ECONOMICS OF BUNCHING IN HARVESTING SHORTLEAF PINE STANDS

By

BUCKY OSCAR FRANKLIN

Bachelor of Science

Oklahoma State University

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ECONOMICS OF BUNCHING IN HARVESTING

SHORTLEAF PINE STANDS

Thesis Approved:

Edward E. Sturgeon
Thesis Adviser

Darrel D. Kletke

Nat Walker

N N Durham
Dean of the Graduate College

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CHAPTER I

ECONOMICS OF BUNCHING IN HARVESTING SHORTLEAF PINE STANDS

Introduction

The timber harvesting industry is one of the most important components of the economy of the South. In recent years, there have been many improvements in methods of timber harvesting, bo th from the standpoints of efficiency and utilization. The powersaw has mechanized fell- and bucking; new and improved skidders have mechanized the skidding operation; and improved methods of hauling have revolutionized the transportation of basic wood products. These improvements have occurred because of greater productivity requirements, increased emphasis on lower production costs, and a shortage of skilled and semiskilled labor.

Harvesting is an integral part of timber management. Relatively low harvesting costs are necessary for the realization of acceptable production profits. To some extent harvesting costs determine how stands are to be managed. Choices in stand management in turn affect harvesting methods and costs. The need for research in timber harvesting methods is particularly urgent in southeastern Oklahoma because of new developments in harvesting machines and procedures.

Major changes are underway in the management and use of the forest lands of southeastern Oklahoma. New developments in the wood-using industries and new plants are creating expanded local markets for wood of major dimensions and more favorable opportunities for profitable timber growing. Also the timber managers plan to convert large forest acreages to pine plantations with more intensive management systems. One large company will probably convert 500,000 acres or more to an even-aged system of management over a period of about 30 years. Investments of at least 3 million dollars in new harvesting equipment may be made in the near future in southeastern Oklahoma.

A highly mechanized operation of the timber harvesting industry is not the final answer, however, because it would require too large a capital investment for many small operators. Machines must be utilized economically on a full-time basis to provide an adequate return on the investment.

"Timber harvesting has been identified as a problem in materials handling and transportation; and it is evident that the area of greatest savings on a ton-mile basis remains in the skidding phase--the initial movement of timber from the stump to the primary assembly point. While such a study and experimentation has been done, it still remains one of the most difficult to evaluate with reference to the efficiency of methods and equipment in various types of forests." (McCraw, 1970).

Cost analysis of harvesting equipment has long been a problem in the wood products industry, mostly because of the high cost of data collection and the difficulty of making allowances for the variation in the natural factors found on each logging site. For these reasons, few scientific studies, including all factors of forest production, have been attempted.

Objectives

In analyzing results of preliminary studies by the Department of

Forestry on different harvesting operations during the summer of 1970 and early spring of 1971, a trend began to be evident in the time-production study of the skidding operation. This trend indicated that the greater portion of the total cycle time was required in picking up single scattered logs. This realization led to the initiation of this study of pre-bunching prior to skidding.

The basic objectives of the study are as follows:

1. To develop machine cost rates and harvesting production costs for each system using:

   (A) pre-bunching and skidding as one system and

   (B) skidding with no bunching as the second system.

2. To develop mean harvesting production rates for each system and to compare these machine production rates with machine production costs for each system.

3. To develop a theoretical production prediction table for both systems.

CHAPTER II

LITERATURE REVIEW

A study of lumber production costs from the standing tree to rough green or dressed lumber indicates that direct costs of cutting and skidding timber amounts to about 40% of the delivered cost of timber, 30% of the rough green costs, and 25% of the dressed lumber costs (McCraw, 1967). The cutting and skidding operation is one of the greatest cost items in the process of producing lumber; and, therefore, it presents a good opportunity for cost reductions. Skidding costs alone comprise approximately one-third of the total cost of a typical harvesting system (Garner, 1966). Since log skidding costs are such a large part of the cost of the finished product, sound estimates of these costs are necessary for any complete economic analysis of a forest enterprise. Most studies of harvesting costs have approached the problem in one of two ways--the simple comparison approach or the time and cost study approach.

The Simple-Cost-Comparison Approach to Machine Cost Analysis

The comparison method is the procedure which experienced loggers normally use for cost appraisals (Tufts, 1964). Logging costs are based on estimates of volume per acre, size of trees and terrain on the present timber tract and are compared with similar tracts previously logged. Naturally there are inherent high risk factors in this method because of the subjective nature of the approach and the possibility of costly mistakes in estimating forest conditions and operation costs. Turner (1959) explained that loggers using this system remain in business only because of the few highly profitable situations encountered during the course of a year.

The Time-and-Cost-Study Approach to Machine Cost Analysis

Carroll (1964) found that the time-and-cost method was in less common usage than the comparison approach. Production and cost figures based on data collected under various field contributions are the key to the time and cost method of cost appraisal. Winer (1961) explained that it contains three general classes of work measurement studies:

1. "The methods-time measurement approach is the most intensive, detailed and expensive of these three methods. It entails extensive studies of the movement of the men and machines on the logging operation--an approach that is normally beyond the range and scope of most current loggers. Studies of motion conservation in assembly lines use this testing technique.
2. A gross time study is one in which times and measurements are not taken on individual trees but are made on groups of movements or operations. An example of this method is a comparison of power saws made by timing two saws under the same conditions to determine production rates; machine rates are then applied to the cutting times, and the better saw can be selected. A more complete gross time study would include a regression

analysis on the stand variables normally encountered by the saw crews. The basic methods of comparison without the regression analysis can be simple and inexpensive; however, better prediction results can be obtained only with careful measurement of the related variables and uses of the regression approach. This increases the cost of the time study.

3. A predetermined time study is intermediate between the methods-time and the gorss-time methods. Most of the conventional time studies fall into this group. This is the method employed in the present study. The method is characterized by the separation of the skidding cycle and the time requirements for each portion of the cycle. The application of machine costs to volume production and time was made through the use of machine rates and other costs. Time studies of this type are expensive but are justified where large, expensive logging equipment is involved. Costs are generally applied to production and time through the use of the break-even cost analysis or other methods first presented to the logging industry by Matthews (1942). The methods of Matthews include the basics of cost analysis adapted to logging machinery and hauling equipment. Matthews also presented other methods to find the most economical position for landings and forest roads based on terrain features. Matthews' early approach has more recently been extended by using modern operations research methods to prepare economic models for logging, to plan production, and to replace machinery."

An early application of cost control was made by Campbell (1953) on teams of horses and two size classes of diesel tractor skidders. Skidding time in this study proved to be determined chiefly by load size and secondly by the distance traveled for all skidding methods. In skidding with horses or mules, the number of logs, species of trees, and slope were also important factors. The regression analysis showed that teams should not skid logs more than 16 inches in diameter, or for distances longer than 1,000 feet, except on slopes of 50 percent or more where the tractor is unsafe and inefficient.

In a discussion of the predetermined time study for logging, Jarck (1965) listed examples of three different machine-rate cost calculations using machine-rate formulas proposed by Matthews. The difference between the three methods is based on the reliability of the data:

1. Calculations made on actual data. This method requires data collection on the individual machine costs as well as on production rates of the machines and is considered to be the most accurate of the methods.
2. Calculations based on the specifications and estimates of dealers. Time and production figures are for the individual machine; however, the cost figures are considered reasonably accurate for an average machine.
3. Calculations based on rule of thumb and guesses. Data on production and time are not taken for these calculations (Appendix A), and the method is not accepted as accurate.

The second method proposed by Jarck is the most widely used because it requires a less extensive study of machine costs and yet yields a cost figure based on the production of the individual machine. The third method listed by Jarck is an example of the comparison method of Tufts previously mentioned.

Results of Time-and Production Approaches to Machine Cost Analysis

To this point our concern has been with analyzing the cost of skidding only while the machines are operating. However, a production system can often be most efficiently analyzed by comparing total production figures instead of figures compiled only when the machines are operating. Thus, as time and cost study methods have been developed for skidding equipment, studies of skidding production have also been expanded. Many logging factors were found to affect production volume and time of skidding. The effects of certain logging factors on actual operating time are apparent from the following studies.

Campbell (1946), in a study of hand and power methods of harvesting, found that the most important variables affecting skidding time were distance and the number of trees per load. Tree DBH (diameter breast high) and cubic feet per load were not significantly important variables. Further study by Campbell (1953) showed that reduced time spent in skidding was no panacea, for less than one-half of the time was spent in traveling to and from the woods, and that long skidding distances reduced production. Load size and slope had a secondary effect on skidding time.

A similar study of rubber-tired wheel tractors by Cobb (1957) indicated that these machines cost less to operate per hour than crawler tractors, but they could not work slopes greater than 40 percent or handle "ground skid" loads of more than 700 board feet. Because of their high speed and low base cost, rubber-tired tractors can easily log enough timber for a small, portable mill and at a more economical rate than a tracked vehicle under the proper conditions.

Other studies of factors influencing the cost of logging, or logging production of rubber-tired skidders, provide additional information:

1. Production varied by the average volume per log in a study by Boe (1963).
2. Bennett, Winer and Bartholomew (1965) found that volume per load, volume per tree, and skidding distance were the most important environmental and operational factors in their study.
3. Wren (1966), in a regression analysis, found that operator ability after a training period, the soil conditions, and the drawbar horsepower of the rubber-tired skidder did not have a significant effect on skidding time. However, the interaction of load weight with slope, maximum slope, and skidding distance contributed significantly to skidding time. Factors having a highly significant effect on skidding time were weight per load, average slope, maximum slope, and skidding distance.
4. The most significant variable affecting skidding time was found by Lawrence (1966) to be the distance between trees. Other variables significantly affecting skidding time were skid distance, number of logs per turn or cycle, and the volume skidded per turn. A "cycle" is defined as the time required to proceed from the log deck to the woods and back with a load of logs, including travel time (loaded and empty), hooking, unhooking, and incidental delays.

In summary, skidding time appears to be dependent upon load size (Boe, 1963; Campbell, 1946, 1953; Lawrence, 1966), distance between trees (Lawrence, 1966), the distance of the skid (Bennett, 1965; Campbell, 1946; Lawrence, 1966), the volume per log (Bennett, 1965), and the slope of the haul (Campbell, 1953).

There is some disagreement between authors of these studies concerning the effect of volume per load on skidding time. The earlier study by Campbell (1946) reported that volume per load did not significantly affect skidding time. Further studies by Campbell (1952, 1953) showed that volume per load had a secondary effect on skidding time. Other studies (Lawrence, 1966; Boe, 1963) show that volume or weight per load had a significant effect on skidding time. It seems probable that the terrain in the Appalachian Mountains of the Campbell study was important enough to overshadow load size as a factor in skidding time.

Because a study of time is needed in any cost analysis, an emphasis is placed on time rather than production in studies of logging operations. Therefore, there are fewer studies of production volumes and the factors which affect logging production. The following publications on logging production have been noted, however.

Campbell (1952, 1953), in an earlier study previously mentioned, found that production is maximized by loading to capacity. Short skidding distances increased production and conversely long skidding distances reduced production. A preliminary study by McCraw (1964) showed that skidding distances were directly responsible for more than two-thirds of the variation in production. Further work by McCraw (1964) provided these results:

1. Factors having a significant effect upon load volumes per turn were tree volume, number and volume of merchantable trees per acre, and the total trees per acre. Residual stand per acre, brush height and density, and skidding distances were non-significant.

2. Load moving elements were also studied. The major factors were

skidding distance and volume per turn, while skid trail preparation and soil stability were of minor importance in the study area (Ontario, Canada).

Biggar (1959) conducted time studies on rubber-tired skidders in an extensive study in Canada. Major headings for his time elements were (a) "assemble load", (b) "trip-loaded", (c) "unhook", (d) "return-trip", and (e) "total turn time". This study showed that because of the high skidding speed of the rubber-tired skidder, increased skidding distances resulted in only a minor increase in total skidding costs. Tree length skidding was successful in hilly and broken terrain. Full loads were skidded without difficulty down slopes as steep as 34 percent and short distances up slopes as great as 10 percent.

McCraw (1964) determined that the high speed of the wheeled skidder was the primary reason for distance not being significantly important to production. Also in this study, pre-bunching, but not pre-choking, did not appreciably increase the skidding production of the wheeled skidder.

Rapid mechanical advances in the logging industry include several models of chokerless or grapple skidders; their development is based on the recognition that a logging system cannot reach its greatest potential until it becomes completely mechanized (Silversides, 1967).

Advantages of the grapple skidder given by Arthur (1967) were: (1) reduced labor requirement, (2) improved working conditions, (3) increased operation time, (4) increased work year, and (5) reduced cost per unit of production.

Thus, the factors which seem to affect logging production most on a per turn basis are skidding distance,tree volume per turn (McCraw, 1964; Campbell, 1952, 1953), total trees per acre (McCraw, 1964), merchantable trees per acre (McCraw, 1964), and average volume per log (Boe, 1963).

CHAPTER III

METHODS AND PROCEDURE

Study Area and Logging Conditions

The logging area studied is located in McCurtain County, northwest of Broken Bow, Oklahoma, in the vicinity of Clebit, Oklahoma. The climate is humid, warm and temperate. Average annual precipitation is 46 inches, and is usually evenly distributed, however, severe summer droughts are common. Frost free days for the area range from 220 to 240.

Topography varies from level to rolling and varies in elevation from 300 to 700 feet above sea level. The level areas occur adjacent to streams and drainage ways. The rolling topography is found in the uplands between such areas.

Harvesting operations are performed on all topography in the area. The primary species is shortleaf pine (Pinus echinata) with a hardwood understory.

Information concerning stand conditions for the logging area was taken by recording data from numerous point samples taken at random near the area of operations. From the random samples taken, the following information was calculated:

1. Average number of trees per acre - 170
2. Average tree diameter in the stand - 9.4 inches
3. Basal area per acre - 90

4. Species mix - 85% pine - 15% hardwoods.

The area of study was on terrain too steep for a feller-buncher machine to operate. All timber was felled by power saw.

Bunching Data

The bunching machine used in this study was a Log-A-Matic. This machine is frequently used by small logging operators to skid logs. The Log-A-Matic is a diesel-powered, two-wheel drive, rubber-tired tractor of the Ford-Ferguson type used in farming but equipped with a hydraulic blade on the front and two hydraulic-operated grapples on the rear. This machine is relatively inexpensive to purchase and operate. Modifications were made to the standard Ford-Ferguson tractor to give it more mobility in the woods and make it safer to operate. Larger tires were mounted on both front and rear of the machine, and a metal skid plate was placed under the engine and differential to protect the hydraulic lines and the operator from below. A roll-bar and heavy metal screening were installed around the operator from both sides and above to prevent sticks and heavier wooden pieces from striking the operator and the controls.

Bunching Time Measurements

The bunching machine was not normally used by the logging crew observed in this study. Therefore, an operator had to be trained in the methods prescribed for this study. After approximately one week of practice, the operator was proficient enough with the machine to provide reliable and consistent data.

A "bunch of logs" is defined as the number of logs (usually 4 to 6) deemed to be, as nearly as possible, a full load for the hydraulic grapplers to close on and for the skidder to pick up and move without undue burden on the power system.

Time measurements were taken on the bunching machine with precision stopwatches. Time was not recorded for individual bunches but on a total time basis for several bunches to include travel time between logs and between bunches in the bunching analysis. Bunching data was recorded as follows:

1. Date
2. Method (for either Franklin skidder or Timber Jack skidder)
3. Bunching time
4. Number of bunches
5. Number of logs per bunch
6. Log measurements
7. Cubic volume per bunch (calculated later in the office)

Numbers were painted on each log at this time to facilitate skidding time measurements.

The different methods of bunching for Franklin and Timber Jack skidders requires that the logs be bunched side by side for the Timber Jack skidder instead of being laid in a "pile" with butt ends nearly even, as for the Franklin grapple machine. A larger bunch of logs can be accumulated for the Timber Jack skidder, since the only restrictions are the number of chokers and the power of the machine.

Time measurements began for a "series" of bunches when the operator dropped his "tong" grapples on the first log of a bunch and was terminated when the observer deemed it a sufficient sample. These bunches were usually 3 or 4 for each sample.

Skidding Data

Data collection began in May, 1971, and continued throughout the summer on the same logging operation. The same skidders were used in each of the two systems studied. The machines used were two Franklin 170-model hydraulic fixed-grapple skidders and three Timber Jack skidders using five chokers each. These machines were timed in operation with logs not bunched and later with bunched logs. Data were recorded for each skidder using different operators to reduce the possibility of operator bias and to determine more nearly average production rates. All operators on each skidder studied had approximately the same amount of experience operating this type of machine. All of these skidders were owned by one company and were operated by the regular operators employed by the company.

The operators were fully aware that data were being collected. However, the observers had collected data on the same logging site at various times and were considered as "part of the crew" by the working men and operators to reduce operator's bias. Data on each operator and machine were recorded for a period of approximately two hours with an attempt made to observe each operator during each different period of the day. These periods were designated as 8:00 - 10:00 a.m., 10:00 - 12:00 a.m., 1:00 - 3:00 p.m., and 3:00 - 4:30 p.m.

Turn Measurements

A "turn" is defined as the complete cycle of the skidder going to the logging site and returning to the deck with logs. It also usually refers to the load of logs skidded. Several measurements were taken on each complete turn of the skidder and include the following:

1. Skidding distance was measured by pacing one way along the skid trail from the point where the last log or bunch was hooked to the skidder, to the log deck.
2. Hook-up time for the load of logs.
3. Number of logs skidded.
4. Landing time.
5. Total cycle time.

Since delay time was not considered as productive time in this study, this time was deducted from the total cycle time.

Because time has a very important influence on a cost analysis or the production of any piece of machinery, special care was taken to see that accurate stopwatches were used and that these watches were checked as often as deemed necessary by the men timing the operation.

Three men were assigned to record observations on each machine; a woodsman and two deckmen. The woodsman was responsible for taking hook-up times, cycle times, pacing out the distances, recording turn number, recording number of logs per turn, and helping make the point samples.

The deckmen recorded the log number or scaled the logs as they were skidded in, recorded the turn number and the number of logs for each turn (Appendix B, Form 3).

The other two observers made and recorded the individual log measurements. Each log measured and numbered was recorded in a notebook as the bunched logs were skidded to the landing.

Data were recorded in small notebooks for ease of handling. Each individual data sheet in the book was headed as in Appendix B, Form 1. Information recorded included the following:

1. Date
2. Skidder type and number
3. Operator
4. Bunched or unbunched
5. Time start and time stop
6. Turn time measurements
    a. Hook-up time
    b. Number of logs
    c. Skid number
    d. Distance
    e. Cycle type
    f. Log numbers
    g. Cubic volume

At the end of each day, data for that day were summarized and recorded on master sheets (Appendix B, Form 2). This data were later punched on computer cards for analysis of production costs.

Log Measurements

Each log was measured by length, butt diameter, and top diameter. The logs were either scaled as they were skidded to the landing or in the woods. The bunched logs were scaled previous to skidding. Each log was numbered on the butt end with paint stick. As the log was skidded to the landing, the deck observer recorded that number in his data sheet. Volumes for each log were later computed using Smalian's cubic foot volume rule. This volume was then recorded with the data for that turn. This data was punched on computer cards in September, 1971.

CHAPTER IV

RESULTS AND DISCUSSION

Two separate methods were used in analyzing the results of this study. They include (1) average machine production and costs per turn for operating machines, and (2) average machine production per week. Both methods are presented for each system. These two methods are widely used for production and cost analysis in the logging industry (Campbell, 1946, 1952, 1953; Cobb, 1957; Garner, 1966; Jarck, 1965; Lawrence, 1966; McCraw, 1964; Matthews, 1942; Tufts, 1964; Turner, 1959).

For this study, time, distance, and volume skidded per cycle are combined to produce a measure of the production capabilities of each system.

Average Machine Rate and Cost Computations

Actual field information about the operational production of five skidders and the bunching machine was combined with cost data from skidder and buncher manufacturers to produce production data, together with the operating costs of the machines. This study follows closely the procedure presented by Jarck (1965) from the American Pulpwood Association. It involves the use of average production figures and cost estimates (supplied from equipment dealers) in estimating machine cost per hour or cost per production unit.

Average production figures for each system were obtained from punched data cards containing the variables of individual cycles. This information was processed by using an IBM 360 computer operated by Oklahoma State University. The completed averages for each type of machine are summarized with their related variables (Appendix C, Calculations 1 and 2). Total time to complete each cycle was subdivided into time spent in travel as well as the average time in hooking and unhooking each turn. Stand characteristics measured included tree diameter for the merchantable trees in the stand, merchantable stand basal area, merchantable trees per acre, and merchantable volume per acre. Other measurements taken were average cycle distance, average number of logs per cycle, and production per cycle in cubic feet.

Machine rate was computed for a sample machine using average production on Calculation 1. Other machine rates for each type of machine used are found in Appendix D. As in other studies (Campbell, 1946; Garner, 1966; Turner, 1959), manufacturer cost estimates were used in this cost study. The following figures were included: straight line depreciation, a yearly charge of 20 percent for average investment, and the local wage for one machine operator. The average annual investment formula used was:

$$AAI = \frac{(C - R)(N + 1)}{2N}$$[1]

where: C = Initial cost

R = Salvage value

N = Years of use

[1] Formula used by Jarck (1965).

As can be seen in the complete machine rate calculations for the Franklin 170 skidder in Table I, the total machine rate of the skidder is largely influenced by depreciation rates, the combined expenses of insurance, taxes, interest, operator wages, and repair costs. Of these expenses, fixed cost, including depreciation, vary as the length of service and the hours of service per year increase. (Other machine rates calculated in Appendix C).

Naturally, the lowest cost per hour figure is found on machines used for the longest number of years and for the most operating hours per year (Table II). Table II shows the depreciation rates for a Franklin 170 skidder for various combinations of years in use and operating hours per year. For the three-year depreciation interval, the difference between 1,400 hours and 2,100 hours use per year can mean an average difference of three dollars per hour over the life of the machine. This is one of the major weaknesses of using the manufacturer's or dealer's estimate rather than actual time.

Production Cost/Cunit

After completing the production rate for each type of machine, production cost per cunit (100 cubic feet of wood) is obtained for each type of skidder used by each separate system by dividing the average total cycle time by average production per cycle and then multiplying the result by the machine cost rate to express the answer as cost per cunit.

Bunching cost per cunit was obtained by dividing average bunching time per log by average cunits per log and then multiplying the result by the machine cost rate to express the answer as cost per cunit for

TABLE I

MACHINE RATE CALCULATIONS FOR A FRANKLIN 170 SKIDDER, BROKEN BOW, OKLAHOMA, 1971

		Cost/Hour
Fixed Costs		
Depreciation	$ 3.487	
Insurance, taxes, interest	1.395	
		$4.882
Variable Costs		
Operator	2.75	
Fuel	.50	
Oil and Lube	.085	
Tires*		
Repairs	1.395	
		4.73
Total Cost		$9.612/hour .16/minute .267/second

<u>Assumptions</u>

Initial cost (C)	$27,000
Salvage (R)	10,000
Years in Use (N)	3
Operating hours per year	1625
Number of men: operator at $2.75/hour	1
Gallons fuel/hour @ 25¢/gallon	2

Oil - 10 quarts/month @ 50¢/quart

Lube - 3 gallons/month @ $2.00/gallon

Repairs - 40% of depreciation

*Tires not replaced in 3 years

Average annual investment $= \frac{(C-R)(N+1)}{2N}$

Interest, taxes, insurance, etc. = 20% of average annual investment

TABLE II

SAMPLE DEPRECIATION COSTS, ANNUAL COST, AND TOTAL FIXED COSTS PER HOUR FOR AN AVERAGE RUBBER-TIRED FRANKLIN 170 SKIDDER[1]

Hours Use Per Year	Type of Cost	Years of Use 1	2	3	4	5	6	7	8
	Depreciation	19.29	9.64	6.43	4.82	3.86	3.21	2.76	2.41
1400	Annual	3.86	2.89	2.57	2.41	2.31	2.25	2.20	2.17
	Total fixed	23.15	12.53	9.00	7.23	6.17	5.46	4.96	4.58
	Depreciation	18.00	9.00	6.00	4.50	3.60	3.00	2.57	2.25
1500	Annual	3.60	2.70	2.40	2.25	2.16	2.10	2.06	2.02
	Total Fixed	21.60	11.70	8.40	6.75	5.76	5.10	4.63	4.27
	Depreciation	16.88	8.44	5.62	4.22	3.38	2.81	2.41	2.11
1600	Annual	3.38	2.53	2.25	2.11	2.02	1.97	1.93	1.90
	Total fixed	20.26	10.97	7.87	6.33	5.40	4.78	4.34	4.01
	Depreciation	15.88	7.94	5.29	3.97	3.18	2.65	2.27	1.99
1700	Annual	3.18	2.38	2.12	1.99	1.91	1.85	1.82	1.77
	Total fixed	19.06	10.32	7.41	5.96	5.09	4.50	4.09	3.76
	Depreciation	15.00	7.50	5.00	3.75	3.00	2.50	2.14	1.88
1800	Annual	3.00	2.25	2.00	1.88	1.80	1.75	1.71	1.69
	Total fixed	18.00	9.75	7.00	5.63	4.80	4.25	3.85	3.57
	Depreciation	14.21	7.11	4.74	3.55	2.84	2.37	2.03	1.78
1900	Annual	2.84	2.13	1.89	1.77	1.71	1.66	1.62	1.60
	Total fixed	17.05	9.24	6.63	5.32	4.55	4.03	3.65	3.38
	Depreciation	13.50	6.75	4.50	3.38	2.70	2.25	1.93	1.69
2000	Annual	2.70	2.02	1.80	1.69	1.62	1.58	1.54	1.52
	Total fixed	16.20	8.77	6.30	5.07	4.32	3.83	3.47	3.21
	Depreciation	12.86	6.43	4.29	3.21	2.57	2.14	1.84	1.61
2100	Annual	2.57	1.93	1.71	1.61	1.54	1.50	1.47	1.45
	Total fixed	15.43	8.36	6.00	4.82	4.11	3.64	3.31	3.06

[1]This table is based on $27,000.00 initial machine cost, annual cost of average annual investment, and no machine salvage value.

bunching.

To include distance, machine cost rate is divided by average skidding time per "station". A "station" is defined as 100 feet of skidding distance. The result is expressed as skidding cost per station. For this study, a one-way skid distance of 500 feet was used to determine hypothetical weekly production rates.

Hook-up time per cunit for each type of machine for each system was computed by dividing hook-up time per log by cunits per log. The result was then divided into machine cost rate to obtain hook-up cost per cunit.

Unhooking time or landing time for this study was determined by taking the average landing time for over 50 cycles for each type skidding machine. The average landing time for the Franklin 170 grapple machine was 34.5 seconds and for the Timber Jack choker-equipped machine was 68 seconds. Number of logs per cycle proved not to be a factor in time required for landing time with the grapple-equipped machine or for the choker-equipped machine since five chokers were used for both systems. The operator of the Timber Jack skidder had to unhook five chokers irrespective of the number of logs per choker.

Skidder travel time per station was determined by taking numerous samples on each type of skidder as indicated in Table III. These samples were distributed ransomly at various distances from and including the station nearest the hook-up point and the landing. Skidding cost per station was determined by multiplying skid time per station by machine rate for each type skidder.

The results of a production cost analysis for the Franklin 170 without bunching are included in Table IV. The results for the remaining machines are in Appendix E. A procedure similar to this is outlined

TABLE III

AVERAGE SKID TIME AND COST PER 100 FT. STATION

Skidder	Machine Rate Per Second (Cents)	Number of Observations	Total Skid Time	Ave. Skid Time Per Station (Seconds)	Ave. Cost Station (Cents)
Franklin	.267	88	1439.167	16.354	4.367
Timber Jack	.257	53	840.370	15.856	4.075

TABLE IV

PRODUCTION COST ANALYSIS FOR FRANKLIN 170
SKIDDER IN UNBUNCHED LOGS,
BROKEN BOW, OKLAHOMA,
1971

Production and cost data based on 81 cycles

Machine rate	16¢/minute or .2674¢/second
Hook time/log	60.524 seconds
Logs/cycle	2.416
Cunits/log	.13904
Skid time/station[1]	16.354 seconds
Landing time	34.5

Hook-up cost

HT/log x logs/cycle x machine rate

60.524 2.416 .2674 = $0.3904

Skidding cost

Skid time/station x 10[1] x machine rate

16.354 10 .2674 = 0.4367

Landing cost

Landing time x machine rate

34.5 .2674 = 0.0921

Total cost/cycle $0.9192

Cost/cunit

Log/cycle x cunits/log = cunits/cycle

2.416 .13904 .33592

$$\frac{\text{Total cost/cycle}}{\text{cunits/cycle}} = \text{total cost/cunit}$$

$$\frac{\$.9192}{.33592} = \$2.736$$

---

[1]A theoretical skidding distance of 500 feet one-way distance will be used for all skidder production cost analysis.

by Matthews (1942) and further subdivided by Jarck (1965).

Production Per Week

A second method of analysis for logging cost studies is based on production per week. This method of analysis is simple and allows an operator or side-foreman to compare his operation to other similar operations. It also allows the owner to determine if his operation is economically feasible in terms of production per week. Weekly production by this method is found by multiplying the average number of turns per week by the average volume per turn.

The average production per week for each type of machine using each system is presented in Tables V and VI. The average production per week for the Log-A-Matic bunching machine is presented in Table VII.

This production prediction is theoretical but would be reliable if the average production rates and machine cost rates remain approximately the same. Time data for two different types of machines and two different systems are compared by such factors as operating hours per week, average turns per week, average production per turn, and production per week.

The average skidding machine operates an average of 6.5 hours per day, 5 days per week, for a total of 32.5 hours, even though the men are paid for 40 hours. Conversely, this means that the machines on an average operation are idle 1.5 hours per 8-hour day. Part of this time is required in greasing and fueling the machine. The remaining time is due to breakdowns and the operator's personal delays. The last factor is due largely to the ability of the supervisor to handle his men. The effect of the supervisor or side-foreman on production per week is best

TABLE V

THEORETICAL PRODUCTION PREDICTION FOR THE FRANKLIN 170 SKIDDER USING EACH DIFFERENT SYSTEM. BROKEN BOW, OKLAHOMA, 1971

Franklin Skidder in Bunched Logs	
Total time/cycle[1]	3.8339 minutes
Logs/cycle	3.7140
Cunits/cycle	.5162
Cycles/hour	15.650
Logs/hour	58.124
Cunits/hour	8.079
Cycles/6.5 hour day	101.725
Logs/6.5 hour day	377.806
Cunits/6.5 hour day	52.514
Cycles/32.5 hour week	508.625
Logs/32.5 hour week	1889.030
Cunits/32.5 hour week	262.568
Franklin Skidder in Unbunched Logs	
Total time/cycle[1]	5.7378 minutes
Logs/cycle	2.416
Cunits/cycle	.3359
Cycles/hour	10.457
Logs/hour	25.264
Cunits/hour	3.512
Cycles/6.5 hour day	67.970
Logs/6.5 hour day	164.216
Cunits/6.5 hour day	22.828
Cycles/32.5 hour week	339.852
Logs/32.5 hour week	821.080
Cunits/32.5 hour week	114.140

[1]Skid distance average 500 feet one-way.

TABLE VI

THEORETICAL PRODUCTION PREDICTION FOR TIMBER JACK SKIDDER USING EACH DIFFERENT SYSTEM. BROKEN BOW, OKLAHOMA, 1971

Timber Jack Skidder in Bunched Logs	
Total time/cycle[1]	5.9660 minutes
Logs/cycle	6.0357
Cunits/cycle	.9227
Cycles/hour	10.057
Logs/hour	60.701
Cunits/hour	9.280
Cycles/6.5 hour day	65.371
Logs/6.5 hour day	394.556
Cunits/6.5 hour day	60.320
Cycles/32.5 hour week	326.852
Logs/32.5 hour week	1972.782
Cunits/32.5 hour week	301.600
Timber Jack Skidder in Unbunched Logs	
Total time/cycle[1]	9.4238 minutes
Logs/cycle	5.0
Cunits/cycle	.7644
Cycles/hour	6.3668
Logs/hour	31.8340
Cunits/hour	4.8668
Cycles/6.5 hour day	41.384
Logs/6.5 hour day	206.921
Cunits/6.5 hour day	31.634
Cycles/32.5 hour week	206.921
Logs/32.5 hour week	1034.605
Cunits/32.5 hour week	158.171

[1]Skid distance average 500 feet one-way.

TABLE VII

THEORETICAL PRODUCTION PREDICTION FOR
LOG-A-MATIC BUNCHING MACHINE
BROKEN BOW, OKLAHOMA, 1971

Log-A-Matic Bunching for Franklin 170 Skidder	
Bunching time/log	55.6137 seconds
Logs/bunch	3.7143
Cunits/log	.13904
Bunches/hour	17.428
Logs/hour	64.732
Cunits/hour	9.000
Bunches/6.5 hour day	113.282
Logs/6.5 hour day	420.758
Cunits/6.5 hour day	58.500
Bunches/32.5 hour week	566.410
Logs/32.5 hour week	2103.790
Cunits/32.5 hour week	292.500
Log-A-Matic Bunching for Timber Jack Skidder	
Bunching time/log	59.9837 seconds
Logs/bunch	6.0357
Cunits/log	.15288
Bunches/hour	9.941
Logs/hour	60.001
Cunits/hour	9.173
Bunches/6.5 hour day	64.616
Logs/6.5 hour day	390.006
Cunits/6.5 hour day	59.624
Bunches/32.5 hour week	323.082
Logs/32.5 hour week	1950.032
Cunits/32.5 hour week	298.122

illustrated by the following discussion by Lawton (1968).

The approach of the supervisor to the problem of obtaining a set weekly production with men working under minimum hour and wage laws generally follows one of two plans: (1) involves maximizing volume per load and (2) attempts to minimize the time per turn. Each method has inherent problems based on the strong points of the other method.

(1) In the first method, large volumes per load reduces the total number of turns required per week. With maximum load, actual rate of speed is not a comparable item because most loaded machines travel at a constant speed. However, a good choking or hook-up procedure is essential to maintain a good production rate.

(2) In reduced time turn, the rate of speed of the machine must be increased along with a decreased choke or hook-up time if maximum production is to be maintained. This method will normally include smaller loads and associated shorter choke or hook-up time. When the volume per turn diminishes, the production per hour or per week is also reduced unless the machine moves more rapidly. In large timber, when volume per load is increased because of larger trees, this method of reduced turn time works well. But in small timber, the operator often makes turns without a good volume and thus reduces the machine production rate.

Lawton's discussion adds more strength to the concept of pre-bunching prior to skidding. The size and volume of the pre-bunched loads can be adjusted to the size of the skidding machine and to the method of hook-up of the load, therefore, assuring maximum load and relatively constant cycle time even in small timber.

CHAPTER V

SUMMARY AND CONCLUSION

This study was not conducted to compare the different types of skidders but to compare the different systems of bunching versus non-bunching prior to skidding in conjunction with the skidding operation. It is apparent that the possibility of bunching logs prior to skidding shows much promise (Table VIII).

Skidding costs for this study are presented as a cost per station, so that the individual operator can adjust this cost to the average skidding distance of his operation.

Total log production of the Franklin 170 skidder is more than twice the production of the same machine handling unbunched logs. Table VIII shows a reduction in total skidding cost of almost one dollar per cunit when the Franklin skidder is working in bunched logs. Log production for the Timber Jack skidder using bunched logs improved almost 100 per cent over the same machine in unbunched logs with a savings of more than 30¢ per cunit of production.

The Log-A-Matic bunching machine used in this study was a unit of study in itself. It was not intended to be a unit of comparison and therefore is not treated as one. There was very little difference in production per hour or cost per unit of production when the Log-A-Matic was used to bunch for the different types of skidders (Table IX). However, the possibility of further reduction in skidding cost may be

TABLE VIII

MACHINE RATES AND PRODUCTION DATA FOR SKIDDERS FOR BOTH SYSTEMS

Machine Rates			Production Data								
System	Machine	Total Cost Per Unit Time	Average Cycles Per Hr.	Average Logs Per Hr	Average HU Time/Log (Seconds)	Average Logs/Cycle	Average Cun/Cycle	Average Cun/Hr.	Cycle Cost Per Cunit (Dollars)	Bunching Cost/Cun (Dollars)	Total Cost/Cun (Dollars)
Bunched	Franklin	$9.612/hr. 16¢/minute .267¢/second	15.650	58.124	8.615	3.7140	.5164	8.079	1.194	.6040	1.798
Bunched	Timber Jack	$9.243/hr. 15.4¢/minute .257¢/second	10.057	60.701	21.770	6.0357	.9227	9.280	.9971	.5925	1.590
Unbunched	Franklin	$9.612/hr. 16¢/minute .267¢/second	10.457	25.264	60.524	2.410	.3359	3.512	2.736	0	2.736
Unbunched	Timber Jack	$9.243/hr. 15.4¢/minute .257¢/second	6.367	31.834	67.774	5.000	.7644	4.8668	1.901	0	1.901

TABLE IX

MACHINE RATE AND PRODUCTION DATA FOR LOG-A-MATIC
BUNCHING MACHINE, BROKEN BOW, OKLAHOMA, 1971

Bunching For:	Machine Rate			Production Data			
	Fixed Cost Per Hour (Dollars)	Operating Cost Per Hour (Dollars)	Total Cost Per Hour (Dollars)	Average Bunches Per Hour	Average Logs Per Hour	Average Cunits Per Hour	Bunching Cost Per Cunit (Dollars)
Franklin	1.866	3.579	5.445	17.428	64.732	9.000	.604
Timber Jack	1.866	3.579	5.445	9.941	60.001	9.173	.592

possible due to the bunching machine. The cost reduction possibility may represent a decrease in the repair cost of the individual skidder. A full load of logs can be obtained with a reduction in movement of the skidder when handling bunched logs. The movements that are reduced are the turning, backing, and twisting required to pick up scattered logs. It is probable that these movements cause a certain amount of wear on the individual skidding machine. This possibility needs further study before any conclusions can be drawn.

The saving in skidding cost per unit of production and the increase in log production per unit of time indicated by this study will make it possible for logging operators to realixe a greater percentage of profit. The only added investment would be a machine for bunching logs.

To conclude this study, a table is presented showing time involvement and cost requirements for a theoretical skidding operation on a tract of timber containing a total volume of 3500 cunits (Table X). Both skidding systems are presented, utilizing each type of skidder, along with the time and cost requirements for the Log-A-Matic bunching machine. Production predictions (Tables V, VI, and VII) and production cost (Appendix E) derived from this study are used in this analysis.

TABLE X

TIME INVOLVEMENT AND COST REQUIREMENTS FOR A THEORETICAL SKIDDING OPERATION[1]

Skidding System	Cunits Per Hour	Cost Per Cunit (Dollars)	Hours Per 3500 Cunits	Bunching Cost/3500 Cunits (Dollars)	Skidding Cost/3500 Cunits (Dollars)	Total Cost/ 3500 Cunits (Dollars)
Log-A-Matic	9.000	.6040	388.889	2114.00		2114.00
Franklin 170 Skidder	8.079	1.194	433.222		4179.00	4179.00
						6293.00
Franklin 170 Skidder	3.512	2.736	996.583		9576.00	9576.00
Log-A-Matic	9.173	.5925	381.555	2073.75		2073.75
Timber Jack Skidder	9.280	.9971	377.115		3489.85	3489.85
						5563.60
Timber Jack Skidder	4.867	1.901	719.129			6653.50

[1]Theoretical average one-way skid distance of 500 feet

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APPENDIX A

WORK SHEET FOR HOURLY OWNING AND OPERATING COST ESTIMATES

WORK SHEET FOR HOURLY OWNING AND OPERATING COST ESTIMATE[1]

Machine: ______________________________ (Tire Size) ______

Attachments: ______________________________

Delivered Price F.O.B. Factory. . . . . $______
Approximate Tire Replacement Cost, 1/3 off list. . . . . . . $______
Depreciation Value (Delivered Price Less Tires). . . . . . . $______*
Depreciation Period Average Conditions Years______ Hours ______

OWNING COSTS

Depreciation: Dep. Val. ________ ÷ Ser. Life, Hrs. ______ $______
Int., Ins. Taxes: ______ x Del. Price ______ ÷ 1000 . . ______**

Total Hourly Owning Cost . . . . $ ______

OPERATING COSTS

Fuels and Lubricants:

Diesel Fuel: ______ gph x ______ per gal . . . . $______
Gasoline (start & clean): ______ per hour . . . . ______
Lube Oil, crankcase: ______ gph x ______ per gal . . . . . ______
Lube Oil, trans. & fin. dr.: ____ gph x ______ per gal . . ______
Hyd. Oil, sterring: ______ gph x ______ per gal. . . . . . ______
Filters: $______ replace, cost ÷ ______ hrs. (oil change period). . . . . ______
Grease: ______ lbs./hr. x ______ per lb. . . . . ______

Repairs (including labor): ______ x hourly dep. cost . . . . ______

Tires: replace cost ______ ÷ tire life (hrs.) ______ . . ______

Total Hourly Operating Cost. . . . . $______

OPERATOR'S WAGE. . . . . $______

TOTAL HOURLY OWNING AND OPERATING COST . . . . $______

*See change in Depreciation
**CAT recommends simplified equation:

Int., Ins., Tax/Hour = .03 x Delivered Price ÷ 1000

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[1] Caterpillar Tractor Company, Peoria, Illinois.

APPENDIX B

FORMS FOR DATA COLLECTION

APPENDIX B, FORM 1

Individual Cycle Data Sheet

Skidder: Method: Date:

Operator: Start_______ Stop_______

Cycle Time Measurement

Skid No.	Hook Time	No. Logs	Distance	Cycle Time	Log No.	Cu. Volume

APPENDIX B, FORM 2

Daily Summary Sheet

Method	Date	Start	Stop	Skid No.	Operator	Skidder	Bunch	HU	Dist.	Cycle	Cu. Vol.

Logs:

APPENDIX B, FORM 3

Deckman Data Sheet

Skidder No.: Date:

Skid Number	Number of Logs	Log Measure or Log Number

APPENDIX C

AVERAGES FOR MACHINES STUDIED

APPENDIX C, CALCULATION 1

Completed Averages for Each Type Skidding Machine[1]

Skidder	Bunch	Operator	Number	Hook Time	Hook/Log
F	B	DH	78	33.116667	7.3973230
F	B	DY	37	34.864865	8.0466281
F	B	FB	31	29.158065	7.7988940
F	B	TS	23	52.491304	14.7583333
F	U	DH	40	183.842500	54.9269585
F	U	DY	41	168.585366	65.9837398
TJ	B	DY	38	138.952632	21.7699373
TJ	U	DY	6	313.000000	62.6000000
TJ	U	FB	15	341.400000	71.0011111
TJ	U	JH	27	308.333333	67.1314815

Overall Mean

Skidder	Bunch	Number	Logs/Bunch	Hook Time	Hook/Log
F	B	169	3.71428571	35.410059	8.6149338
F	U	81	2.41604160	176.119753	60.5236008
TJ	B	39	6.03571429	138.952632	21.7699373
TJ	U	48	5.00000000	319.250000	67.7743056

[1] Time in seconds

APPENDIX C, CALCULATION 2

Completed Averages for All Bunching Data[1]

Machine Bunched For	No. of Bunches	Logs/Bunch	Seconds/Log	Cunits/Log
Franklin	112	3.71428571	55.6136672	0.13904297
Timber Jack	56	6.03571429	59.9837076	0.152880814
overall mean	168	4.48809524	37.2027728	0.143655588

[1]All time in seconds

APPENDIX D

MACHINE RATE CALCULATIONS

APPENDIX D, CALCULATION 1

Machine Rate Calculations for a Timber Jack Skidder.
Broken Bow, Oklahoma, 1971

		Cost/Hour
Fixed Costs		
Depreciation	$3.282	
Insurance, taxes, interest, etc.	1.313	$4.595
Variable Costs		
Operator	2.75	
Fuel	.50	
Oil and Lube	.085	
Tires*		
Repairs	1.313	
Total Cost		4.648
		$9.243
		15.4¢/minute
		.257¢/second

Assumptions

Initial cost (C)	$24,500
Salvage (R)	8,500
Years in use (N)	3
Operating hours/year	1625
Number of men: operator at $2.75/hour	1
Gallons fuel/hour @ 25¢/gallon	2

Oil - 10 quarts/month @ 50¢/quart
Lube - 3 gallons/month @ $2.00/gallon
Repairs 40% of depreciation
*Tires not replaced in 3 years

Average annual investment = $\frac{(C-R)(N+1)}{2N}$

Interest, taxes, insurance, etc. = 20% of average annual investment

APPENDIX D, CALCULATION 2

Machine Rate Calculation for a Log-A-Matic Buncher.
Broken Bow, Oklahoma, 1971

		Cost/Hour
Fixed Costs		
Depreciation	$1.333	
Insurance, taxes, interest, etc.	.533	$1.866
Variable Costs		
Operator	$2.75	
Fuel	.25	
Oil and Lube	.046	
Tires*		
Repairs	.533	3.579
Total Cost		$5.445/hour 9.08¢/minute .151¢/second

Assumptions

Initial Cost (C)	$8,500
Salvage (R)	2,000
Years in use (N)	3
Operating hours/year	1625
Number of men: operator at $2.75/hour	1
Gallons fuel/hour @ 25¢/gallon	1

Oil - 6 quarts/month @ 50¢/quart
Lube - 1.5 gallons/month @ $2.00/gallon
Repairs 40% of depreciation
*Tires not replaced in 3 years

Average annual investment = $\frac{(C-R)(N+1)}{2N}$

Interest, taxes, insurance, etc. = 20% of average annual investment

APPENDIX E

COST ANALYSIS CALCULATIONS

APPENDIX E, CALCULATION 1

Production Cost Analysis for Franklin 170 Skidder in Bunched Logs, Broken Bow, Oklahoma, 1971

Production and cost data based on 169 cycles

Machine rate	16¢/minute or .267¢ per second
Hook time/log	8.615 seconds
Logs/cycle	3.7140
Cunits/log	.13904
Skid time/station	16.354 seconds
Landing time	34.5 seconds

Hook-up Cost

Hook time/log x	logs/cycle x	machine rate	
8.615	3.714	.267	.0854

Skidding Cost

Skid time/station x	10[1] x	machine rate	
16.354	10	.267	.4367

Landing Cost

Landing time x	machine rate	
34.5	.267	.0945

Total Cost/Cycle $0.6166

Cost/Cunit

Logs/cycle x	cunits/log =	cunits/cycle
3.714	.13904	.5164

$$\frac{\text{Total Cost/Cycle}}{\text{Cunits/Cycle}} = \text{Total Cost/Cunit}$$

$$\frac{.6166}{.5164} = \$1.194$$

Total Skid Cost/Cunit + Bunching Cost/Cunit = $1.798

$1.194	.6040	Total Cost/Cunit

[1]A theoretical skid distance of 500 feet one-way distance will be used for all skidder production cost analysis.

APPENDIX E, CALCULATION 2

Production Cost Analysis for Timber Jack Skidder in Unbunched Logs, Broken Bow, Oklahoma, 1971

Production and cost data based on 48 cycles

Machine rate	15.4¢/minute or .257¢/second
Hook time/log	67.774 seconds
Logs/cycle	5.0
Cunits/log	.15288
Skid time/station	15.856 seconds
Landing time	68.0 seconds

Hook-up Cost

Hook time/log x logs/cycle x machine rate

67.774 5.0 .257 = .8709

Skidding Cost

Skid time/station x 10[1] x machine rate

15.856 10 .257 = .4075

Landing Cost

Landing time/machine rate

68.0 .257 = .1748

Total Cost/Cycle = $1.453

Cost/Cunit

Logs/cycle x cunits/log = cunits/cycle

5.0 .15288 = .7644

$$\frac{\text{Total Cost/Cycle}}{\text{Cunits/Cycle}} = \text{Total Cost/Cunit}$$

$$\frac{1.453}{.7644} = \$1.901$$

[1]A theoretical skid distance of 500 feet one-way distance will be used for all skidder production cost analysis.

APPENDIX E, CALCULATION 3

Production Cost Analysis for Timber Jack Skidder in Bunched Logs, Broken Bow, Oklahoma, 1971

Production and cost data based on 39 cycles

Machine rate	15.4¢/minute or .257¢/second
Hook time/log	21.770 seconds
Logs/cycle	6.0357
Cunits/log	.15288
Skid time/station	15.856 seconds
Landing time	68.0 seconds

Hook-up Cost

Hook time/log x logs/cycle x machine rate

21.770   6.0357   .257 = .3377

Skidding Cost

Skid time/station x 10[1] x machine rate

15.856   10   .257 = .4075

Landing Cost

Landing time x machine rate

68.0   .257 = .1748

Total Cost/Cycle = $0.9200

Cost/Cunit

Logs/cycle x cunits/log = cunits/cycle

6.0357   .15288   .9227

$$\frac{\text{Total Cost/Cycle}}{\text{Cunits/Cycle}} = \text{Total Cost/Cunit}$$

$$\frac{.9200}{.9227} = \$0.9971$$

Total Cost/Cunit + Bunching Cost/Cunit =

.9971   .5925 $1.59

Total Cost

[1] A theoretical skid distance of 500 feet one-way distance will be used for all skidder production cost analysis.

APPENDIX E, CALCULATION 4

Production Cost Analysis for Log-A-Matic Buncher Bunching for Franklin 170 Skidder, Broken Bow, Oklahoma, 1971

Production and cost data based on 112 bunches

Machine rate	9.08¢/minute or .151¢/second
Bunch time/log	55.6137 seconds
Cunits/log	.13904

Bunching Time/Cunit

$$\frac{\text{Bunch time/log}}{\text{Cunits/log}} = \frac{55.6137}{.13904} = 399.9835 \text{ seconds}$$

Bunching Cost/Cunit

Bunching time/cunit x machine rate
399.9835 .151¢ = $0.6040

APPENDIX E, CALCULATION 5

Production Cost Analysis for Log-A-Matic Buncher Bunching For Timber Jack Skidder, Broken Bow, Oklahoma, 1971

Production and cost data based on 56 bunches

Machine rate	.151¢
Bunch time/log	59.9837 seconds
Cunits/log	.15288

Bunching Time/Cunit

$$\frac{\text{Bunch time/log}}{\text{Cunits/log}} = \frac{59.9837}{.15288} = 392.358 \text{ seconds}$$

Bunching Cost/Cunit

Bunching time/cunit x machine rate
392.358 .151¢ = $0.5925

VITA

Bucky Oscar Franklin

Candidate for the Degree of

Master of Science

Thesis: ECONOMICS OF BUNCHING IN HARVESTING SHORTLEAF PINE STANDS

Major Field: Forest Resources

Biographical:

Personal Data: Born at Chouteau, Oklahoma, July 10, 1940, the son of Mr. and Mrs. Oscar Franklin, Jr.

Education: Graduated from Locust Grove High School, Locust Grove, Oklahoma, in 1958; received Bachelor of Science degree, with a major in Forestry, at Oklahoma State University, in January 1970; completed the requirements for a Master of Science degree, May, 1973.

Professional Experience: Worked as a graduate research assistant and as a graduate teaching assistant for the Oklahoma State University Forestry Department during the years 1970 through 1972. Worked during the summers of 1968 and 1969 for U.S. Plywood-Champion Paper, Inc., in Central Oregon doing logging work.