OPTIMIZING COMBINATIONS OF SKIDDER TYPES AND
ROAD SPACING IN CLEARCUT LOGGING
IN SOUTHEASTERN OKLAHOMA

By

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CHAPTER I

INTRODUCTION

Since the time the settlers arrived in America, American forests have played a vital economic role in this nation's development. Large scale commercial lumbering developed during the latter part of the last century. Since that time, lumbering has been an important part of the American economy. The virgin forests have been largely cut over, and the industry has had to make major adjustments in transition to dependence on second- and third-growth forests.

In recent years the lumbering industry has been waging a bitter struggle with substitute materials for present and future markets. Lumbermen strive continually to improve their products and develop new ones. To stay competitive, they must reduce production costs. This is difficult in the face of rising costs of raw materials, equipment, and labor. The timber now being harvested from our forests is smaller in size and must be transported longer distances to the point of manufacture. Much real progress has been made in both the milling and logging phases of lumber manufacture. However, logging, which accounts for over half the cost of converting trees to green lumber, still offers many opportunities for improvement.

Not many years ago, logging in North America was, in many cases, a labor-intensive operation in which capital requirements for tools and equipment were small. However, mechanization has increased tremendously during the last 15 years. Management questions have become more critical, because each successive step toward mechanization has become increasingly more expensive in terms of capital requirements and in terms of the costliness of errors in judgement. A single logging side[1] employing one feller-buncher, six hydraulic skidders, one bulldozer and one self-propelled hydraulic heelboom loader requires an investment in excess of $400,000 and with the purchase of chain saws, haul trucks and other supporting equipment this figure becomes even more staggering. Present annual expenditures on logging equipment in the United States are reported to be in excess of $400,000,000 (5).

Today the woods manager who must decide whether or not to purchase an $80,000 multi-purpose machine to replace a conventional combination of men and single-purpose machines knows he must have an accurate knowledge of the real cost of alternative machines and methods, and the factors that influence costs.

The factors affecting logging costs are many and varied, involving men, machines, and the environment. The adverse effects of some of these factors can be reduced through changes in methods and equipment; others can be reduced but only at a prohibitive cost. For example, extremely low temperatures can play havoc with hydraulic hoses, which may become very brittle at temperatures well below zero. Even metals may react unfavorably to such low temperatures. Roughness of terrain will limit the use of some machines, and extreme slopes prohibit the use of most wheeled or tracked vehicles. On the other hand, many of

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[1]Side is a commonly used logging term that refers to a single logging crew, including men and machines.

the problems of the environment have already been overcome. In removing a large part of the hard physical effort of logging, mechanization has greatly reduced the effects of environment on labor productivity.

Both the growing complexity and costs of modern mechanized logging operations and the rapidity of changes in techniques and equipment emphasize the need for reliable cost data and a complete understanding of the factors influencing these costs in order to control present costs and to compare objectively current costs with those costs to be incurred if prospective alternate systems and equipment are used.

This study concerns alternatives relating to a relatively recent development in logging equipment-- the 4-wheel drive, articulated-frame, rubber-tired skidder for use in skidding tree-length stems or pre-cut logs. In the past, rubber-tired skidders incorporated only the use of a winch, cable and choker system to collect and skid logs. In recent years, however, an alternate method has been introduced to replace wire rope chokers. This method incorporates the use of a device known as a hydraulic grapple mounted on the rear of the skidder.

The use of wire rope chokers requires the skidder operator or a choker setter to connect and disconnect the chokers manually from the logs, whereas the hydraulic grapple can perform the same operation mechanically with the operator remaining on the skidder, thus eliminating the necessity for a choker setter.

Important economic questions about skidding alternatives exist in current logging operations under a wide range of conditions in southeastern Oklahoma, where both types of skidders are being used on more than 50 logging sides that range in capital costs (new equipment basis) from about $50,000 to more than $600,000 per side.

Road costs, which are directly related to skidding costs also make up a major investment item. About 600 miles of permanent all-weather roads were constructed in 1973 on the 1.8 million-acre ownership on which this study was conducted.

Objective

In the context of concern in southeastern Oklahoma, questions exist not only about the comparative efficiency of the two types of skidders in doing the skidding job, but also with respect to optimum combinations and uses of types of skidders on a side, and other related choices such as in bunching practices and in road spacing and skidding distance.

This study was designed to provide information on selected questions for given logging conditions. Primary study objectives are:

(1) to compare grapple and choker skidders in terms of economic efficiency;

(2) to determine the break-even point (if it exists) in skidding distance, between grapple and choker skidders; and

(3) to apply these results in determining optimum road spacing-skidding distance combinations for each type of skidder and for a combination of skidder types on a side.

The logging conditions, methods and side organization in men and equipment are described in Chapter III. A review of the literature on research of this nature follows.

CHAPTER II

LITERATURE REVIEW

Skidding Phase

Mechanized tractor skidding, in some form, has existed since woods-worthy tractors were built and put to use in the 1920's (17). The tractor, when first introduced to the woods, merely replaced the animals then used. Consequently, the logs were skidding directly from the drawbar. Later, as timber harvesting costs increased, other units such as skidding pans and arches were added to improve the efficiency of pulling logs to the landing. Even though the use of tracked vehicles such as the crawler tractor proved to be an efficient method of skidding, as compared to animal skidding, an equally important innovation in skidding machines was the 4-wheel drive rubber-tired skidder which first made its appearance in 1948 (19).

The first 4-wheeled drive tractors used in logging were essentially off-road trucks. Their main period of use lasted until 1960 and there are few, if any, of these units operating in the forest today. The weakness of this type of machine lay in its use of conventional Ackermann steering and the rigidity of its frame (16).

In 1954 the Canadian Pulp and Paper Association, recognizing the need for a more suitable wheeled unit to operate off-road in the forest, established a project to design and develop such a machine.

This development culminated in 1955 in the Mark V Bonnard Hauler, apparently the first articulated-frame forest tractor in North America (16).

Rapid advances have since been made in the development of the rubber-tired skidder. They are now available in a variety of sizes. The principle features of such skidders are high clearance; four-wheel drive with no-spin differential in the rear axle; and steering by wheel control or by a hydraulically operated joint between front and rear axles. This articulated-frame construction permits great maneuverability and a short turning radius and also enables these skidders to "duck walk" over obstructions and through soft spots. The development of skidders of this type have had the greatest impact on logging since the introduction of the chain saws (17).

The integral arch, winch and cable system was incorporated into the wheeled skidder, and in the early 1960's rubber-tired choker skidders in their present configuration first made their appearance.

In 1968, Pulpwood Production Magazine reported the development of a hydraulic grapple attachment mounted on the rear of the skidder. This eliminated the need for the chokers, the choker setter and the delay in unhooking the logs at the landing (12).

Detailed research studies comparing the choker skidder and the hydraulic grapple skidder are limited in number. However, those available show conclusive results for the areas in which they were conducted.

In 1970, in a study conducted in Louisiana, it was concluded that under uniform conditions grapple skidders would outproduce the choker skidders at virtually all distances on the operation studied, and that important savings could have been expected by replacing the choker skidders with grapple skidders (12).

In British Columbia a six-month study revealed that grapple skidders outproduced choker skidders by 30 percent under similar conditions. Top productivity for the grapple skidder was 580 trees in a nine-hour shift as compared to 300 trees for the choker skidders. The average hook-up time for the choker skidders was 14 minutes and 18 seconds as compared to 4 minutes and 19 seconds for the grapple skidder. At the landing the grapple skidder took 3 seconds to release the load while the choker skidder took 2 minutes and 10 seconds (6).

When alternative methods of accomplishing the same task are considered, it is helpful to determine the break-even point. For skidding systems this is the distance at which the cost of skidding for one method equals the cost of skidding for an alternate method. At distances above and below the break-even point, one method can produce wood at a lower cost. A study in Louisiana, comparing choker and grapple skidders, found the break-even point to be 270 yards. At distances less than 270 yards, choker skidders operated at a lower cost than did grapple skidders (12).

Road Spacing

In timber harvesting, the cost of performing one step is often influenced by how another step is done. Matthews (10) and Wackerman (17) noted that skidding cost is influenced by road spacing.

The costs of roads as well as skidding are necessarily a part of logging costs per unit volume. The road cost per unit distance (the 100 foot station, the chain, or the mile) is translated to a cost per unit of volume by spreading it over the volume moved over the road. The total volume available will depend on the volume per acre to be harvested and on the area served by the road. The latter varies directly with spacing.

Wackerman (17) and Matthews (10) stated that road cost per unit of area to be harvested increased as the mileage per unit of area to be harvested increases. When roads are spaced one mile apart, each mile of road serves 640 acres or a strip one mile long and one-half mile deep, on both sides of the road. Likewise when roads are at one-half mile intervals, each mile of road serves 320 acres. In the first instance, the road cost would be spread over the timber on 640 acres; in the second case it would be spread over the timber on 320 acres, and similarly for other spacings.

With increased spacing of roads, there is a reduction of road cost per unit of product but an increase in skidding distance and therefore in skidding cost. Consequently, at some point there is a least-cost trade-off between road spacing and skidding distance. This is true for any method of skidding, including the use of rubber-tired skidders, even though their increased speed makes distance less a problem.

The lowest combined cost of both skidding and roads can be achieved at the spacing where the road cost per unit of product is equal to the total variable cost of skidding per unit of product.[1]

Theoretically, the only skidding cost affected by distance is the travel cost per unit of volume. This is termed variable cost

[1]This assumes that the value and marginal output of the product (the marginal value product) remains unchanged with respect to distance skidded.

and is the only skidding cost pertinent to the road spacing analysis.

Optimum road spacing may be calculated by a number of methods. Whatever method is used, road spacing is dependent on the relationship among three factors; road construction costs, skidding costs, and volume per acre to be harvested. Wallace (18) reported on applying a ratio method. Ratios were given for a wide range of conditions of landing spacing and landing costs, as well as skidding and road costs for both one-way and two-way skidding. Using these ratios both landing and road spacing can be calculated.

The optimum spacing is relatively easy to determine. When roads are regularly spaced,[2] there is a constant relationship between road spacing and skidding distance; average skidding distance is always one-fourth of road spacing. As explained by Wackerman (17), the optimum spacing can be determined mathematically by solving for S in the formula $Vu\ (S/4) = \frac{Rm/12.1}{CaS}$ where:

Vu = Variable skidding cost per unit of volume per 100 feet.

S = Road spacing in 100-foot units.

Rm = Road cost per mile.

Ca = Number of units of volume to be cut per acre.

S/4 = Average skidding distance.

12.1 = Number of acres served by one mile of road at a spacing of 100 feet.

The optimum spacing and the total combined cost at the optimum can also be determined graphically by plotting fixed and variable skidding costs and road costs at various combinations of road spacing

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[2]When not spaced regularly, an average spacing can be used in the analysis.

and skidding distance. This method was applied in Chapter IV for purpose of illustration, although the mathematical solution was used to check the results.

CHAPTER III

METHODS AND PROCEDURES

The data on skidding production used in this study were obtained as part of a more comprehensive project on the economics of alternative systems of clearcut harvesting. Study methods and field procedures were designed for the particular logging conditions, and also in order to obtain data without changing or interfering with normal logging operations. Logging conditions and study procedures are briefly described as follows.

Study Area

Skidding data were obtained in McCurtain County in 1972 on three logging sides which are equipped with both conventional choker skidders and hydraulic grapple skidders. These operations were located southeast of Broken Bow, Oklahoma on gently rolling Coastal Plain topography. The climate is warm and temperate with an annual precipitation of 47 inches. Shortleaf Pine (pinus echinata) and Loblolly Pine (pinus taeda) were the primary timber species being harvested, with a scattering of about 15 percent of hardwoods in association.

Data were obtained during the summer months, May through August. Weather during the study was usually sunny, hot and humid. There was occasional cloudy weather and light rain. Ground conditions were usually dry and firm.

Logging Conditions

Logging operations are carried out on a year-round basis. Each logging side consisted of one feller buncher, four or five grapple skidders and one or two choker skidders, six haul trucks, one bulldozer, one self-propelled hydraulic heelboom loader, and other equipment including two-way radios, chain saws, pickup trucks, crew buses and fuel-lubricant trailers. All sides aimed at a daily harvesting goal of 115 cunits of tree-length stems.[1] Settings varied from 300 to 600 acres in size.[2] Ninety percent of all one-way skidding distances were within the range of 150 feet to 700 feet. Trees were skidded and decked at the roadside. Decks were often less than 150 feet apart.

The harvesting system consisted of cutting and partial bunching of the trees with the feller buncher and skidding the entire tree to the landing, where the limbing and bucking were done prior to loading for truck-hauling to the mill. The skidders were also used to clear the landing area of accumulated slash and debris and to pile the logs after they had been limbed and bucked.

The bulldozer was used to push out landing areas, in temporary road construction and also to pile the log decks.

The hydraulic grapple skidders observed were Clark Ranger 667 models equipped with fixed grapples. The Clark 667 grapple skidder

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[1]One cunit is equal to 100 cubic feet.

[2]Settings are planned logging units (areas) assigned to a side, and for which a logging plan is written.

weighs 23,500 pounds with a horsepower rating of 110.

The choker skidders observed during the study were also Clark Ranger 667's weighing 18,857 pounds with a horsepower rating of 112. Both choker and grapple skidders were equipped with 28.1 x 26 tires.

Maintenance was performed on skidders and other equipment from 7:30 to 8:00 each morning with actual work beginning at 8:00. A half hour lunch break was taken at noon and work was completed each day at 4:00 p.m. Preventive maintenance was done daily from 4:00 to 4:30.

Each of the skidder operators observed had several months experience prior to the study. Since they had been under observation during previous studies, it is believed that any bias introduced because of the presence of study personnel was minimal and not an important factor in the results.

A factor to be considered in making use of these results is the transitional nature of the operations. Previous to a change in management policy that took place two years prior to the time of this study, only selective cutting was practiced. It involved the removal of a relatively low volume per acre, and sawlogs were the major product. The skidding methods employed consisted mainly of choker-equipped, rubber-tired skidders and crawler tractors.

The former operation contrasts greatly with present methods of clearcutting all usable material, with a major portion of the volume going for pulp. In addition to the company-owned sides, as many as 80 logging contractors are employed. Almost all skidding is accomplished by rubber-tired choker and grapple skidders. Recent operations have involved experimentation and frequent changes in equipment and techniques. The rapidity of change has presented problems in improving efficiency within given logging systems and in other aspects of management.

Field Procedures

Time Measurements

Two men, using small ledgers and stop watches, recorded time in minutes and seconds where skidding distances were long. Data collection was a one-man job on some samples where skidding distance was short.

Samples were selected by a system of two-stage sampling, in which the primary unit consisted of the quarter-day, and the secondary units being the first ten skidding cycles in the quarter day. Six primaries were obtained for each of seven grapple skidders, and three primaries for each of four choker skidders. Data were obtained on 416 grapple skidder cycles, and on 113 choker skidder cycles (a few primaries did not contain ten complete cycles). The skidding data were recorded on separate phases of the skidding cycle as follows:

Skidding Phase

Time Out

Hook-up Time

Time In

Release-Load Time

Landing Time

Reasons for any delays in excess of ten seconds in each operation were recorded.

Distance and Volume Measurements

One-way skid distance was recorded for each trip made by the skidder being observed. This distance was determined by: (a) selecting the midpoint of the area from which trees were being skidded, and measuring this distance, and (b) estimating for each cycle the difference between this distance and the actual direct distance skidded, as a plus-or-minus factor in establishing the total skidding distance for each cycle.

After the load had been released at the landing, species (hardwood or softwood), total merchantable length in feet and diameter in inches outside bark at the midpoint between butt and top were estimated (with periodic check measurements) and recorded on all stems. Volumes were later computed using Huber's formula (7).

Office Procedures

Upon completion of field observations the data were punched on computer cards for analysis at the Oklahoma State University Computer Center.

Road construction costs, volume per acre of areas logged and other information needed for analysis were obtained from industrial sources.

In determining average production rates, data that included delays due to getting stuck or to breakdown were excluded. Only eight cycles out of a total of 529 measured were excluded for these reasons. This was done in order to hold the conditions of the study more constant, and because the study design did not allow adequate sampling of these types of delays. Such delays and their effects on production necessarily are subjects for separate study.

CHAPTER IV

RESULTS AND DISCUSSION

Production Rates

During the course of this study grapple skidders completed 416 cycles averaging 2.1 stems and 76.1 cubic feet per load, as compared to 113 cycles for choker skidders which averaged 2.1 stems and 86.7 cubic feet per load. Because of the different characteristics previously mentioned, it is interesting that both grapple and choker skidders averaged the same number of logs per load. Both types of skidders worked approximately the same distance from the log decks. The grapple skidders produced an average of 190 cubic feet more per operating hour than the choker skidders. A summary of individual results for each system is given in Table I.

Table II shows the distribution of average operating times by phases of the skidding cycle for both skidder types. Hooking-up and releasing the chokers comprised a larger percentage of total cycle time for conventional choker skidders than did the grappling operations performed by the hydraulic grapple skidders. These percentages point out the most significant difference between the two skidding methods.

Landing time is made up of the time used by the skidder operator in clearing landing areas and piling logs. Landing times do not differ between skidder types, because skidders frequently worked

TABLE I

A SUMMARY OF PRODUCTION DATA OF SKIDDER OPERATION STUDIED

Observation	Conventional Choker Skidder	Hydraulic Grapple Skidder
Total Machines Studied	4.0	7.0
Total Loads	113.0	416.0
Total Stems	240.0	892.0
Average Stems per Load	2.1	2.1
Average Volume per Load (Cubic Feet)	86.7	76.1
Average Time per Load (Minutes)	7.5	5.2
Average Distance per Load (Feet)	327.6	319.7

TABLE II

DISTRIBUTION OF AVERAGE OPERATING TIMES BY PHASES OF THE SKIDDING CYCLE FOR CHOKER AND GRAPPLE SKIDDERS

Phase of Skidding Cycle	Conventional Choker Skidder		Hydraulic Grapple Skidder	
	Time in Minutes	Percent of Total	Time in Minutes	Percent of Total
Travel Empty	1.3	17.1	1.0	19.2
Hookup Load	2.2	28.9	1.0	19.2
Travel Loaded	1.6	21.1	1.3	25.0
Release Load	.7	9.2	.1	2.0
Landing Time	1.8	23.7	1.8	34.6
Total	7.6	100.0	5.2	100.0

together on these jobs and there is no reason for time involved to differ between skidder types. Total landing time was determined and pro-rated between skidder types according to number of cycles.

Average operating times by phases of the skidding cycle are summarized on a per-cunit basis in Table III. Grapple skidders required 50 percent less time than choker skidders to load one cunit of logs. The average release-load time per cunit for grapple skidders was about 90 percent less than the average time required by choker skidders. These times indicate the chief advantage the grapple skidder has over the choker skidder.

The times for traveling empty and traveling loaded were combined as moving time per 100 feet of one-way skidding distance per cunit of logs skidded. The grapple skidders moving time per hundred feet per cunit was about 12 percent faster than for choker skidders. This small variation is probably attributable to operator differences and the slightly larger average load carried by the choker skidders, and is not related to skidder characteristics. The choker skidders averaged 10.6 cubic feet (about 540 pounds) more per load than the grapple skidders (Table I).

Figure I shows the time required by both choker and grapple skidders to produce one cunit at distances of 100 to 800 feet. As indicated, productivity for grapple skidders is higher at all distances. At a distance of 100 feet the choker skidder takes 2.5 minutes longer per cunit of logs delivered to the landing while at 800 feet it takes 3.9 minutes longer than the grapple skidder. This change in time over distance is attributed to the difference in moving time per 100 feet per cunit.

TABLE III

AVERAGE OPERATING TIMES BY PHASES OF THE SKIDDING CYCLE PER UNIT OF VOLUME FOR CHOKER AND GRAPPLE SKIDDERS

Item	Choker	Grapple
Hookup Time per Cunit (Minutes)	3.6	1.8
Unhook Time per Cunit (Minutes)	.9	.1
Landing Time per Cunit (Minutes)	2.1	2.4
Moving Time per Cunit per Hundred Feet (Minutes)	1.6	1.4
Total Time to Produce One Cunit	8.2	5.7

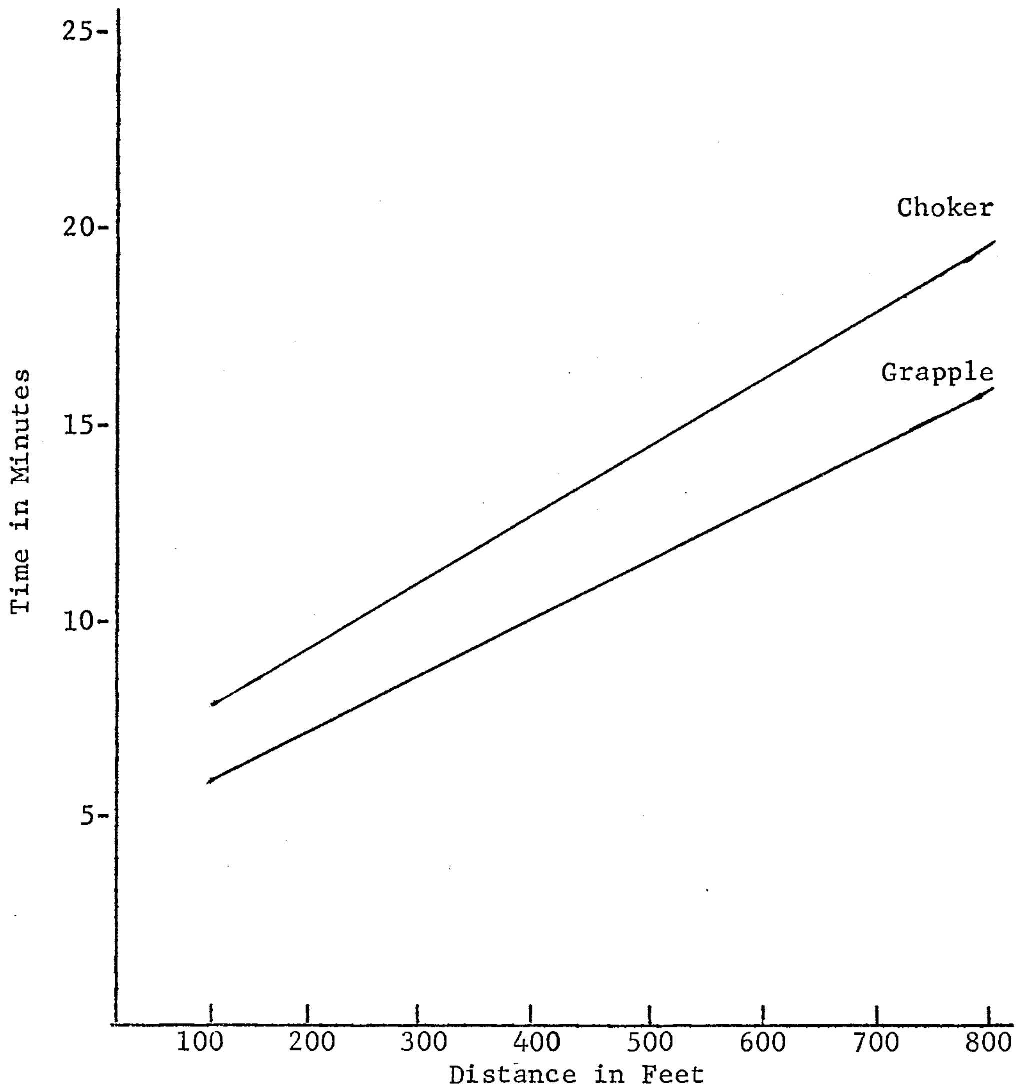

Figure 1. Time to Produce One Cunit of Wood at Different Skid Distances for Choker and Grapple Skidders.

Skidding Costs

Skidding costs per hour for hydraulic grapple skidders and conventional choker skidders were obtained by using Jarck's (8) method of computing machine rates and operator costs on a per-hour basis. A total operating cost per hour of $17.69 was computed for grapple skidders. A similar total operating cost per hour of $16.76 was calculated for conventional choker skidders. A detailed description of these calculations is given in Appendix A.

Using these costs (reduced to total operating cost per minute) and the time required to produce one cunit of wood from Figure 1, skidding costs per cunit were determined for grapple and choker skidders at distances of 100 to 800 feet. Figure 2 shows the comparative estimated costs that were obtained from this study for each system. Cost per cunit for grapple skidders was lower at all distances than for choker skidders. At a working distance of 100 feet the cost per cunit was 27 percent lower for a grapple skidder while at 800 feet grapple skidder cost per cunit was 16 percent lower than the choker skidder cost per cunit. Cost calculations are shown in Appendix B.

Other studies have found break-even skidding distances, in comparing different types of skidding equipment. No break-even exists in the results of this study. With different skidding practices, such as discussed later, a break-even point may occur.

Table IV shows the distribution of hourly cost by phases of the skidding cycle for choker and grapple skidders. These results suggest the possibility of cost reductions within each system.

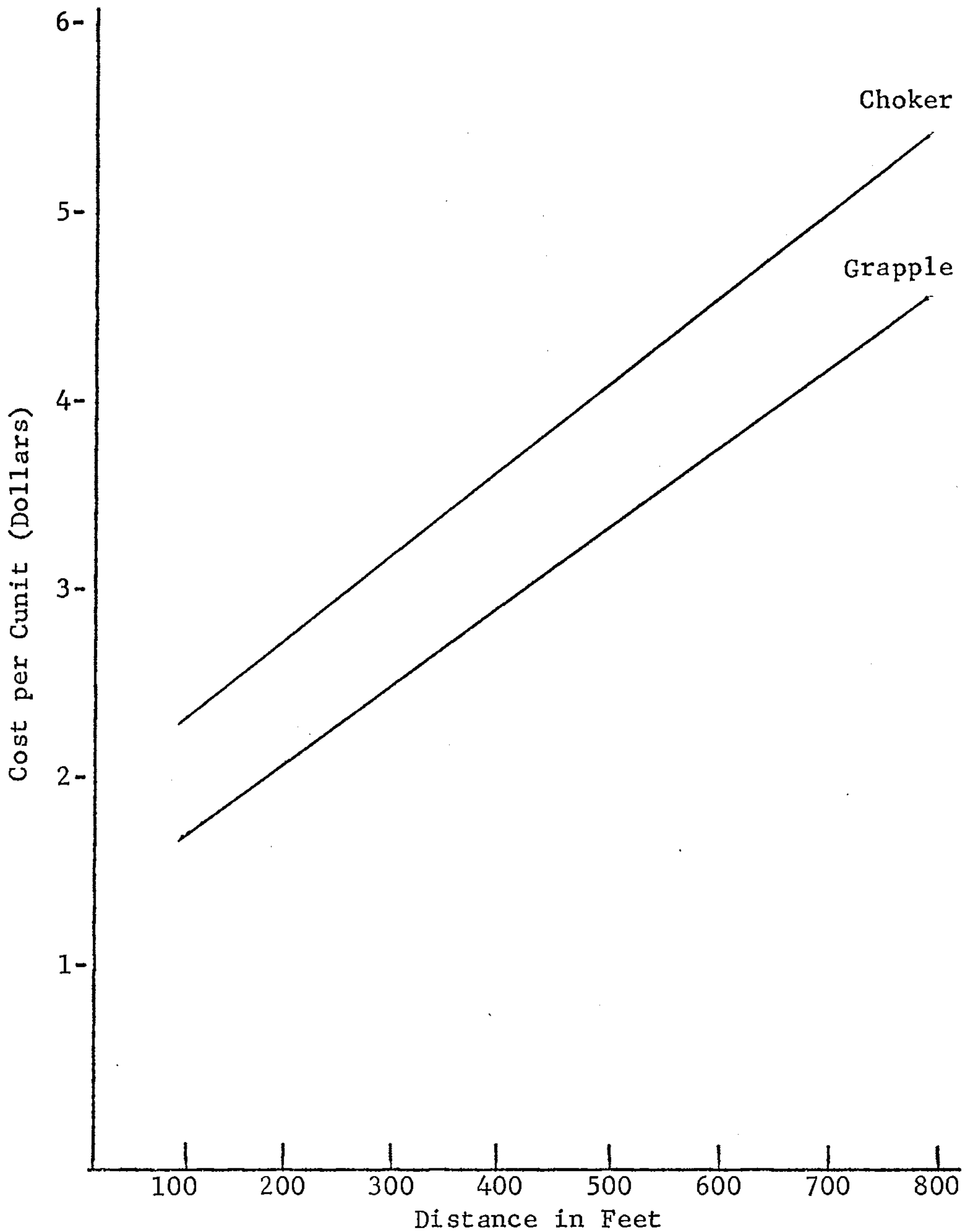

Figure 2. Cost to Produce One Cunit of Wood at Different Skid Distances for Choker and Grapple Skidders.

TABLE IV

DISTRIBUTION OF OPERATING COSTS BY PHASES OF THE SKIDDING CYCLE FOR CHOKER AND GRAPPLE SKIDDERS

	Choker Skidder		Grapple Skidder	
Phase of Skidding Cycle	Percent of Cycle Time	Cost Per Hour	Percent of Cycle Time	Cost Per Hour
Travel Empty	17.1	$ 2.87	19.2	$ 3.40
Hookup Load	28.9	4.84	19.2	3.40
Travel Loaded	21.1	3.54	25.0	4.42
Release Load	9.2	1.54	2.0	.35
Landing	23.7	3.97	34.6	6.12
Total	100.0	$16.76	100.0	$17.69

Landing time, which contributes more than one-third of total cost for grapple skidders, and nearly one-fourth for choker skidders, is an important area of potential cost reduction. Substantial reduction in direct skidding costs could be realized if the skidders did not have to perform the tasks of clearing debris from the landing area and piling the log decks. The time spent performing these operations could actually be classified as delay time from the standpoint of production, since the skidders are not actually producing logs. If more bulldozer time were allocated to clearing the landings and piling the log decks, the skidders could increase log production. Another alternative to reduce costs would be to assign a choker skidder to perform these operations and thus enable the more productive grapple skidders to work full time on skidding.

Optimum Road Spacing and Skidding Distance

In the Coastal Plain region of southeastern Oklahoma, roads generally can be located with few problems arising from difficulties with terrain. For the most part, road location and spacing can readily be done to meet requirements of skidding efficiency for any particular block of timber.

Data were analyzed to determine the optimum spacing of permanent all-weather roads. The analysis was based on allocation of the full cost of roads as a logging cost. However, the permanent roads were planned for other uses in addition to logging. Roads allow access for fire protection and suppression, recreational purposes and other activities. These uses are difficult to value and were not considered in this study. If part of the total road cost could reasonably be allocated to other uses, the analysis could be adjusted accordingly, and the result would be a decreased optimum road spacing.

For the operations sampled for this study, the average volume per acre harvested was 1,300 cubic feet. Road construction costs (obtained from industrial sources) for the area average about $4,250 per mile. Using these values and cost relationships developed by Matthews (10), Figures 3 and 4 were constructed to determine the optimum road spacing for choker and grapple skidders.

Figure 3 presents the cost relationships for grapple skidders. Since optimum road spacing occurs at the point where variable skidding cost per cunit is equal to road cost per cunit ($1.66), roads should be spaced 1,622 feet apart, at which average skidding distance is 406 feet. The total cost of skidding and roads would be $4.59 per cunit.

Figure 4 shows the same relationship for choker skidders. Optimum road spacing and skidding distance are about five percent lower than for grapple skidders. Total cost of skidding and roads at the optimum spacing is 16 percent higher than for grapple skidders.

The data for this study were taken in the summer when surface conditions were dry and near the optimum for grapple skidders. Under wet or boggy conditions choker skidders have the particular advantage of being able to winch logs out of areas which grapple skidders would be unable to reach. The current practice is to combine the two skidding methods in order to achieve lower average annual costs per unit volume and to maintain output during the wet season. As pointed out, this analysis is limited to dry season logging; the full picture of costs can be determined only if wet

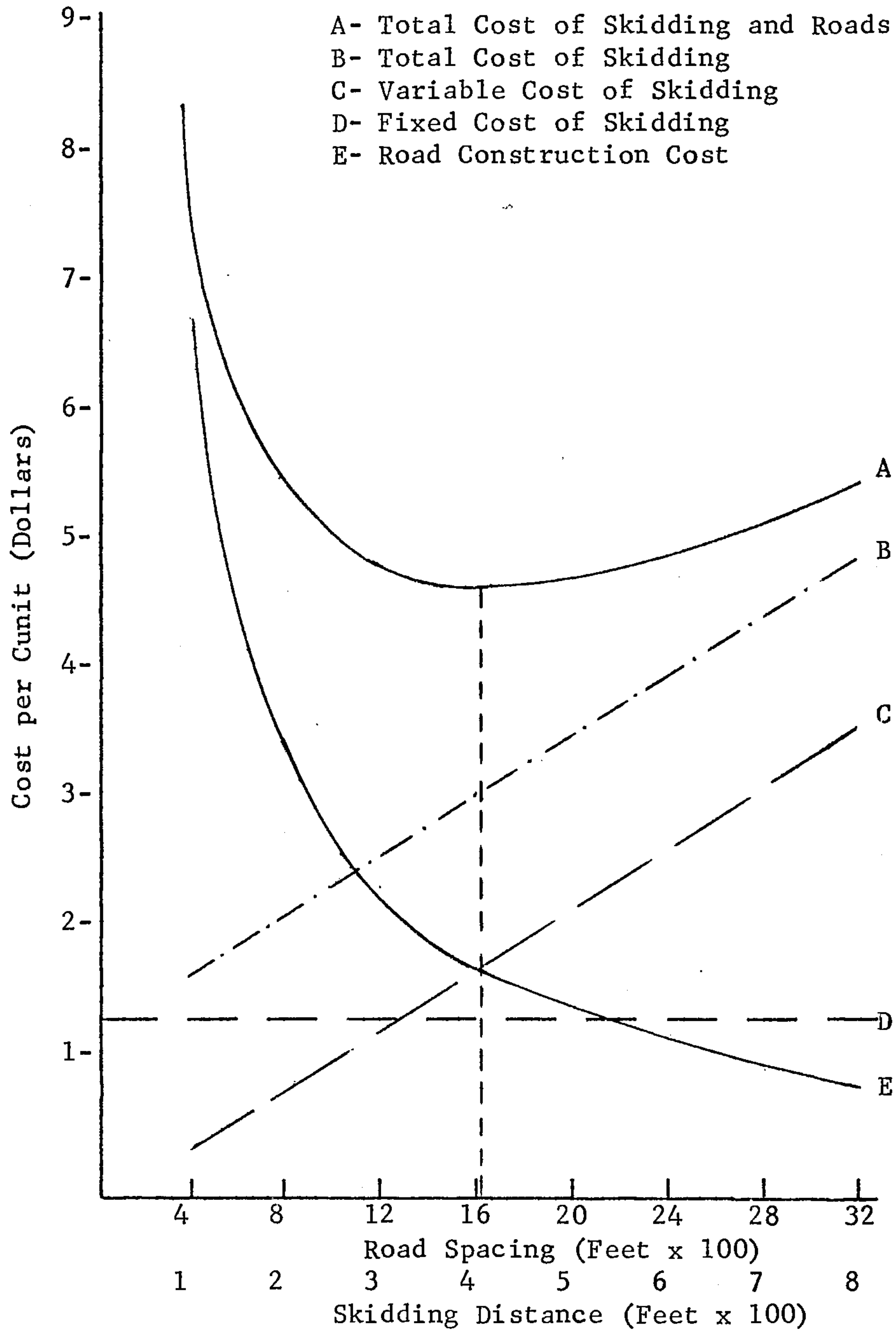

Figure 3. Skidding and Road Costs per Cunit for a Grapple Skidder.

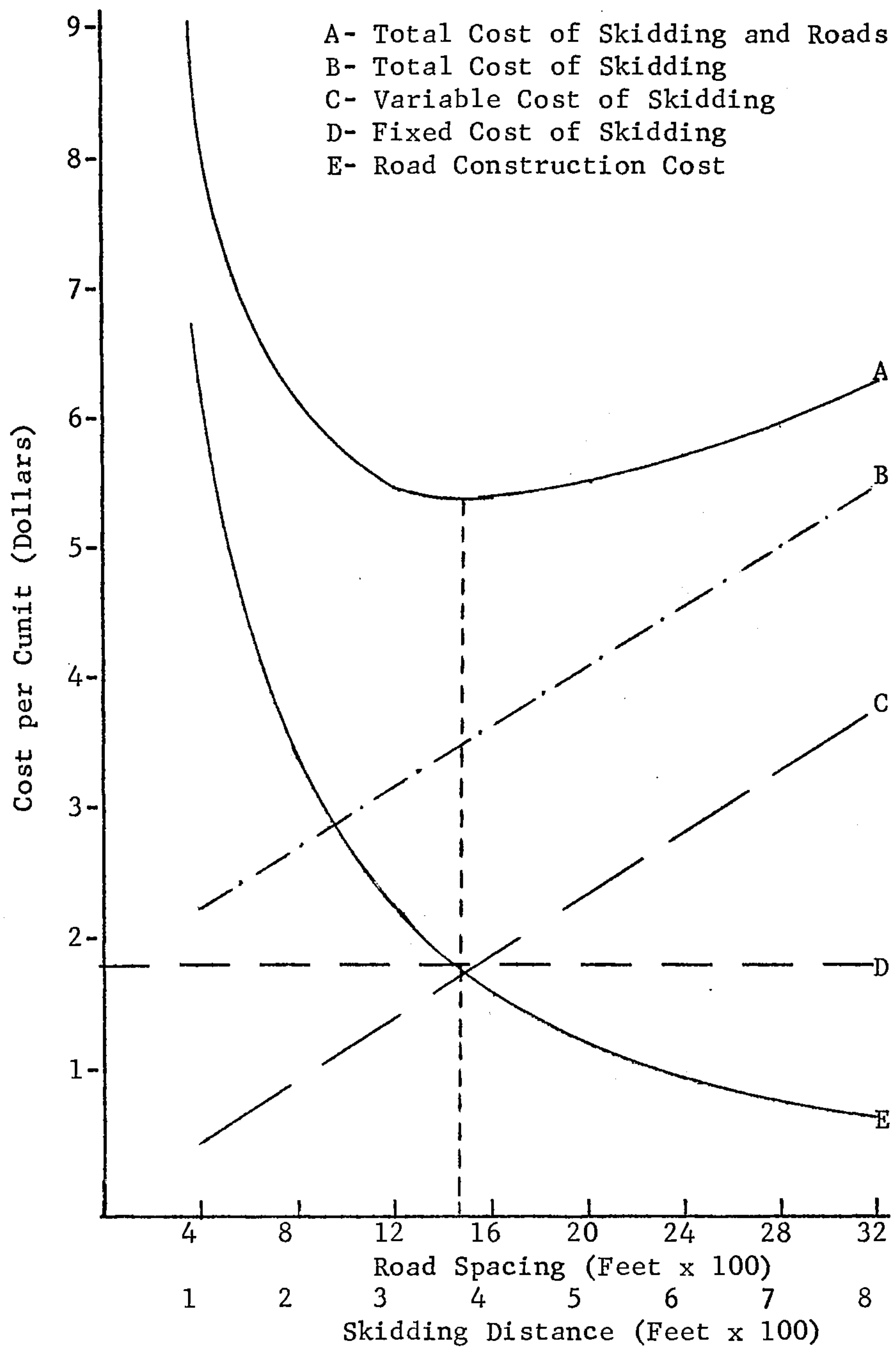

Figure 4. Skidding and Road Costs per Cunit for a Choker Skidder.

season analysis is included. This is presently being studied as a part of the project.

Figure 5 indicates the cost relationships when two choker and four grapple skidders are employed on the same logging side, operating under the conditions that existed at the time of this study. When the two methods of skidding are employed in this proportion, the average operating cost per hour is $17.38 (Appendix A). Fixed costs are $1.48 per cunit and variable costs $0.44 per cunit per 100 feet of one-way skidding distance. The optimum road spacing under this system would be 1,566 feet and the total cost of skidding and roads at this spacing is $4.92 per cunit with an average skidding distance of 392 feet.

The curves depicted in Figures 3, 4 and 5, representing the total cost of skidding and roads, illustrate the importance of proper road spacing. A range of about 600 feet exists above and below the optimum spacing distance, within which changes in road spacing will result in small changes in total cost. It should be noted that the changes in road spacings below about 1,200 feet are much more critical in terms of total costs, than corresponding changes at greater spacings. For example, in Figure 5, if road spacing is decreased to 800 feet below the optimum, total cost is 18 percent higher than at the optimum. A corresponding shift to a road spacing 800 feet above the optimum produces only a six percent increase in total cost of skidding and roads.

Results indicate, that for logging conditions and practices studied, the total cost of skidding and roads per unit volume is considerably higher for conventional choker skidders than for

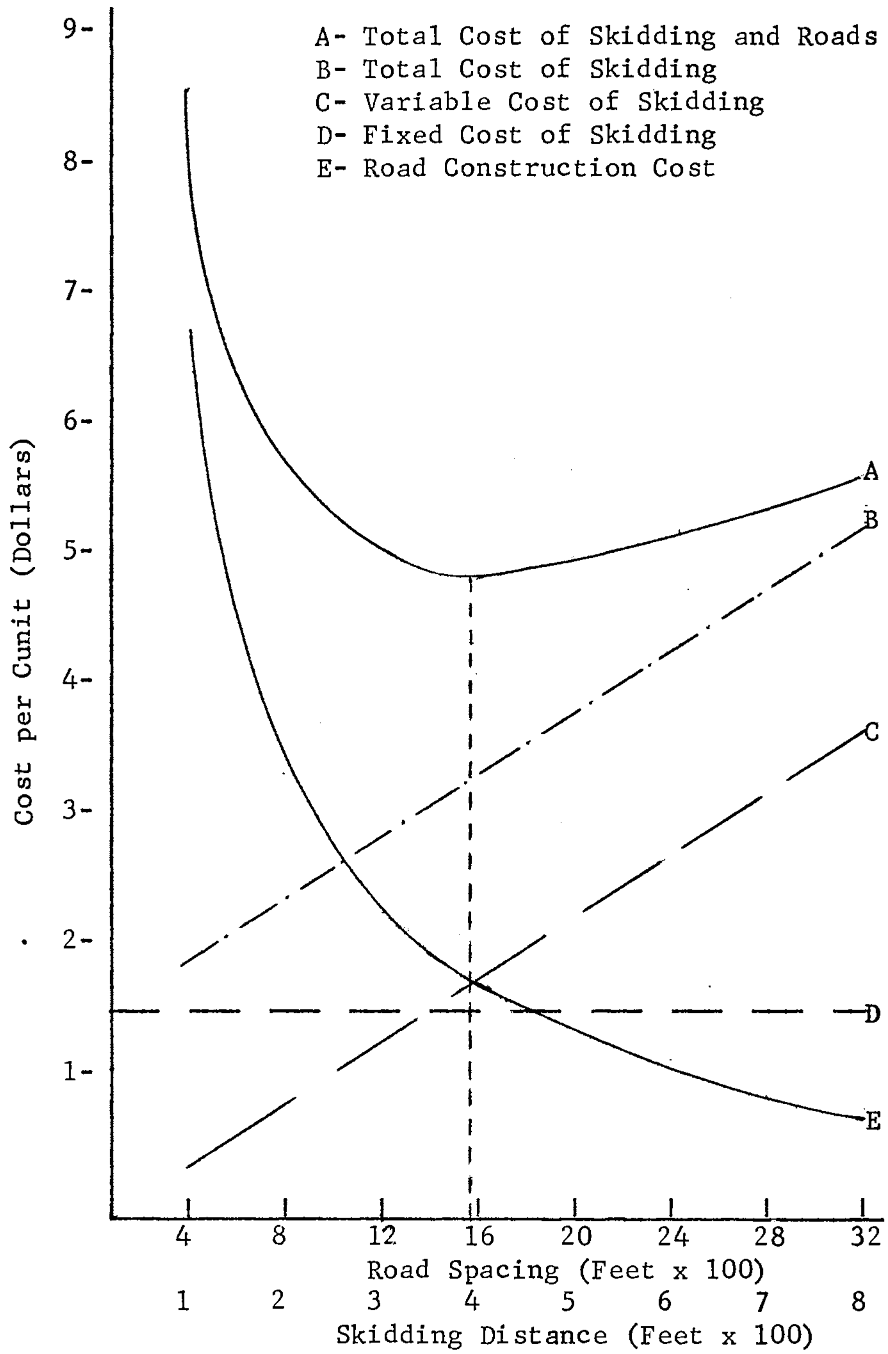

Figure 5. Skidding and Road Costs per Cunit for Combined Systems.

hydraulic grapple skidders. Thus, combining systems results in a total cost of skidding and roads that is seven percent higher than if grapple skidders alone were used. Choice of skidder type has very little effect on choice of road spacing.

As would be expected, the two skidder types differ mainly in fixed cost (hook-up and landing costs). As pointed out below, operators differed considerably in assembling loads. The most efficient size of load and hooking-up practices have not been investigated. If the most efficient size of load and hooking-up practices were known and consistently applied, cost of alternative skidding systems may be substantially different than as indicated by this study.

Operational Practices and Variables

For practical application, results need to be considered with respect to operating practices that affect production, and also to measures of efficiency and variability of operations. Additional results are presented as follows on practices that affected production, and on production variability.

As previously mentioned, both grapple and choker skidders averaged slightly more than two logs per load. However, for the conditions studied, two logs ordinarily do not make a capacity load. As another consideration, the two skidder types differ in procedure and efficiency in hooking-up the load and consequently may differ in most efficient size of load. Each of the choker skidders observed was equipped with five chokers and could have carried at least that number of logs. A choker skidder does not have to be positioned over the log to be picked up. The mainline can be pulled out to pick up logs at a considerable distance from the skidder. A grapple skidder operator must locate his grapple over the log, and once the log is grappled it becomes difficult to position the skidder to pick up another log if backing is involved.

Table V shows the variation among operators in load size and hook-up times. It appears that very little additional bunching was done during the skidding operation, considering all operators as a group. The averages indicate about two-thirds of the loads consisted of one or two logs, with little difference between skidder types in this respect. There is some correlation between average load size and the way the timber was felled and bunched. Bunching data gathered on the feller-bunchers during the course of this study revealed an average of 1.9 logs per bunch. Only 24 percent of the bunches measured contained three or more trees, while 43 percent consisted of just one tree. Average load for a given hook-up time would be larger if more bunching were done with the feller-buncher.

Considerable variation existed among operators in practices in assembling a load. For example, operators A and B had a high average percentage of three- and four-log loads, and also a high average hook-up time. On the other hand, operator C had a high average percentage of three- and four-log loads, but with an average hook-up time that was quite low. There was less variation of this nature among choker skidder operators (H, I, J and K), where average hook-up time increased consistently with the proportion of multiple log loads. Under the practices generally applied in assigning skidding areas, two or more operators often skidded from the same general area. This allowed an operator the opportunity

TABLE V

PERCENTAGE DISTRIBUTION OF SKIDDER LOADS BY NUMBER OF LOGS PER LOAD BY OPERATOR

Operator*	Percent of Loads by Number of Logs per Load				Average Logs per Load	Average Hook-up Time in Seconds
	Number of Logs					
	1	2	3	4+		
A	15	36	22	27	2.6	81
B	13	37	40	10	2.6	73
C	17	41	24	18	2.5	48
D	27	45	27	1	2.0	87
E	37	45	13	5	1.9	37
F	40	42	14	4	1.8	95
G	55	35	5	5	1.6	15
Average	29	40	21	10	2.1	62
H	21	31	31	17	2.6	168
I	30	26	26	18	2.4	148
J	36	32	25	7	2.0	125
K	65	21	14	0	1.5	78
Average	38	28	24	10	2.1	130

*A through G operated grapple skidders. H through K operated choker skidders.

to select his loads and may explain the differences noted above between grapple skidder operators.

In view of the high proportion of skidding time involved in hooking-up the load, and the evident wide variations in practices among operators, important opportunities are likely to exist for reducing costs. Substantial cost reductions may be realized by determining and applying the most efficient practices in assembling the skidder loads under given conditions.

Table VI is presented as another illustration of the variation which occurs on a skidding operation. The operators were selected on the basis of similar experience and were considered to be among the most experienced operators present on the operations studied. Operators A and B drove grapple skidders, while operator C drove a choker skidder. As expected, major differences occur between systems in hook-up time and release load time.

The average hook-up times for operators A and B differed by 25 seconds. Considering the similarities in experience, skidding machines and average number of logs per load, the difference was apparently due to operator variability. Operator B took longer to assemble a load than operator A, but had a substantially lower coefficient of variation, indicating he was more consistent in his practices.

Another source of variation in the results of this study arose from minor delays that occur under normal skidding conditions. About 19 percent of the cycles studied contained a delay in some phase of the skidding cycle, excluding landing time. About 90 percent of these delays were less than 30 seconds in duration. Table VII

TABLE VI

VARIABILITY OF OPERATOR PERFORMANCE IN SKIDDING

Phase of Skidding Cycle	Operator	Average	Range	Coefficient of Variation
Hook-up Time (Seconds)	A	48	5-183	77
	B	73	15-332	58
	C	168	50-450	57
Moving Time per 100 Feet (Seconds)	A	23	9-68	43
	B	22	8-48	34
	C	23	8-59	50
Release Load (Seconds)	A	5	1-8	24
	B	6	1-8	23
	C	43	17-183	47
Average Logs per Load	A	2.5	1-5	44
	B	2.6	1-5	30
	C	2.6	1-7	49

TABLE VII

NUMBER OF DELAYS BY PHASE OF THE SKIDDING CYCLE

Delay	Number of Delays			
	Time Out	Time In	Hook-up Time	Landing
Clear Landing and Pile Logs	0	0	0	128
Dropped Log*	0	11	0	0
Wait on Bucker**	0	12	0	11
Other Minor Delay***	29	27	3	71
Total	29	50	3	210

*Stopping to pick up log that slipped from grapple while travelling.

**Waiting for bucker to complete limbing and bucking of the previous load.

***Includes stopping for conversation with other personnel, personal needs of operator and other minor delays.

presents delays by phase of the skidding cycle. It is evident that clearing landings and piling logs are the most significant activities not related to actual skidding work.

As previously mentioned, cycles containing major delays such as breakdown were excluded from the analysis. Results do not account for a substantial amount of operating time not used in actual skidding work. This is evidenced by other data and also by the theoretical daily production of 204 cunits (based on the study data), which is about 75 percent greater than actual daily production goals.

CHAPTER V

SUMMARY AND CONCLUSIONS

Results

The results of this study indicate that, given the conditions and methods studied, hydraulic grapple skidders will out-produce conventional choker skidders at all skidding distances. Although a grapple skidder has a slightly higher operating cost per hour ($17.69) than a choker skidder ($16.76), it can produce a cunit of wood at a lower cost because of its higher production rate. This high production rate is directly related to the characteristics of the hydraulic grapple, which allows the skidder operator to hook-up and release a load of logs much quicker than a choker skidder operator. As would be expected, the two skidder types differ mainly in fixed costs of skidding (costs of hooking-up and releasing loads).

Costs of hooking-up and releasing loads made up a large part of skidding costs, consisting of 21.2 percent and 38.1 percent of total skidding costs for grapple and choker skidders, respectively. Because of the high proportion of skidding time involved in hooking-up the load, and the substantial variation among operators in hooking-up practices, as evidenced by this study, important opportunities for reducing costs in this phase of skidding appear likely to exist. Substantial cost reductions may be realized by determing and applying the most efficient practices in assembling the skidder loads.

The analysis indicates very little additional bunching was done during the skidding operation. Results show that, for both skidder types, about two-thirds of the loads consisted of only one or two logs. Since the feller-buncher averaged less than two logs per bunch, it is evident that average load size and skidder production could be increased if more bunching were done with the feller-buncher.

A possibility for cost reduction is also indicated by the amount of landing time for each skidding method. Choker skidders spent almost one-fourth of the total observed time on the landing while grapple skidders spent somewhat more than one-third of their total observed time on the landing. This time was used in piling the log decks and clearing debris from the landing area. If more bulldozer time could be allocated to clearing the landings and piling logs, the skidders could increase log production. Another alternative would be to assign a choker skidder to perform these operations.

Results indicate that for logging conditions and practices studied, the total cost of skidding and roads per unit volume is considerably higher for conventional choker skidders than for hydraulic grapple skidders. However, on the logging operations studied the current practice is to combine the two skidding methods in order to achieve lower average annual costs per unit volume, and to maintain production during the wet season.

Two choker skidders and four grapple skidders were employed on most logging sides observed. When skidding systems are combined in this manner, results indicate that total cost of skidding and roads in dry-season logging is seven percent more than would be the case if grapple skidders alone were used.

Results indicate an optimum road spacing of 1,566 feet for the combination of four grapple skidders and two choker skidders. Choice of skidder type had very little effect on optimum road spacing.

The analysis shows a range of approximately 600 feet exists above and below the optimum road spacing distance, within which changes in road spacing will result in small changes in total cost of skidding and roads. Changes in road spacings at distances less than 1,200 feet are much more critical costwise, than corresponding changes at greater spacings.

Needs for Further Research

Results of this analysis point up several questions on which further research may bring about substantial improvements in harvesting efficiency within the systems studied. Important questions exist about bunching methods, optimum size of skidder load, and skidder combinations and work assignments.

Several alternatives exist for bunching the skidder loads. Additional bunching may be done by the feller-buncher, by the skidders, or possibly by a smaller skidder selected for the purpose. Further research would be necessary to determine which method is economically most efficient for particular logging conditions.

The optimum size of skidder load is affected by skidding distance, skidder type, degree of bunching, stand conditions and other factors. No data are available for determing optimum size of load for given conditions. The large amount of variation in average load size, and the fact that most loads were considerably below skidder capacity suggest the possibility for substantial improvement through studies of optimum load size.

Questions of combinations of skidder types and sizes exist, and of work assignments and practices for a given side make-up and logging conditions. As a related question, moving time per unit distance is indicated to decrease as skidding distance increases, according to another preliminary project analysis. Further analysis will be required to determine if this relationship is significant to choices in practices.

To resolve such questions would involve substantial and relatively complicated research, because of the variability in logging conditions and the indicated interrelationships of choices in bunching practices, skidder type and size, skidder load size, work assignments and skidding distance. However, even partial answers can be useful. The most immediate need appears to lie in determining bunching and skidding production rates for alternative bunching practices.

Such research needs must of course be considered along with other production decision questions, such as in setting logging plans and in balancing of cutting and skidding as conditions change. While the study was not directly concerned with these aspects, the results indicate some research priority. Results indicate that short-duration delays are not critically important, except for the matter of use of skidders at the landing. However, theoretical production based on the time study data was found to be much greater than current daily average production goals. This suggests the need to examine other conditions that determine the amount of skidder time actually used in skidding and how their effects might be reduced.

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APPENDIXES

APPENDIX A

MACHINE RATE CALCULATIONS

TABLE VIII

VALUES USED IN MACHINE RATE COMPUTATIONS

Item	Choker	Grapple
Initial Cost (IC)	$29,870.00	$36,350.00
Salvage Value (SV)(20% of IC)	$ 5,974.00	$ 7,270.00
Expected Life in Hours (EH)	8,000.00	8,000.00
Expected Life in Years (EY)	4.00	4.00
Fuel Used (Gallons per Hour)	3.25	3.25
Fuel Cost per Gallon	$ 0.20	$ 0.20
Oil and Lubricant Cost per Hour	$ 0.05	$ 0.05
Maintenance Cost per Hour*	$ 7.50	$ 7.50
Operator Rate per Hour	$ 3.60	$ 3.60
Payroll Fringe (20% of Base Pay)	$ 0.72	$ 0.72

*This item includes tire cost. Average tire life--2,000 hours.

TABLE IX

MACHINE RATE CALCULATION FOR CLARK 667
DIESEL POWER SHIFT CHOKER SKIDDER

Item	Cost per Hour
Depreciation:	
$\frac{IC - SV}{EH} = \frac{\$29,870 - \$5,974}{8,000}$	\$ 2.99
Average Fixed Investment (AFI):	
$\frac{(IC - SV)(EY + 1)}{2EY} + SV$	
$\frac{\$29,870 - \$5,974\ (5)}{8} + \$5,974 = \$20,909$	
Interest, Insurance and Taxes:	
$\frac{12\% \times AFI}{\text{Operating Hours per Year}} = \frac{.12 \times \$20,909}{2,000}$	1.25
Operating Costs:	
Fuel used per hour x cost per gallon = 3.25 x \$0.20	0.65
Lubricants	0.05
Maintenance	7.50
Operator Expense:	
Base rate per hour	3.60
Payroll fringe	0.72
Summary of per hour costs: Fixed Cost	\$ 4.24
Operating Cost	\$ 8.20
Machine Rate	\$12.44
Operator Cost	\$ 4.32
Total Cost	\$16.76

TABLE X

MACHINE RATE CALCULATION FOR CLARK 667
DIESEL POWER SHIFT GRAPPLE SKIDDER

Item		Cost per Hour
Depreciation:		
$\frac{IC - SV}{EH} = \frac{\$36,350 - \$7,270}{8,000}$		\$ 3.64
Average Fixed Investment (AFI):		
$\frac{(IC - SV)(EY + 1)}{2EY} + SV$		
$\frac{\$36,350 - \$7,270\ (5)}{8} + \$7,270 = \$25,445$		
Interest, Insurance and Taxes:		
$\frac{12\% \times AFI}{\text{Operating Hours per Year}} = \frac{.12 \times \$25,445}{2,000}$		1.53
Operating Costs:		
Fuel used per hour x cost per gallon = 3.25 x \$0.20		0.65
Lubricants		0.05
Maintenance		7.50
Operator Expense:		
Base rate per hour		3.60
Payroll fringe		0.72
Summary of per hour costs:	Fixed Cost	\$ 5.17
	Operating Cost	\$ 8.20
	Machine Rate	\$13.37
	Operator Cost	\$ 4.32
	Total Cost	\$17.69

APPENDIX B

COST ANALYSIS CALCULATIONS

TABLE XI

PRODUCTION COSTS PER CUNIT FOR A GRAPPLE SKIDDER AT DIFFERENT SKIDDING DISTANCES

Skidding Distance	Variable Cost*	Fixed Cost**	Total Cost
100	$0.41	$1.27	$1.68
200	0.82	1.27	2.09
300	1.23	1.27	2.50
400	1.64	1.27	2.91
500	2.05	1.27	3.32
600	2.46	1.27	3.73
700	2.87	1.27	4.14
800	3.28	1.27	4.55

*Variable Cost:

Operating Cost per Minute = $0.295

Moving Time per Hundred Feet per Cunit (Minutes) 1.4

Variable Cost per Cunit = 1.4 x $0.295 = $0.41

**Fixed Cost:

Hook-up Time per Cunit (Minutes)	1.8
Release Load Time per Cunit (Minutes)	.1
Landing Time per Cunit (Minutes)	2.4
Total Time per Cunit (Minutes)	4.3

Fixed Cost per Cunit = 4.3 x $0.295 = $1.27

TABLE XII

PRODUCTION COSTS PER CUNIT FOR A CHOKER SKIDDER AT DIFFERENT SKIDDING DISTANCES

Skidding Distance	Variable Cost*	Fixed Cost**	Total Cost
100	$0.45	$1.84	$2.29
200	0.90	1.84	2.74
300	1.35	1.84	3.19
400	1.80	1.84	3.64
500	2.25	1.84	4.09
600	2.70	1.84	4.54
700	3.15	1.84	4.99
800	3.60	1.84	5.44

*Variable Cost:

Operating Cost per Minute = $0.279

Moving Time per Hundred Feet per Cunit (Minutes) 1.6

Variable Cost per Cunit = 1.6 x $0.279 = $0.45

**Fixed Cost:

Hook-up Time per Cunit (Minutes)	3.6
Release Load Time per Cunit (Minutes)	.9
Landing Time per Cunit (Minutes)	2.1
Total Time per Cunit (Minutes)	6.6

Fixed Cost per Cunit = 6.6 x $0.279 = $1.84

TABLE XIII

PRODUCTION COSTS PER CUNIT FOR COMBINED SKIDDING SYSTEMS AT DIFFERENT SKIDDING DISTANCES*

Skidding Distance	Variable Cost**	Fixed Cost***	Total Cost
100	$0.44	$1.48	$1.92
200	0.88	1.48	2.36
300	1.32	1.48	2.80
400	1.76	1.48	3.24
500	2.20	1.48	3.68
600	2.64	1.48	4.12
700	3.08	1.48	4.56
800	3.52	1.48	5.00

*All values are weighted averages of the times observed during this study which would occur if two choker skidders and four grapple skidders were combined on the same logging side.

**Variable Cost:

Operating Cost per Minute = $0.29

Moving Time per Hundred Feet per Cunit (Minutes) 1.5

Variable Cost per Cunit = 1.5 x $0.29 = $0.44

***Fixed Cost:

Hook-up Time per Cunit (Minutes)	2.4
Release Load Time per Cunit (Minutes)	.4
Landing Time per Cunit (Minutes)	2.3
Total Time per Cunit (Minutes)	5.1

Fixed Cost per Cunit = 5.1 x $0.29 = $1.48

TABLE XIV

ROAD COSTS

Road Spacing (Feet)	Road Cost per Cunit*
400	$6.75
800	3.38
1200	2.25
1600	1.69
2000	1.35
2400	1.12
2800	0.96
3200	0.84

*Computations:

Road Costs per Mile: $4,250

Volume per Acre to be Harvested: 13 Cunits

Example:

Cost of roads when spacing is 1200 feet = $\frac{\$4,250/12.1}{13 \times 12}$ = $2.25

Cost of roads when spacing is 2000 feet = $\frac{\$4,250/12.1}{13 \times 20}$ = $1.35

VITA

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