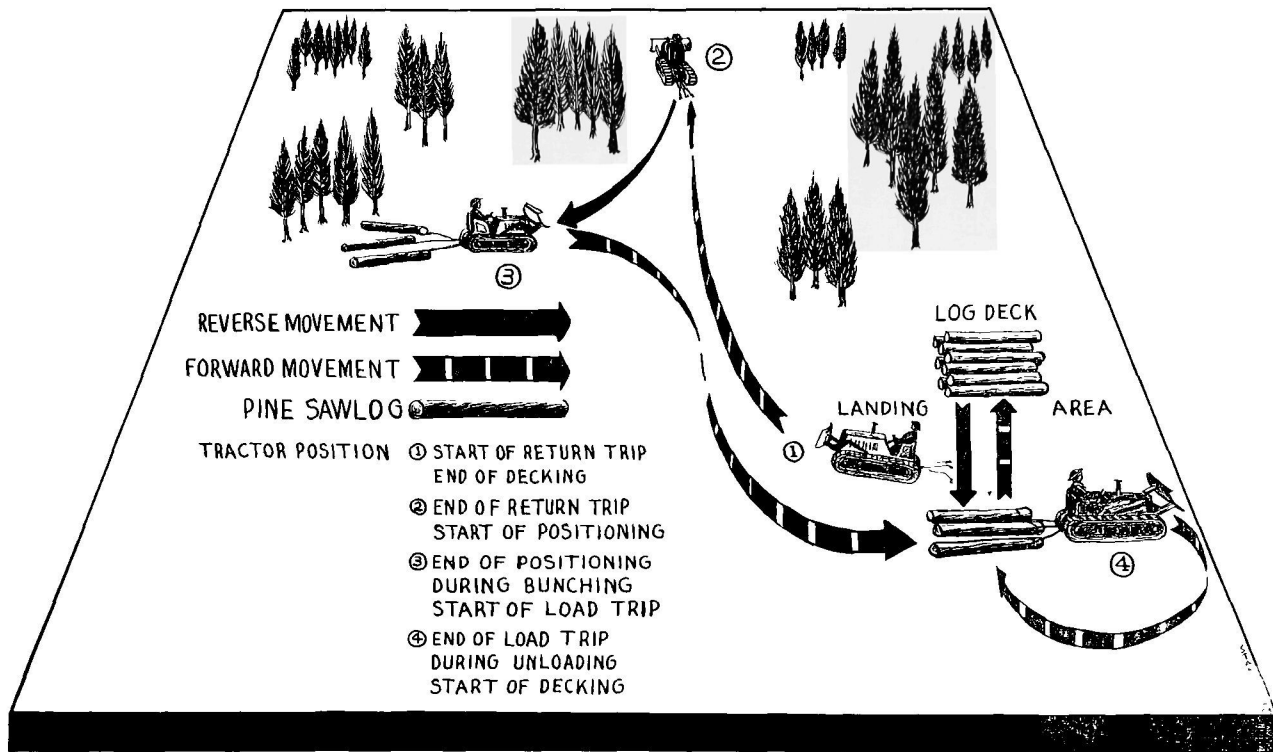


Figure 2. A schematic representation of the activities in an operating cycle for a pine sawlog operation.

*Delay* — stoppage for any cause during normal activities in any phase component.

Each of the above phase components of a skidding and yarding cycle can be differentiated by either a complete stop or distinct hesitating action of the tractor before it proceeds into a subsequent component. While other arrangements as to subdivision of tractor activities are possible, it must be cautioned that the initiation of a phase component should be distinguishable during observation from the completion of the preceding phase for proper evaluation by time-study methods. This reduces the possibility of overlapping the phase components and, therefore, allows more precise time determinations around each component.

Some of the phase components are illustrated in figure 1 and schematically described in figure 2.

### **Measurements**

Time-study techniques were employed, with phase components of 75 complete cycles measured by stop watch to the nearest second. For each individual cycle the load volume and number of logs in that load were determined, as was the distance of the load trip. Slope and other terrain factors were not measured because of the uniform ground conditions of the study area. A day's operations were divided into quarters with ground-skidding, for example, undertaken during the first and last quarters and arch-yarding during the second and third quarters. The following day the procedure was reversed. This was done to minimize any position effect that might have occurred. The data were reported on a standard form with time in minutes and seconds, volume in board feet (International 1/4 inch Log Rule Scale), logs in number, and distance in feet.

## ANALYSIS and RESULTS

### **Estimating Equations**

The time required to complete the activities inherent in a phase component can be influenced by many factors. These times, therefore, are dependent upon a set of conditions or independent factors. As noted above the independent factors measured in the progress of this study were distance and load size. Averages and ranges for the independent variables are reported in table 1. Not all phase components are influenced by the same set of variables. For example, return-trip time was dependent only on the distance that a tractor must move — load size having no effect (not affecting). In positioning for bunching none of the independent variables were considered to affect the time of this phase component. However, distance and

load size criteria conceivably do influence the time of the load trip. Whether the independent variables significantly influenced the time of phase component or of the total operation was determined during the linear regression analysis procedures used in this study. The number of variables developed initially in each regression equation was based upon a judgment as to a conceivable effect. Those independent variables that proved not significant in their contribution to time were eliminated from the estimating equations recorded in table 2. The independent variables were sequentially entered into a predicting equation in descending order of importance of their contribution to time. Therefore, an independent variable that is not significant can be interpreted as having no particular effect on time in combination with other variables already recognized as higher contributors to this effect. The appendix (page 16) presents the relationship of all independent variables to their respective phase components and a summary of the percentage of variation in predicted time accounted for by significant and non-significant variables ( $R^2$ ).

The relationship between the variables of the equations in table 2 can be illustrated with the following example. For a skidding distance of 400 feet and a load size of 290 board feet in 3 logs, the total cycle time of the skidding operation can be estimated from the equation:

$75.61 + 0.920 (X_1) + 116.140 (X_2) =$  Total cycle time for skidding operation.

$75.61 + 0.920 (400) + 116.140(3) = 792$  seconds or 13.2 minutes

Some phase components are not represented by equations in the table because the independent variables were considered as not affecting the phase component or were not significant in their effect. The latter was the case for both decking and delay. However, these phase components can be approximated by their average times presented in table 3. Within-variable analysis of variance for positioning-for-bunching phase component indicated a highly significant time difference between crawler positioning with the arch and without the arch.

### Comparison Test

A comparison between arch-yarding and ground-skidding times for the various phase components and the whole operating cycle was made adjusting for the variability of individual cycle data associated with the recognized independent variables encountered by the two operating methods. Covariance analysis revealed that elevation and

TABLE 1

Average values and ranges of values for distance, volume, log numbers within types of operations

Type of Operation	One Way Distance		Load Volume		Logs in Load	
	Average	Range	Average	Range	Average	Range
	(ft.)	(ft.)	(bd. ft.)	(bd. ft.)	(no.)	(no.)
Arch-yarding	241.1	33 - 611	246.7	70 - 450	2.8	2 - 4
Ground-skidding	267.4	33 - 652	203.4	50 - 435	2.4	1 - 4
Significance between type averages*	Not Significant	- -	Not Significant	- -	Not Significant	- -

\* Within-variable analysis of variance.

TABLE 2  
Regression equations for estimated activity times  
of phase components in seconds by operation type.

ARCH-YARDING		
27.78	$0.327(X_1)$	Return trip time
-141.69 +	$0.365(X_2)$	$84.277(X_3) =$ Bunching time
12.20	$0.532(X_1)$	Load trip time
15.09 +	$14.720(X_3)$	= Unloading time
48.11 +	$1.087(X_1) + 119.322(X_3)$	= Total yarding time per cycle
and		
GROUND-SKIDDING:		
39.98 +	$0.258(X_1)$	Return trip time
8.05 +	$60.388(X_2)$	= Bunching time
15.65 +	$0.348(X_1)$	Load trip time
8.63	$23.220(X_3)$	Unloading time
75.61 +	$0.920(X_1) + 116.140(X_3)$	= Total skidding time per cycle
Where		
$X_1$	one-way distance in feet	
$X_2$	volume of load in board feet	
$X_3$	number of logs in load	

slopes of corresponding regression equations were not significantly different except for the decking regression which proved to be significant in elevation. This suggested that corresponding non-significant regressions could be combined into a single regression.

However, this was not done because, with a tractor operating as a single unit, a judgment made to use an arch would preclude the other possibility of not using the arch. In addition, it was deemed that a combined estimating equation for some phase components and not for others would serve little purpose, even though in some cases the combined equation might be statistically greater in strength.

### Computations

The regression analysis, within-variable analysis of variance, and the analysis of covariance including applicable F-tests were accomplished through the service of a digital computer.

## DISCUSSION and CONCLUSIONS

The comparison of the total operating cycle for ground-skidding and arch-yarding revealed no significant differences between the two methods when operating on reasonably level terrain under the described conditions. While there were some differences in specific phase components, the over-all effect of using an arch did not prove to be of benefit. In fact, the average ground-skidding time for a complete cycle was less than that of arch-yarding. However, even this unproven difference tends to become minimal with the exclusion of

TABLE 3

Average times and ranges of time for phase components within types of operations

Phase components	Arch-yarding		Ground-skidding		Significance between type averages °
	Average (secs.)	Range (secs.)	Average (secs.)	Range (secs.)	
Return trip	106.6	17-273	109.0	19-240	Not significant
Positioning for bunching	39.0	0-184	20.0	0-70	Highly significant (1%)
Bunching	181.3	32-460	155.9	33-368	Not significant
Load trip	140.4	22-468	140.3	31-254	Not significant
Unloading	55.8	21-117	65.1	17-138	Not significant
Decking	91.0	34-190	71.5	33-168	Significant (5%)
Delay	27.2	0-216	45.3	0-384	Not significant
Total operation cycle	641.3	160-1669	607.1	190-1285	Not significant

° Within-variable analysis of variance.

decking activities, which, for some operating systems, may not be included in the skidding or yarding function.

Any judgment as to use of the arch for sawlog operations should, if possible, weigh factors that have been considered exterior to and not in the realm of this study. One such factor may be the skill of the tractor operator. Significant differences between the two operating methods in positioning for bunching and decking give evidence to the possibility that, because a backing-up motion is required in these phase components, the presence of an arch behind the tractor provides the operator with added difficulties in maneuvering.

Naturally, these differences and others could be attributed to a variety of reasons. The reporting of statistical differences and the percentages of variation in time accounted for by significant and non-significant independent variables allows the reader to reach independent conclusions whether or not suggestions have been advanced herein.

In this regard, it should be noted that for some phase components less than half their variation in completion time was accounted for by the measured independent variables. Obviously some other factors that have not been recognized are making a notable contribution to time. Nevertheless, for most phase components at least one or more independent variables have proven to be significant factors and, considering the inherent diversity encountered in day-to-day logging activities, it is suggested that  $R^2$  values in the neighborhood of 36 percent represent a reasonably strong relationship. Significant  $R^2$  values of this study ranged from 16 percent to 81 percent in the case of load trip (appendix). For the total operating cycle under both methods of operation over 50 percent of the variation in cycle time was accounted for by distance between load make-up area and the landing and the number of logs in the load.

Other points of consideration in choosing equipment for secondary transportation methods in sawlog operations include:

1. the efficiency of other contributing crew members;
2. advantages of keeping logs relatively clean and free from gravel, dirt, etc.;
3. preservation of skid-trails and roads;
4. initial cost of equipment and subsequent up-keep costs; and
5. physical land and operating conditions encountered.



APPENDIX

Summary of relationships between independent and dependent variables

Phase component	Type of operation	Intercept	One way distance coefficient (ft.)	Load volume coefficient (bd. ft.)	Logs in load coefficient (number)	Significant variables	All affecting variables
		a	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	R <sup>2</sup>	R <sup>2</sup>
Return trip	Arch-yarding <sup>o</sup>	27.78	0.327	Not affecting	Not affecting	61	61
	Ground-skidding	39.98	0.258	Not affecting	Not affecting	54	54
Positioning for bunching	Arch-yarding <sup>o</sup>	39.03*	Not affecting	Not affecting	Not affecting	—	—
	Ground-skidding	20.03*	Not affecting	Not affecting	Not affecting	—	—
Bunching	Arch-yarding <sup>o</sup>	-141.69	Not affecting	0.365	84.277	39	39
	Ground-skidding	8.05	Not affecting	Not significant	60.388	34	38
Load trip	Arch-yarding	12.20	0.532	Not significant	Not significant	63	64
	Ground-skidding	15.65	0.348	Not significant	Not significant	81	83
Unloading	Arch-yarding	15.09	Not affecting	Not significant	14.720	16	18
	Ground-skidding	8.63	Not affecting	Not significant	23.220	47	49
Decking	Arch-yarding	91.03*	Not affecting	Not significant	Not significant	—	1
	Ground-skidding	71.51*	Not affecting	Not significant	Not significant	—	4
Delay Total operation cycle	Arch-yarding	27.24*	Not significant	Not significant	Not significant	—	8
	Ground-skidding	45.30*	Not significant	Not significant	Not significant	—	9
cycle	Arch-yarding	48.11	1.087	Not significant	119.322	52	54
	Ground-skidding	75.61	0.920	Not significant	116.140	63	67

<sup>o</sup> Average values (see table 3)