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DESIGNING
Efficient Logging Systems for Northern Hardwoods, Using Equipment Production Capabilities and Costs

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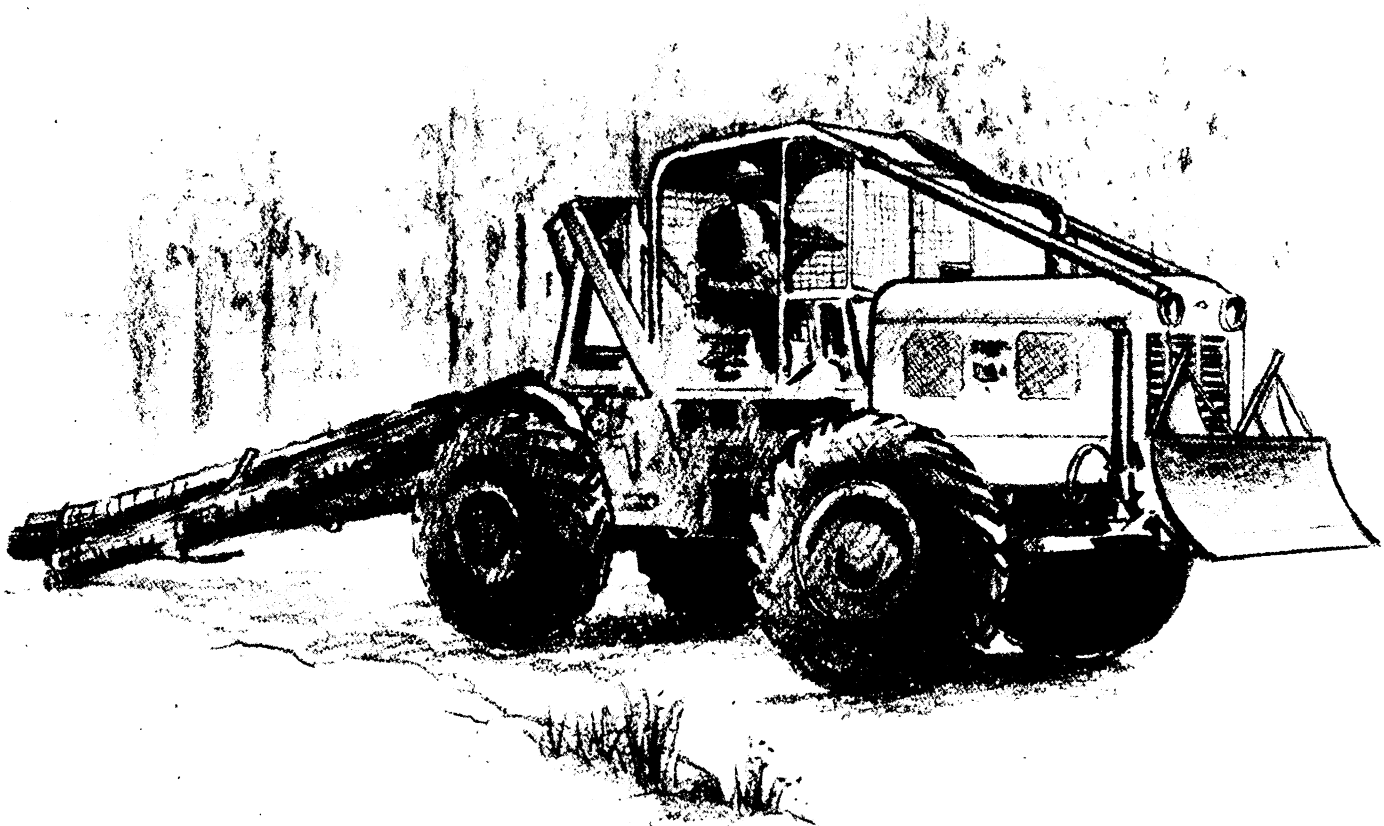

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CONTENTS

Designing Efficient Logging Systems For Northern Hardwoods

Using Equipment Production Capabilities and Costs

R. B. GARDNER

Equipment available to loggers today covers a wide range of types and capabilities. Many loggers lose considerable profits by failing to design an efficient system and by operating equipment in other than optimum range for given conditions.

The essential elements for analysis and design of a logging system are: (1) Specifications of the conditions of a logging operation (size and type of stand, number of trees to be cut per acre, skidding and hauling distances, etc.), (2) an analysis of each step of the operation (such as felling, bucking, skidding) and the conditions under which each will be carried out (soil, slope, amount of brush, etc.), and (3) a knowledge of the equipment available and its limitations for each operation.

The first sections in this paper describe a typical logging system used in the Lake States and Northeastern States, discuss each step in the operation, and present a simple method for designing an efficient system for such an operation.

The last part of the paper discusses specific equipment types and gives production capabilities and costs under conditions typical of the region.

No attempt is made to present a rigorous treatment of all logging equipment and operating conditions. The methods presented here, however, can be used to estimate equipment performance under many operating conditions and should be helpful in designing improved logging systems for the Lake and Northeastern States.

A Typical Logging System

A typical but not necessarily average logging system often used for both sawtimber and pulpwood harvesting in the northern forest types may call for the following equipment and manpower:

- A 4-ton tracked vehicle.
- A 6-horsepower power saw.
- A 150-horsepower truck; stake body of approximately 2.0 MBF (thousand board feet) capacity.
- A 3,500-pound capacity hydraulic or cable loader (may be mounted on the hauling unit).
- Three men—feller-bucker, skidder operator, and truck driver-loader.

NOTE: R. B. Gardner, at the time this information was collected, was the Project Leader and Principal Civil Engineer at the North Central Forest Experiment Station, Forest Engineering Laboratory, Houghton, Mich., and is now in charge of forest engineering research for the Intermountain Forest and Range Experiment Station, Bozeman, Mont. The Forest Engineering Laboratory at Houghton is maintained in cooperation with Michigan Technological University.

Table 1 shows the average cost, manpower, and mechanization level of a typical operation. Total production is 1.2 thousand board feet per man-day. The mechanization level in each operation is indicated by its percentage of the total mechanical energy demand.

The table reveals two important facts: (1) Nearly 50 percent of the manpower is used in lopping, bucking, and skidding. Obviously greater mechanization is needed to lower manpower requirements for these operations. (2) Sixty-four percent of the mechanical energy is used in hauling. Although hauling is completely mechanized, more planning effort is required to obtain optimum hauling capacity in relation to the rest of the harvesting system. The following discussions will show how these objectives can be accomplished.

Table 1.—Costs, manpower, and mechanization level for each operation of a typical logging system

Operation	Cost: Per MBF[1]	Cost: Percent of total	Man-days: Per MBF[1]	Man-days: Percent of total	Mechanical energy: Foot pounds (million)	Mechanical energy: Percent of total
Felling	$ 1.40	6	.100	12	3.2	0.6
Lopping & bucking	7.50	32	.234	28	15.2	2.9
Skidding	7.00	29	.168	20	34.8	6.7
Loading	1.70	7	.084	10	66.6	12.9
Hauling[2]	4.65	19	.168	20	330.0	64.0
Unloading	1.70	7	.084	10	66.6	12.9
Total	$23.95	100	[3] .838	100	516.4	100.0

[1] MBF = thousand board feet.
[2] Based on a 25-mile haul.
[3] Or 1.20 MBF per man-day.

Operations and Equipment

Felling and Bucking

To assist in analyzing felling and bucking operations, they have been subdivided into their six principal elements. The times given are attainable with an efficient operation (from Merz *et al* 1965).

Item	*Man-minutes per MBF*	*Percent of time*
Travel between trees	3.88	6.4
Felling	11.96	19.8
Limbing and marking	12.71	21.0
Bucking	9.62	15.9
Maintenance	12.00	19.8
Rest	10.33	17.1
Total	60.50	100.0

The figures apply to an average sawtimber stand of central hardwoods using one-man crews. One-man crews are more efficient than two-man crews.

The slope of the ground, excluding extremely steep slopes, has little effect on total production. If bucking is done at the landing, the times can be slightly reduced; but, more important, grade recovery can often be increased.

Skidding, Bunching, and Decking

Skidding and bunching production depends on slope, soil, tree size, stand density, season of the year, distance, amount of brush and down timber, silvicultural requirements, and logging methods. (See a later section of this Paper for typical skidding production capabilities.) Decking production depends only on the slope of ground, height of piles, and size of timber.

Soil properties and ground slope are the most critical variables influencing equipment operation. Table 2 shows the influence of slope on the performance of different equipment types using two skidding methods (ground and arch) and two slopes (level and 30+ percent). (Also see figs. 5 and 7 in a later section.)

The maximum load values in table 2 were computed from information found in Herrick's (1955) skidding studies made in cooperation with Caterpillar Tractor Company in southern Illinois. When soil conditions differ from those used in Herrick's study, methods developed by Bekker (1959, 1960) can be employed to compute drawbar pull capabilities for

Table 2.—*Maximum skidding loads, assuming a rolling resistance of 130 pounds per ton for crawler tractors and 90 pounds per ton for rubber-tired tractors (dry silty clay loam soil)*

Horsepower (B=Brake; DB=Drawbar)	Speed (miles per hour)	Maximum drawbar pull (pounds)	Skidding method	Maximum load: On level ground	Maximum load: With a 30+ percent slope[1/]	No. of 16-inch d.b.h.[2/] trees per load: On level ground	No. of 16-inch d.b.h.[2/] trees per load: With a 30+ percent slope[1/]
			STANDARD CRAWLER TRACTOR				
25 DB	2.4	5,000	Ground	5,600	4,200	3.7	2.9
	(2nd gear)		Arch	7,100	4,600	4.9	3.2
48 DB	2.4	10,000	Ground	11,200	9,000	7.5	6.0
	(2nd gear)		Arch	15,000	10,000	10.5	7.0
			RUBBER-MOUNTED CRAWLER TRACTOR				
115 B	4.0	5,000	Ground	5,600	4,200	3.7	2.9
	(1st gear)		Arch	7,100	4,600	4.9	3.2
			RUBBER-TIRED TRACTOR				
61 B	3.5	5,400	Ground	6,000	4,500	4.2	3.1
	(1st gear)		Arch	7,500	5,200	5.2	3.6
61 B	6.0	3,500	Ground	3,800	2,900	2.7	2.0
	(2nd gear)		Arch	4,200	3,000	2.9	2.1
58 DB	3.5	6,300	Ground	6,900	5,300	4.8	3.7
	(1st gear)		Arch	9,000	6,300	6.3	4.4

1/ For downhill skidding the arch maintains a near constant 200-percent advantage over ground skidding.

2/ d.b.h. = Diameter breast high. (A tree-length weight for hard maple of 1,430 pounds was used for determining the number of trees.)

tracked and rubber-tired vehicles for any combinations of the soil properties of porosity, moisture content, bearing strength, angle of friction, and coefficient of cohesion. The effect that slope has on drawbar pull for soils that have a different rolling resistance than that used in table 2 will be increased or decreased in nearly the same proportion to the maximum drawbar pull as those shown in the table.

Techniques for assessing the influence of brush and down timber, silvicultural requirements, and logging methods on skidding production are very difficult to devise; and no attempt is made to analyze their effects in this Paper. Because of the heterogeneous nature of these variables, they do not lend themselves to theoretical analysis by the development of empirical formulas.

Bunching and decking times are directly proportional to the number of trees or logs handled per thousand board feet. Bunching time is also directly proportional to the number of trees cut per acre. The most critical evaluation that can be made of these operations (not conducted concurrently) is a comparison of log-length vs. tree-length bunching and decking times as shown below:

	Man-min./MBF
Bunching:	
4 logs	3.02
2 tree lengths	2.54
Difference	0.48 (16 percent)
Decking:	
4 logs	7.26
2 tree lengths	6.47
Difference	0.79 (11 percent)
Total:	
4 logs	10.28
2 tree lengths	9.01
Difference	1.27 (12.4 percent)

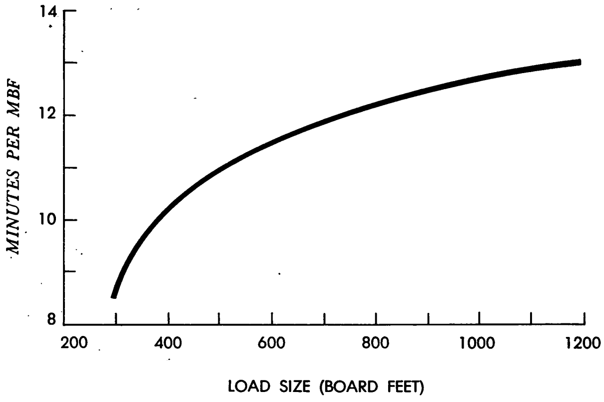

Figure 1.—Bunching time (minutes per thousand board feet) based on a cut of 18 trees per acre and an average d.b.h. of 16 inches.

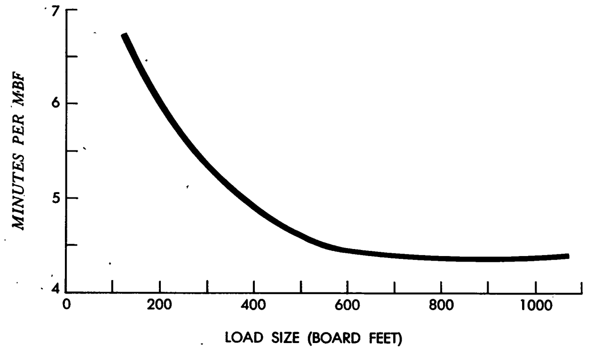

Figure 2.—Decking time; basis same as in figure 1.

These figures show the principal advantage of tree-length logging. The influence of number of trees per acre and board-foot volumes per turn on bunching, decking, and skidding times can be seen in figures 1 through 3. Figure 4 shows the combined results.

From the slope of figure 3 the pronounced effect of underloading readily can be evaluated.

Loading and Hauling

Loading.—Loading by hydraulic loaders is standard practice for most loggers. The size and efficiency of the loaders vary, but if an average size loader is used (3,500-pound capacity) a typical production is 26.0 MBF per man-day when idle time is kept within normal limits (less than 15 percent).

Hauling.—The principal variables controlling hauling times and costs are delay and standby, length of haul, road standard, season of the year, and loading and unloading methods. Log hauling costs can be estimated satisfactorily with the help of the

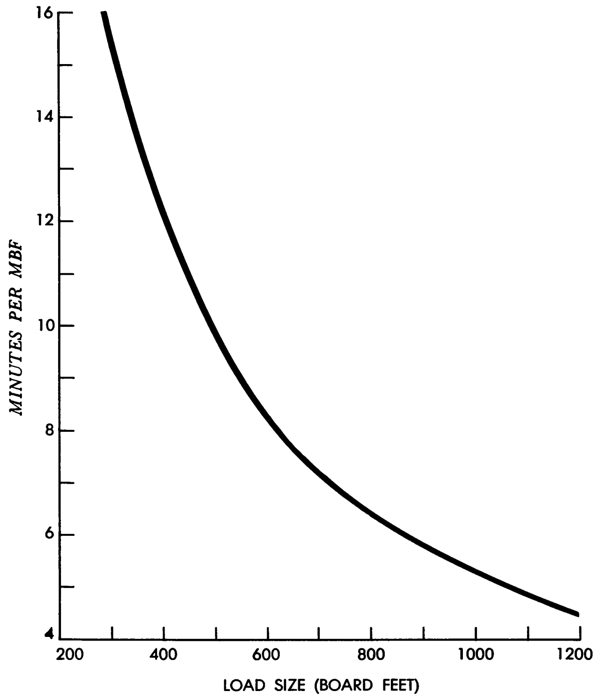

Figure 3.—Skidding time (both ways) using a 30- to 35-drawbar horsepower crawler tractor and a 500-foot skidding distance; basis same as in figure 1.

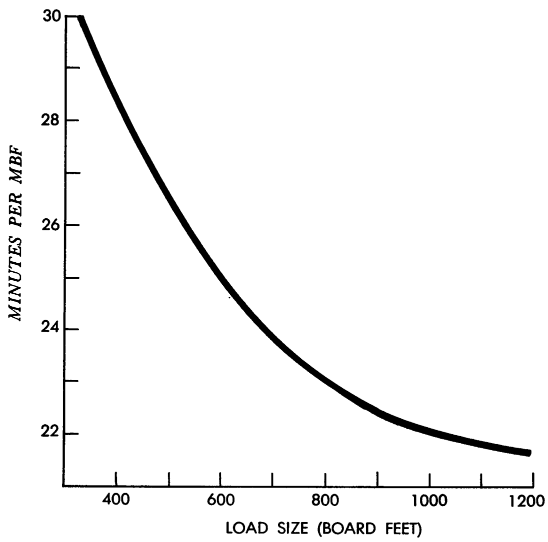

Figure 4.—Combined bunching, skidding, and decking time using data from figures 1, 2, and 3.

handbook by Byrne *et al.* (1960) if road standard information (grade, alignment, width, and surfacing) is available.

For comparison in this paper, the following traveling speeds for four road standards are assumed:

Road standard	*Loaded (MPH)*	*Empty (MPH)*
Woods road	10	10
Secondary haul	15	20
Main haul	20	25
Highway	50	60

Round-trip hauling times for any haul distance can be calculated by using the method shown in table 3. For example, by using the figures in table 3 for woods, secondary, and main-haul roads and adding the difference to highway mileage, the result for a 100-mile round trip is 127.0 minutes; for a 200-mile round trip, it is 237.0 minutes.

The total hauling time and resulting costs for several load sizes and hauling distances are shown in table 4. To prepare the table, the following assumptions, based on performance of typical equipment available for these jobs, were made:

1. Self-loading or unloading time, using 0.20-MBF capacity loader operating at a rate of 3.5 MBF per hour:

   2.0 MBF load=0.571 hr. or 34.3 minutes
   4.0 MBF load=1.14 hr. or 68.5 minutes
   6.0 MBF load=1.72 hr. or 103.0 minutes

2. Crane unloading times at mill or siding, using a crane with a 0.50-MBF capacity and operating at a rate of 9.0 MBF per hour.

   2.0 MBF load=.222 hr. or 13.3 minutes
   4.0 MBF load=.444 hr. or 26.6 minutes
   6.0 MBF load=.666 hr. or 39.9 minutes

3. Truck sizes and operating costs including trailer or stake body and operator:

Gross vehicle weight (pounds)	*Capacity (MBF)*	*Cost/minute (dollars)*
27,000	2.0	.0655
41,000	4.0	.1055
70,000	6.0	.1310

Table 4 shows that for either method of unloading (loading times are the same) the lowest costs are realized by using the 2.0- to 4.0-MBF capacity truck when the majority of the hauling distances are in the 25- to 50-mile range and the 4.0- to 6.0-MBF capacity truck when hauling distances are in the 50- to 100-mile range. The cost differences for each truck size in these hauling ranges are greatly influenced by the fixed loading and unloading times associated with each size class.

Table 3.—Round-trip hauling times using a 25-mile hauling distance (50-mile round trip) with assumed mileages in each road standard

Road standard	Miles (one way)	Speed (miles/min.)		No. of minutes for trip		
		Loaded	Empty	Loaded	Empty	Total (round trip)
Woods	.25	.167	.167	1.5	1.5	3.0
Secondary	1.50	.250	.333	6.0	4.5	10.5
Main	2.50	.333	.418	7.5	6.0	13.5
Highway	20.75	.835	1.000	24.8	20.8	45.6
Total	25.00			39.8	32.8	72.6

Table 4.—Hauling costs for different distances, truck and load sizes, and unloading methods

Load size MBF	Unloading method[1]	Total time[2]	Cost (dollars) Per minute	Total	Per MBF	Per MBF/mile
			25-MILE HAUL			
2.0	C	120.2	.0655	7.87	3.94	0.158
	S	141.2		9.25	4.62	.185
4.0	C	167.7	.1055	17.69	4.42	.177
	S	209.6		22.11	5.53	.221
6.0	C	215.5	.1310	28.23	4.70	.188
	S	278.6		36.50	6.08	.243
			50-MILE HAUL			
2.0	C	174.6	.0655	11.44	5.72	.114
	S	195.6		12.81	6.40	.128
4.0	C	222.1	.1055	23.43	5.86	.117
	S	264.0		27.85	6.96	.139
6.0	C	269.9	.1310	35.36	5.89	.118
	S	333.0		43.62	7.27	.145
			100-MILE HAUL			
2.0	C	284.6	.0655	18.64	9.32	.093
	S	305.6		20.02	10.01	.100
4.0	C	332.1	.1055	35.04	8.76	.088
	S	374.0		39.46	9.86	.099
6.0	C	379.9	.1310	49.77	8.29	.083
	S	443.0		58.03	9.67	.097

[1] C = Crane; S = Self unloading by same equipment (or same capacity) as that used for loading.
[2] Fixed times of loading and unloading plus hauling time.

Systems Designing

The designing of logging systems is divided into two separate but related operations: (1) Problem definition and specifications, and (2) planning and programming. A thorough treatment of design is not attempted in this paper, but the simple method given here will be useful on many logging chances.

For this example the following conditions and objectives will be assumed:

Conditions

Northern hardwood timber stand
70-percent hard maple
Cut, 2 MBF per acre
Average tree size, 16 inches d.b.h.
18 trees cut per acre
Average tree volume, 130 board feet
Average tree weight, 1,430 pounds
50-mile hauling distance
Average skidding distance, 500 feet.

Objectives

To design a balanced system composed of equipment that produces the lowest unit cost.
To hold investment costs to the minimum level for a balanced system.

Most of the tabular data given in this Paper will apply for the conditions listed above.

One of the commonest mistakes made by loggers today is their failure to give adequate attention to continuity of equipment use. Expensive and time-consuming trial-and-error methods need not be employed to improve the efficiency of a logging system. Table 5 illustrates a simple method for balancing man-day production rates for each segment of the system. The only information needed for the computation is the man-day production figures for each operation—in this case, those that produce the lowest unit cost. The more accurate the production figures, of course, the better the results.

A system is always built around the key piece of equipment, which is usually the skidder. For this example, a skidder with a production rate of 20.5 MBF per man-day for these conditions is used. This then controls the total production rate of the other phases of the operation.

To balance the rest of the system with the skidders (thus balancing subsystem inputs and outputs),

Table 5.—Logging system design table

Operation	Equipment[1]	Production per unit (MBF/man-day)	Number of units for a balanced system	Total production (MBF/man-day)
Felling and bucking	Power saw, 6-hp. class	6.7	3	20.1
Bunching & decking	58 DB, rubber-tired skidder	22.0	1	22.0
Skidding[2]	Same equipment used for B&D above (capacity approximately 0.60 MBF)	20.5	1	20.5
Loading	Hydraulic, tractor mounted (approximately 0.20 MBF capacity)	26.0	1	26.0
Hauling (50 miles)	41,000# G.V.W., 190-hp. truck with trailer (approximately 4.0 MBF capacity)	8.1	3	24.3

[1]Abbreviations used are: hp, horsepower; DB, drawbar; B&D, bunching and decking; MBF, thousand board feet; G.V.W., gross vehicle weight; #, pounds.

[2]Key piece of equipment.

it is only necessary to determine the number of units for each operation that will produce approximately 20.0 MBF per man-day. For instance, three operators with power saws will fell and buck 20.1 MBF per man-day (table 5).

The system designed in table 5 calls for 9 men, 3 power saws, 2 skidders, 1 loader, and 3 trucks to produce 20.0 MBF per day. This is an average of 2.22 MBF per man-day, more than twice the production for a typical logging system shown in table 1.

This system does not utilize the loader or trucks to their maximum capacity as noted in the last column of the table. However, it would be virtually impossible for any system to perfectly balance all operations. The objective is to approach this condition as nearly as possible. Although this procedure is simple, it is often bypassed in favor of the educated guess, which usually requires considerable adjustment in the field.

Unique and very difficult logging chances usually require special equipment and design methods. However, for most logging chances in the Lake States and Northeast, the information in this Paper should be helpful in analyzing or designing logging systems. Good data-collecting methods must be used to obtain the input information for any logging system analysis or design.

The next section gives typical production figures for many different classes of equipment and a listing of equipment manufacturers and approximate purchase prices. This information will also be useful for planning a logging operation.

Equipment Types, Production Capabilities, and Costs

Equipment types and classes are discussed briefly in this section, and a partial listing of equipment manufacturers and approximate list prices are given in the Appendix. More detail on general specifications and costs, and pictures of a large sample of the logging equipment types used in America today may be found in manufacturers' catalogs and in other papers, such as Wallbridge's[1] treatise on harvesting systems for the pulpwood stands of the Tennessee Valley.

Harvesting and transporting equipment types can be grouped into five general classifications, each descriptive of the work it does in the total job:

- Combines or harvesters
- Skidders or forwarders
- Processors
- Loaders
- Transporters

The following sections describe equipment in the above classifications. Production and cost data were derived from an analysis of information obtained from many publications, such as the American Pulpwood Association and the Pulp and Paper Magazine of Canada. Equipment manufacturers were also a valuable source of information.

The costs shown in tables 6 through 12 (data collected during 1963 and 1964) include all equipment costs and labor but not overhead costs, which vary greatly between producers. Cost per cord is given in most of the tables. Approximate cost per MBF can be found by using the conversion constant of 500 board feet per cord.

Combines or Harvesters

Combines (table 6) are relatively new in the logging industry. They can be used to very good advantage under moderate slope (5 to 10 percent) conditions when clear cutting timber. Each machine performs more than one of the harvesting operations.

Skidders and Forwarders

The major variables affecting skidding and forwarding equipment as noted previously are: slope, tree size, soil, and distance. Figures 5 through 8 illustrate the effect of these variables on skidding production.

Each equipment type has its advantages with different combinations of the variables. These advantages, of course, are reflected in production and cost figures.

Some of the other important variables affecting production (also mentioned in an earlier section) are: density of the residual stand, amount of brush and down timber, season of the year, machine availability, elevation, silvicultural requirements, and logging methods. The combined effect of all of these variables, as they may occur in any particular operation, has been the subject of many studies. Unfortunately very little reliable data are available for determining their individual effects. Net effects on year-round production are shown in tables 7 to 9. These tables are for typical soil, slope, and stand density conditions.

[1] *Wallbridge, T. A., Jr. The design of harvesting systems and machines for use in the Tennessee Valley as dictated by extensive forest management. Dissertation submitted in partial fulfillment of the Ph. D. requirements at the University of Michigan, 1960.*

Table 6.—Combines; production and cost data

Equipment type and operation performed	Specifications for operation	Skidding distance	Av. production: Per man-day	Av. production: Per hp-day	Estimated unit cost per cord
		Feet	Cords	Cords	Dollars
12-ton, rubber-tired, self-propelled, feller-limber-slasher-skidder; similar to the Busch Combine*	Clear cut 3-20" d.b.h.	700	8.0	.08	10.50
4-ton, rubber-tire-mounted, belt-track, self-propelled, feller-skidder-buncher; similar to the Vit Feller-Buncher	Clear cut 3-20" d.b.h.	900	18.5	.16	2.75
25-ton, tracked, self-propelled, feller-limber-lopper; similar to the Hiabob Harvester	Clear cut 3-20" d.b.h.	(1/)	34.0	(2/)	3.38

1/Does not skid.
2/Production figures not available.
*The manufacturers and model numbers of the equipment mentioned in this Paper are for identification only, and no endorsement by the Forest Service, USDA, is implied.

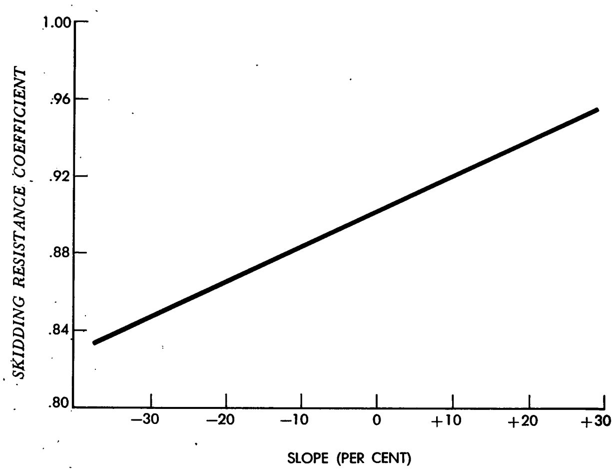

Figure 5.—Influence of slope on skidding resistance, from Herrick, 1955.

Figure 6.—Influence of tree size on skidding production, from Campbell, 1953.

Standard tracked vehicles (table 7).—For this type of equipment working at full capacity and skidding full-length trees, the effect of variable tree diameters on production is most significant. Differences in soil, slope, stand density, and other variables will have the same general effect on each piece of equipment.

Rubber mounted, belt-tracked vehicles (table 8).—Steep and rolling terrain is easily negotiated by this equipment. Excellent flotation (1.3 to 1.5 p.s.i.) characteristics make them better suited to conditions of unstable ground than most other types.

Rubber-tired tractors (table 9). — Rubber-tired skidders are used extensively in Canada and many parts of the U.S. especially for pulpwood operations. Operating limits for slopes are in the neighborhood of 20 percent adverse and 35 percent favorable. Due to the economic advantages of rubber-tired skidders for longer skidding distances, this equipment is particularly advantageous when road building costs are high. Operators generally like the equipment because of its ease in handling, speed, and the cushioning effect provided by the rubber tires.

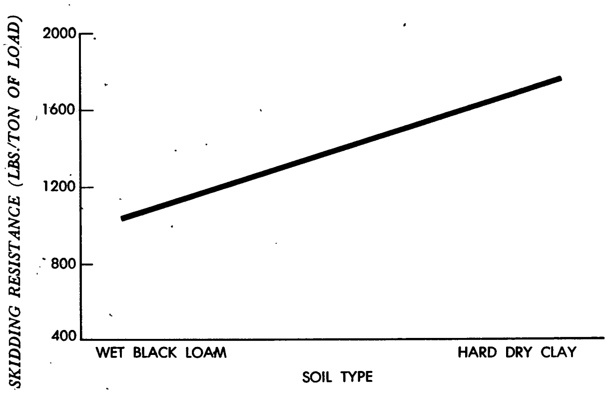

Figure 7.—Influence of soil on skidding resistance, from Forbes, 1961.

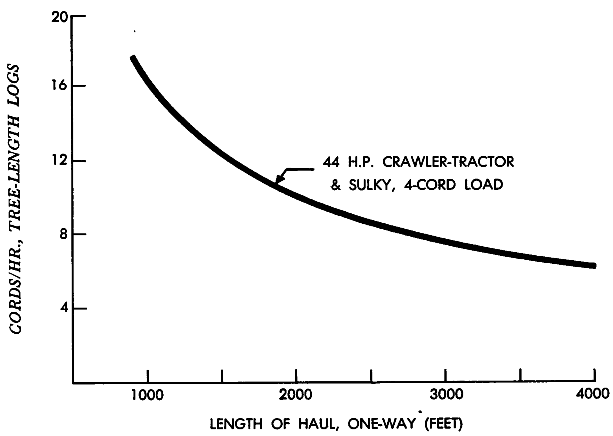

Figure 8.—Influence of distance on skidding production, from Forbes, 1961.

Table 7.—Standard tracked vehicles; production and cost data (assumes selection cutting, tree-length ground skidding, and a skidding distance of 500 feet)

Equipment type	Specifications for operation	Av. production: Per man-day	Av. production: Per hp-day	Estimated unit cost per cord	Trees per load, average diam. 9"
		Cords	Cords	Dollars	Number
3-ton, 25-drawbar hp; similar to the OC-4	1.0 cord, 6-12" d.b.h.	7.8	.41	3.35	7
5-ton, 50-drawbar hp; similar to the D-4	1.8 cords, 8-14" d.b.h.[1]	14.0	.54	2.00	7
9-ton 75-drawbar hp; similar to the HD-9	3 cords, 16-20" d.b.h.[1]	38.0	.81	.96	4

[1] Large loads of small logs (6 to 12 inches in diameter) cannot be skidded economically unless prebunched and bundled.

Table 8.—Rubber-mounted, belt-tracked vehicles; production and cost data

Equipment type	Specifications for operation	Av. production: Per man-day	Av. production: Per hp-day	Estimated unit cost per cord
		Cords	Cords	Dollars
2-1/2-ton, 115 hp; similar to the Bombardier Red Ram	Diam.-limit cutting, tree-length skidding, 8- to 12-inch diam. trees, 1/2-cord load, 500-ft. skidding distance	10.5	.18	3.35
4-ton, 115 hp; similar to the Bombardier HDW	Forwarding 8-foot wood prebunched, 1-cord load, 1,250-ft. forwarding distance	20.0	.35	1.90

Table 9.—Rubber-tired tractors; production and cost data

Equipment type	Specifications for operations	Av. production: Per man-day	Av. production: Per hp-day	Estimated unit cost: per cord	Trees per load, average diam. 9"
		Cords	Cords	Dollars	Number
3-1/2-ton, 48 hp; similar to the Garrett Tree Farmer	Diam.-limit cutting, tree-length, 350-ft. skidding distance, 1/2-cord load, 6- to 10-inch diam.	15.0	.31	3.20	5-6
3-1/2-ton, 60 hp; similar to the Timberjack	Clear-cutting, log-length, 425-ft. skidding distance, 1/2-cord load, 6- to 10-inch diam.	15.0	.24	3.35	5-6
5-ton, 80 hp; similar to the Pettibone M-8	Diam.-limit cutting, log-length, 400-ft. skidding distance, 3/4-cord load, 6- to 10-inch diam.	17.5	.22	3.25	8-9

Processors

Processors have been designed to perform two or more parts of the harvesting operation. One type of processor barks, chips, and loads, whereas others perform such operations as barking and slashing (table 10). Auxiliary logging equipment must be available to complement the operation of each processor. For example, some of the processors accomplish the loading operation while others do not. Many units are still in the experimental stage, but they are listed here for information purposes.

Loaders

Loaders vary greatly in size and design; they range from the home-made log jammer used by the small part-time logger to the truck- or cat-mounted crane used at mill sites or sidings (table 11). The small to medium hydraulic loader has proved the most economical for most northern forest operations. The hydraulic-boom, clam-grapple type can be mounted on the hauling device or on the rear of a crawler tractor. The front-end, fork-grapple type can be mounted on a tracked or rubber-tired tractor. The type of loader to be used in any particular situation, of course, will depend on its planned use in the overall harvesting operation.

Transporters

There are many different types of primary and secondary transportation equipment. These include the extremes of 2- to 3-cord capacity, small, stake-body trucks and 12-cord semitrailers and the 35-cord gondolas used in rail transportation. Unit production costs vary with volume, weight, and size of the material, size of the truck trailer or rail car, road conditions, distance from market, delays, and stand-by time. Small volumes cannot be hauled economically for long distances. The secret to economic hauling for any distance is to minimize delay, loading, and stand-by time. Table 12 shows typical hauling costs for three different truck sizes and hauling distances.

Table 10.—Processors; production and cost data

Equipment type and operation performed	Production units per hour[1/]	Estimated unit cost per cord	Operators
		Dollars	Number
Semiportable limber-slasher-loader; similar to the Bombardier Processing Unit	6.5 cords of 4-ft. wood	2.29	3
Self-propelled, tracked, limber-barker-slasher; similar to the C.P.I. Harvester	6.5 cords of 8-ft. wood	[2/]	2
Self-propelled, rubber-tire-mounted, barker-slasher; similar to Consolidated barker-slasher	7 cords of 4-ft. wood	2.95	2
Semiportable, rubber-tire-mounted, barker-chipper-loader; similar to Nicholson Utilizer II	12 cords of 3/4" chips	1.15	1

[1/] 12-inch diameter at stump height.
[2/] Data not available.

Table 11.—Loaders; production and cost data

Equipment type	Production units per hour	Estimated cost
Hydraulic boom, clam-grapple (3,000-lb. class) loader mounted on truck or cat	8 cords of 8-ft. wood av. 10" d.b.h.	Loader and operator only.........$0.35 per cord Including 40 hp, 3½-ton tracked or rubber-tired cat.... .65 per cord
	3.5 MBF of 16-ft. logs av. 16" d.b.h.	Loader and operator only......... .78 per MBF Including 40 hp, 3½-ton tracked or rubber-tired cat.... 1.50 per MBF
Hydraulic front-end, fork-grapple type loader, tractor mounted (4,000-lb. class)	Production and costs for similar operations should be approximately the same as above.	
Winch-operated cable-boom jammer, including hooker or choker	6 cords of 8-ft. wood av. 10" d.b.h.	.... .70 per cord

Table 12.—Transporters; production and cost data (in dollars)

Equipment type[1]	Estimated cost per cord for a--[2]		
	25-mile haul	50-mile haul	100-mile haul
Transporters, highway[3]			
22,000-lb. GVW, 165 hp, gas 10-wheeler flat-bed, 5-cord capacity	2.04 (0.082) .41	3.16 (0.063) .315	5.36 (0.054) .27
41,000-lb. GVW, 190 hp, gas tractor with trailer, 8-cord capacity	2.14 (0.086) .688	3.27 (0.065) .52	5.29 (0.053) .424
45,000-lb. GVW, 240 hp, diesel tractor with trailer, 12-cord capacity	2.15 (0.086) 1032	3.00 (0.060) .72	4.76 (0.048) .576
Transporters, rail[4]			
108,000-lb., 5,500 cu. ft., open-top gondola or closed box car (about 35 units of chips[5])	$8.00 for a 250-mile haul (0.032)		

1/GVW is gross vehicle weight.
2/Data in parentheses are costs per cord per mile.
3/Includes loading and unloading time, but no delay or standby time in the woods. Woods and highway speeds assumed.
4/Not including loading and unloading.
5/Approximately 200 cu. ft., loose volume, or 150 to 160 ft. compacted 25 percent.

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Appendix

Table 13.—Equipment manufacturers and approximate purchase price

Manufacturer	Name and description of equipment[2]	Approximate purchase price (dollars)
TRUCKS	(ready for hauling including bed or trailer, heavy-duty axles, and air brakes)	
Ford Motor Company	T-850, 39,000# GVW, 60,000 GCW, gas, 6x2	$14,100
Detroit, Mich.	T-850, 41,000# GVW, 70,000 GCW, gas, 6x2	16,810
Chevrolet Motor	C60H, 23,000# GVW, 42,000 GCW, gas, 4x2	5,000
Div. of G. M.	M-80, 36,000# GVW, 51,000 GCW, gas, 6x2	11,900
Detroit, Mich.		
Mack Trucks, Inc.	B-42S, 42,000# GVW, gas, 6x4	16,820
Chicago, Ill.	B61SX, 44,000# GVW, diesel, 6x4	24,700
STANDARD TRACKED TRACTORS		
Caterpillar	D-4, 5-ton, diesel, 50 DBH	12,500
Peoria, Ill.	D-6, 9-ton, diesel, 75 DBH	20,000
Allis Chalmers	HD-6, 6-ton, diesel, 52 DBH	3/
Milwaukee, Wis.	HD-11, 10-ton, diesel, 77 DBH	3/
John Deere	1010, 5-ton, diesel, 42 DBH	10,000
Minneapolis, Minn.		
Oliver Corp.	OC-43G, 2-ton, diesel, 25 DBH	6,000
Cleveland, Ohio	OC-t, 3.5-ton, diesel, 25 DBH	9,300

1/The costs given in these tables are estimates. Since there is a wide variety of optional equipment, any particular item should be quoted by an authorized dealer.
2/Abbreviations used in this table are: # = pounds; GVW = gross vehicle weight; DBH = drawbar horsepower; BHP = brake horsepower; horiz. = horizontal; cap. = capacity.
3/Data not obtained.

Table 13 cont'd.

Manufacturer	Name and description of equipment[2/]	Approximate purchase price (dollars)
RUBBER TIRED SKIDDERS AND FORWARDERS		
Pettibone-Mulliken Chicago, Ill.	M-4, 3.5-ton, gas, 43 DBH	9,500
	M-8, 5-ton, gas, 79 DBH	11,900
Timberland-Ellicot Woodstock, Ontario, Can.	Timberjack 200, 3.5-ton, gas, 61 DBH	11,000
Canadian Car Ft. Williams, Ontario, Can.	C.I.T.F. Tree Farmer, 3.5-ton, gas, 48 DBH	9,000
	C.4.T.F. 4-ton, gas, 61 DBH	3/
Koehring Branford, Ontario, Can.	Forwarder, 15-ton, diesel, 100 BHP	49,000
Beloit Ashland, Wis.	Tree Triever, 8-ton, gas, 75 BHP	17,750
RUBBER MOUNTED BELT-TRACK TRACTORS		
Bombardier Valcourt, Quebec, Can.	Red Ram, 2-1/2-ton, gas, 115 DBH	6,750
	HDW-H-2, 4-ton, gas, 115 DBH	8,900
Robin Nodwell Calgary, Alberta, Can.	Logger being redesigned, near 5 tons	16,000
COMBINES		
Timberline Equipment Dallas, Tex.	Busch Combine, 7-1/2-ton, diesel, 70 DBH	37,000
Efficient Equipment Co. Baie Comeau, Quebec, Can.	Vit feller-buncher, 4-ton, gas, 115 DBH	15,000
Beloit-Hiabob Ashland, Wis.	Hiabob Harvester, est. 20-ton, diesel, 200 DBH	66,000
PROCESSORS		
Bombardier Valcourt, Quebec Can.	Bombardier Processing Unit (portable)	45,000
Canadian International Paper Co., Can.	CIP Harvester, self-propelled, tracked	3/

See footnotes on first page of table.

Table 13 cont'd.

Manufacturer	Name and description of equipment[2/]	Approximate purchase price (dollars)
PROCESSORS cont'd.		
Consolidated Paper Co. Can.	Consolidated barker-slasher, self-propelled, rubber tire mounted, 40-ton; cost of prototype	100,000
Nicholson Mfg. Co. Auburn, Wash.	Utilizer II, self-propelled, trailer-mounted, 8' x 35' trailer with 420 hp primepower	77,000
Canadian Sumner Iron Works, Vancouver, Brit. Columbia, Can.	Portable barker-chipper, trailer-mounted with 225 hp primepower	55,000
LOADERS		
Prentice Hydraulics Inc., Prentice, Wis.	BAAB-2, 2750# horiz. lift cap., 1/3-cord grapple	2,700
	FEBA-2, 3100# horiz. lift cap., 1/3-cord grapple	3,900
Beloit-Hiabob Ashland, Wis.	B-9, 3200# horiz. lift cap., 1/3-cord grapple	3,600
	C-25, 3500# horiz. lift cap., 1/3-cord grapple	4,400
John Deere Minneapolis, Minn.	850-C, 5-ton, diesel, tractor-mounted, 42 DBH	11,400
TRAILERS		
Fruehauf Trailer Co. Milwaukee, Wis.	P-SI-C, 20,000# capacity, single axle trailer	2,115
	NB-SR, 40,000# capacity, spread-tandem -axle platform trailer	4,700
Challenge-Cook Bros. Los Angeles, Calif.	45,000#, 2,000-cu. ft. straddle trailer for wood chips	14,500
Truck Eng. Ltd. Woodstock, Ontario, Can.	King T-1 logger, 38,000#, tandem-axle trailer with front rack, stakes, etc.	7,500
Peerless Truck and Trailer Service Portland, Oreg.	50,000#, 2,800-cu. ft. chip trailer	8,000
Beall Pipe & Tank Co. Portland, Oreg.	60,000#, 3,200-cu. ft. chip trailer	9,000

See footnotes on first page of table.

THE FOREST SERVICE CREED

The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.