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Sawmill Efficiency in the Eastern Ozark Region

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SUMMARY

The sawmilling industry in the Eastern Ozark Region of Missori is important to the economy because it employs more than 1,600 workers and purchases materials and services from other businesses. Sawmills provide the main market for timber; it is here that most primary and secondary products undergo their initial breakdown.

Sawmill operation is unstable and many businesses fail each year. Many mills are operating under such handicaps as worn equipment, inadequate financing, and unbusinesslike methods of operation. The result of this is often low-value lumber produced at high cost.

A time study was conducted at four sawmills. Time requirements for sawing oak logs of various diameters and lengths were derived by multiple regression techniques. The marginal log was determined by applying hourly mill rates to time requirements. An examination was made of the relationship of investment in mill equipment to hourly rate of lumber output and average variable cost of production. Return on investment for 1960 was computed for each mill, and non-productive sawing time was analyzed. From the study it was concluded:

1. Relative sawing time for logs of different sizes was similar at all mills.
2. The time required to saw a thousand board feet of lumber declined with an increase in log diameter to the optimum size for both men and machines -- 16 inches at three mills and 20 inches at one mill. For larger logs, sawing time per M thousand board feet increased with log diameter.
3. Sawing time per M board feet decreased with log length.
4. Based on average lumber grade yields from another study and prevailing lumber prices, eight-inch logs 8 to 16 feet in length and 10-inch logs of short length cost more to saw than the value of lumber produced.
5. Logs 16 inches in diameter and 16 feet in length generally required the least sawing time per M board feet of lumber and resulted in the greatest dollar conversion surplus.
6. As investment in equipment increased, rate of lumber output increased.
7. Average variable cost ranged from $40.71 to $44.98 per M board feet of lumber. With the exception of one mill that reported the highest variable cost, variable cost of production was less if a

mill had a greater investment in equipment. Costs probably were influenced more by the owner's managerial ability than investment in equipment.

8. With logs that cost $30 per M board feet delivered to the mill and average prevailing lumber prices, the two larger mills earned more than 11 percent on the owner's initial investment in mill and equipment. The smaller mills returned 5.6 and 7.1 percent. The lower return at these mills resulted in part, from intermittent operation.
9. The mills averaged 102 minutes of non-work time in an eight-hour day. One hour of this time was used to file the headsaw, remove debris from the mill, and lubricate and adjust equipment.

Sawmill Efficiency in the Eastern Ozark Region

RAYMOND M. MISCHON AND RICHARD C. SMITH

INTRODUCTION

The Eastern Ozark Region includes 14 counties 1/, an area of 9,610 square miles which is 70.4 percent forested. The proportion of commercial forest land within counties ranges from 51.3 percent in St. Francois County to 83.2 percent in Carter County. The area has a sawtimber inventory volume of 3,298 million board feet. Oaks, comprising 59 percent of this total, are the most important species(12).

The sawmilling industry in Missouri flourished during the years 1880 to 1920, until merchantable timber resources were depleted. The large sawmills subsequently moved west or south to other old-growth timber supplies. Mill workers either followed the sawmills or stayed and attempted to farm the land, The growth and peak in population of the area corresponds closely to this period of heavy

During the second World War, the sawmilling industry experienced a resurgence. Maximum production was encouraged to supply the war effort, and lumber prices were attractive even though they were controlled by government ceiling prices. In 1943, Kellogg (8) reported 477 active mills in the Eastern Ozark Region. By 1947 the number of mills had increased to 763 (10).

The margin of profit for sawmill operators narrowed during the 1950's because lumber prices failed to keep pace with rising sawmilling costs. Wholesale lumber prices increased only 10 percent during this period; but steel prices went up 37 percent, aluminum 35 percent, and all other commodities at the wholesale level, 17 percent (11). The industry became extremely competitive and many small operators were eliminated. Smith (15) found only 357 mills in operation in 1960.

Sawmills in the Eastern Ozarks employ 1,600 people and nearly the same number supply logs to the mills during peak seasons. Forest land owners realize their largest market for standing timber as sawlogs. More than 60 percent of the timber cut in Missouri is sawed into lumber, and about one-third of the total production comes from the heavily forested Eastern Ozark Region. Missouri lumber production in 1959 was 303 million board feet. Of this amount, mills in the Eastern Ozark Region produced 101 million board feet.

Problems of the sawmilling industry in the Eastern Ozarks are essentially the same as those of many decentralized activities where lack of adequate financing and management is common.

1/ Bollinger, Butler, Carter, Crawford, Dent, Iron, Madison, Oregon, Reynolds, Ripley, St. Francois, Shannon, Washington, and Wayne.

Lumber buyers are unable to utilize the full-time output of existing small sawmills even though the number of mills has decreased markedly since 1947. Low product prices and inadequate return on investments result. Many sawmills are operated seasonally. The owner's principal occupation is farming or he holds another job. Many of these owners do not have the capital necessary to purchase the most efficient equipment. As a result, much equipment in use has long been out-of-date, or badly worn. Not only does this reduce rate of output, but in many cases it causes mismanufactured lumber.

Most small sawmillers have a meager knowledge of accounting procedures. They keep a minimum of records, usually only those required for filing income tax returns. Without essential cost data and business insight, they are ill equipped to make wise management decisions. Owners have limited opportunities to become acquainted with new developments in production techniques, sawmilling equipment, and market opportunities. Too often those who are offered advice are indifferent to suggestions.

Meredith 2/, in discussing poor marketing procedures, listed these chief barriers to efficient marketing: (1) lack of communication among buyers and sellers, (2) production problems created by inefficient equipment, and (3) insufficient published information on specifications and prices of timber products.

If sawmill operators are better informed on costs and returns associated with logs of different sizes and ways of increasing their rate of lumber production in order to lower unit costs, they can make more rational decisions to increase net returns. The objectives of the study were to:

1. Determine the size of the marginal log 3/, for typical Ozark sawmills.
2. Find out whether a relationship exists between investment in equipment and the rate of lumber output and variable cost of production.
3. Determine rates of return for Ozark sawmills with different initial investments.

2/ Theodore H. Meredith, Marketing Of Rough Forest Products In The Eastern Ozark Region, unpublished Master's thesis, The University of Missouri, Columbia, 1962.

3/ Products sawed from a marginal log bring just enough income to pay direct or variable processing costs. Fixed costs--such as taxes, insurance, and interest--are not considered because they are incurred regardless of mill operation and do not vary with log sizes sawed.

RESULTS

With the time and funds available it was not possible to select an adequate sample by random methods to represent the entire population of sawmills. Based on conversation with foresters and others familiar with mill operation in the region, four mills, each with a different investment in equipment, were selected for case study. In other respects the mills selected were similar. All mills had a circular headsaw, they were set up to operate for several years at a single location, they operated more or less regularly throughout the year, and their principal product was lumber one inch in thickness. Details of the method of study, a description of the sawmills, and their equipment and operating methods are given later in the report.

Average Log Size and Rate of Output

Average statistics on log size and rates of output at the four mills are given in Table 1. At two mills with a low rate of production and small variation in log size, observations were made on about 100 logs. At the other two mills observations were made on about 200 logs. Average scaling diameter of logs at all mills was 11.5 inches and the average length was 9.8 feet. Average lumber tally per log at three mills was between 45 and 55 board feet, and at the fourth mill, 72 board feet. Overrun, based on the International 1/4-inch log rule, exceeded 10 percent at three mills, with an over-all average of 14.3 percent.

The two largest mills, equipped with a headsaw, edger, and trim saw, produced approximately one M board feet of lumber per hour. At Mill 4, a mill of medium size with a crew of 3 men operating the headsaw and edger, two hours were required per M board feet. The smallest mill, Mill 3, with only a headsaw, required 3.25 hours to produce one M board feet of lumber.

TABLE 1 - AVERAGE LOG SIZE, LUMBER YIELD, AND SAWING TIME PER M BOARD FEET OF LUMBER AT FOUR MILLS STUDIED

Mill Number	Number of Logs Timed	Scaling Diameter Inches	Log Length Feet	Lumber Tally Bd. ft.	Overrun Percent	Sawing Time Minutes
1	189	12.2	10.5	72.1	18.0	60.9
2	198	11.2	9.2	50.1	12.0	67.2
3	85	12.7	8.1	53.3	8.1	195.8
4	105	9.8	10.8	46.3	15.5	120.0
All mills	577	11.5	9.8	57.1	14.3	93.7

Sawing Time

Sawing times per M board feet by log diameter and length are shown for each mill in Fig. 1, 2, 3, and 4. Curves for all mills slope down and to the right, indicating that less time is required as log diameter increases. Long logs require less time than short ones. If logs exceeded 16 inches in diameter at three of the mills and 20 inches at one mill, sawing time increased. When optimum size for both men and machinery is exceeded, sawing time curves begin to turn upward. For example, it requires more time to turn excessively large logs on the carriage. All mills sawed logs larger than the point of peak efficiency.

Marginal Log Size

Lumber grade yields by log diameter used to develop log values are shown in Table 2. Average prices during 1961, based on quotations by

TABLE 2 - LUMBER GRADE YIELD AND VALUE BY LOG DIAMETER

Log Diameter (Inches)	Lumber Grades: Firsts and Seconds	1 Common	2 Common	3 Common	Mill Cuts[1] 4 to 6 Feet	Total per M Board Feet
			Percent of Volume			
8	0	9	43	42	6	100
10	0	6	32	57	5	100
12	1	9	24	61	5	100
14	3	15	18	59	5	100
16	5	21	14	54	6	100
18	7	24	13	49	7	100
20	10	23	13	47	7	100
22	13	15	14	51	7	100
			Value per M board feet[2]			
	$115.00	$95.00	$58.00	$35.00	$30.00	
			(Dollars)			
8	--	8.55	24.94	14.70	1.80	49.99
10	--	5.70	18.56	19.95	1.50	45.71
12	1.15	8.55	13.92	21.35	1.50	46.47
14	3.45	14.25	10.44	20.65	1.50	50.29
16	5.75	19.95	8.12	18.90	1.80	54.52
18	8.05	22.80	7.54	17.15	2.10	57.64
20	11.50	21.85	7.54	16.45	2.10	59.44
22	14.95	14.25	8.12	17.85	2.10	57.27

1/ Short pieces of lumber used for local construction

2/ Average of informal quotations by mill operators

Source: based on prevailing lumber prices and unpublished lumber grade-yield data by W. J. O'Neil; summarized in Selling Mill-Run and Graded oak lumber. Missouri Agricultural Experiment Station Research Bulletin 685. 1959.

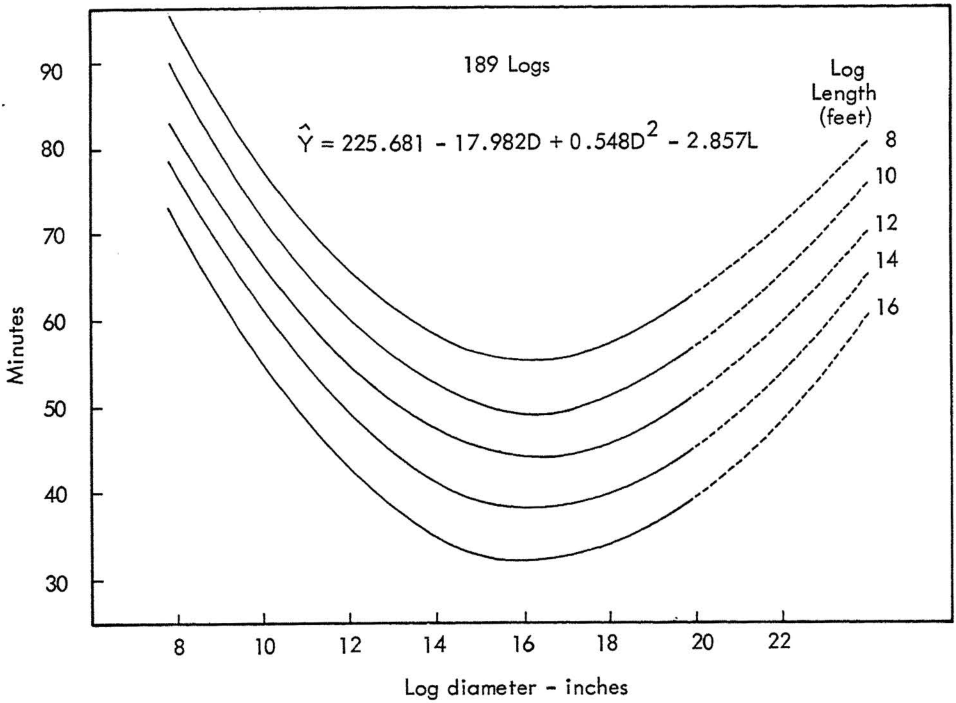

Fig. 1 -- Sawing time per M board feet of lumber by log diameter and length, Mill 1.

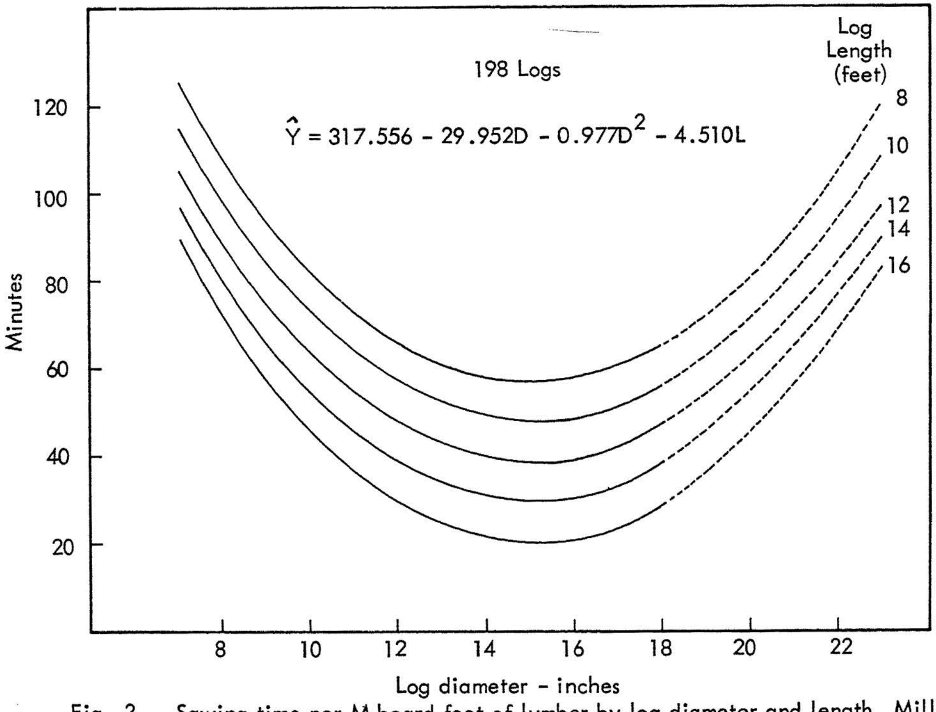

Fig. 2 -- Sawing time per M board feet of lumber by log diameter and length, Mill 2.

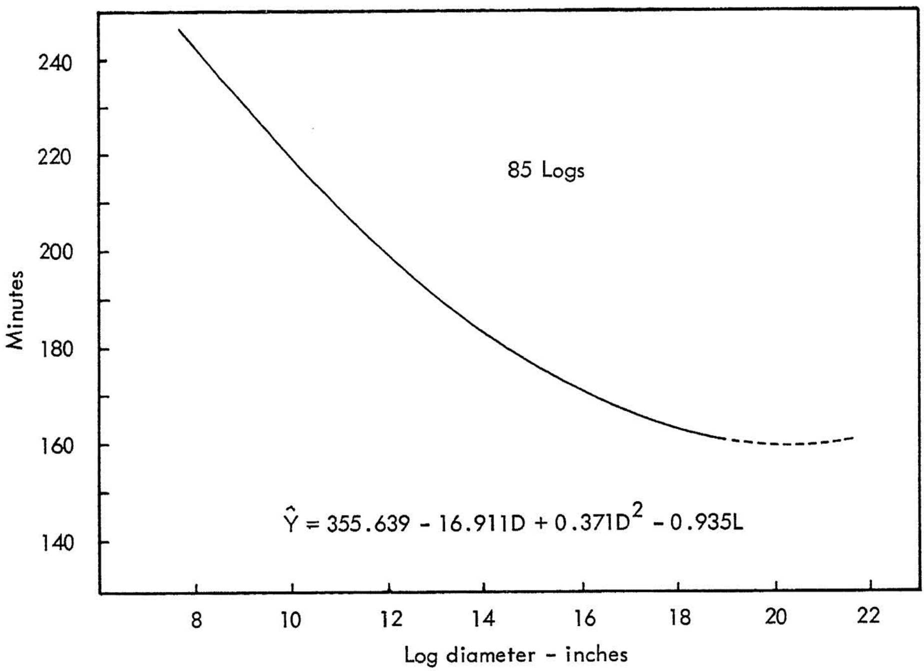

Fig. 3 -- Sawing time per M board feet of lumber from eight-foot logs, Mill 3.

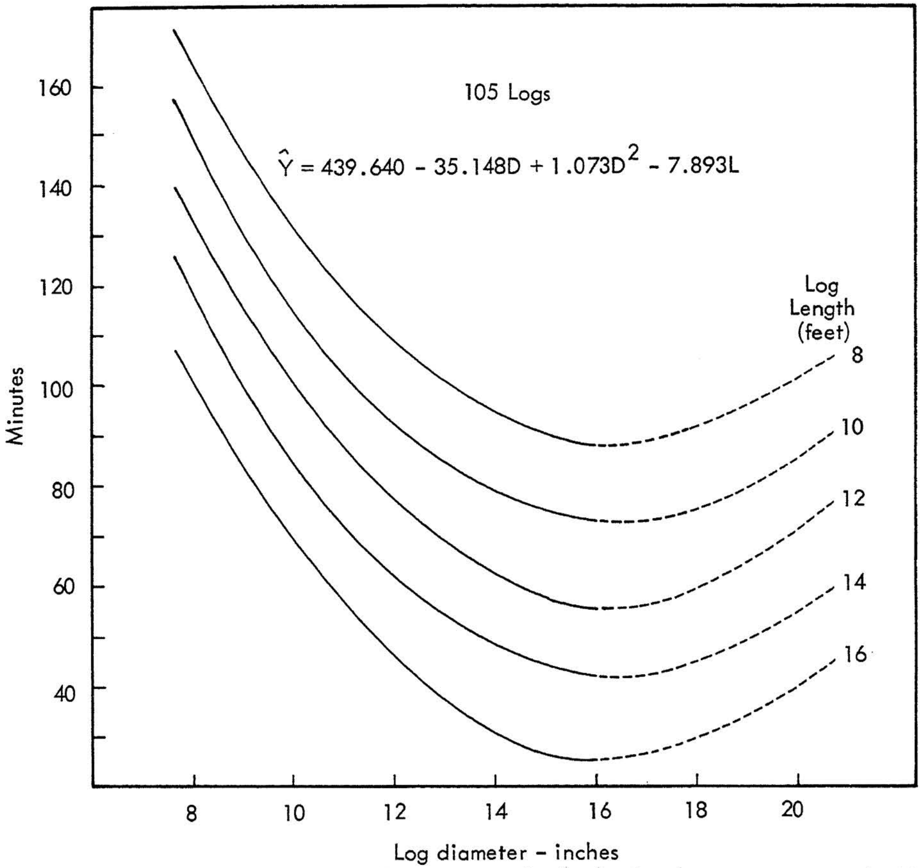

Fig. 4 -- Sawing time per M board feet of lumber by log diameter and length, Mill 4.

mill owners, and the grade yields in percent were used to obtain dollar values per M board feet of logs of various diameters (lower part of the table). Income per M board feet increases from $50.00 for lumber cut from 8-inch logs to almost $60.00 for lumber from 20-inch logs. Larger logs, because they have a higher percentage of Firsts and Seconds and Number 1 Common grades, yield more valuable lumber. Table 2 indicates that 8-inch logs have a higher value than 10-inch and 12-inch logs because they contain slightly larger proportions of number 1 Common and number 2 Common lumber. This may have been caused by a random variation in the logs studied, or it may indicate that only the better quality 8-inch logs are delivered to mills.

Variable costs for each mill were converted to an hourly basis, Table 3. Estimated mean regression of sawing time by log size was multiplied by the hourly mill rate to obtain the direct cost of sawing one M board feet of lumber from logs of various diameters and lengths (Tables 4, 5, 6, and 7.)

If the sales value of lumber sawed from a log equals but does not exceed the variable or direct costs of production, the log is marginal. When the variable cost of production was subtracted from lumber value by log size for each mill the term, marginal, was not applicable, precisely, to logs whose diameter was measured in whole inches and length, in feet. That is, the conversion surplus of all log sizes was either negative (submarginal) or positive (supermarginal), Tables 8, 9, 10, and 11. However, the break between negative and positive conversion surplus indicates logs of marginal size. For the rates of production, costs, and lumber prices used, the sale of products would not cover variable costs for the following log sizes:

Mill	Diameter, in.	Length, ft.
1	8	8 - 16
	10	8 - 12
	12	8
2	8	8 - 12
	10	8
3	8	8
	10	8
4	8	8 - 10
	10	8

In general, then, with lumber prices and estimates of cost as stated, it is doubtful that 8-inch logs of all lengths and 10-inch logs of short length pay their way.

Lumber prices frequently quoted in 1960 were used to compute the marginal log. High direct costs at Mills 1 and 3 resulted in a large

TABLE 3 - VARIABLE SAWMILLING COSTS PER HOUR

Item	Mill 1	Mill 2	Mill 3	Mill 4
		Dollars		
Labor	9.60	8.70	3.70	5.05
Mill repairs	--	0.13	0.14	1.41
Fuel, oil, grease	2.50	0.76	0.40	0.82
Logs, delivered cost[1]	27.37	24.80	8.53	13.90
Office and overhead	2.90	0.20	0.43	0.15
Miscellaneous	1.92	1.74	--	--
Total	44.29	36.33	13.20	21.33

[1] At $30.00 per M feet log scale

TABLE 4 - VARIABLE COST PER M BOARD FEET OF LUMBER BY LOG DIAMETER AND LENGTH, MILL 1

Log Diameter (Inches)	Log Length (Feet) 8	10	12	14	16
			Dollars		
8	69.40	64.97	60.54	56.82	52.40
10	57.58	53.15	48.72	45.04	40.61
12	48.72	44.29	40.61	36.18	31.76
14	42.83	39.11	34.68	30.25	25.82
16	40.61	36.18	32.46	28.04	23.61
18	42.08	37.65	33.22	29.50	25.11

TABLE 5 - VARIABLE COST PER M BOARD FEET OF LUMBER BY LOG DIAMETER AND LENGTH, MILL 2

Log Diameter (Inches)	Log Length (Feet) 8	10	12	14	16
			Dollars		
8	64.16	58.75	53.30	47.85	42.40
10	49.66	45.41	38.76	33.31	27.83
12	39.96	34.51	29.06	23.61	17.55
14	35.09	29.65	23.23	18.78	13.33
16	34.51	29.06	23.61	18.17	12.72
18	39.96	34.51	28.45	23.61	17.55

TABLE 6 - VARIABLE COST PER M BOARD FEET OF LUMBER FOR LOGS EIGHT FEET IN LENGTH, MILL 3

Log Diameter (Inches)	Cost
	Dollars
8	53.46
10	48.18
12	43.82
14	40.39
16	37.62
18	36.04
20	35.24

TABLE 7 - VARIABLE COST PER M BOARD FEET OF LUMBER BY LOG DIAMETER AND LENGTH, MILL 4

	Log Length (Feet)				
Log Diameter (Inches)	8	10	12	14	16
			Dollars		
8	57.95	52.62	46.93	41.23	35.56
10	47.29	41.23	35.56	30.57	24.89
12	39.10	32.70	27.37	22.03	16.34
14	33.77	27.73	22.40	16.70	10.67
16	31.29	25.96	19.56	14.57	8.89

TABLE 8 - CONVERSION SURPLUS PER M BOARD FEET OF LUMBER BY LOG DIAMETER AND LENGTH, MILL 1

	Log Length (Feet)				
Log Diameter (Inches)	8	10	12	14	16
			Dollars		
8	-19.41	-14.98	-10.55	-6.83	-2.41
10	-11.87	-7.44	-3.01	0.67	5.10
12	-2.25	2.18	5.86	10.29	14.71
14	7.46	11.18	15.61	20.04	24.47
16	13.91	18.34	22.06	26.48	30.91
18	15.56	19.99	24.42	28.14	32.53

TABLE 9 - CONVERSION SURPLUS PER M BOARD FEET OF LUMBER BY LOG DIAMETER AND LENGTH, MILL 2

Log Diameter, (Inches)	Log Length (Feet)				
	8	10	12	14	16
			Dollars		
8	-14.17	-8.76	-3.31	2.41	7.59
10	-3.95	0.30	6.95	12.40	17.88
12	6.51	11.96	17.41	22.86	28.29
14	15.20	20.64	26.06	31.51	36.96
16	20.01	25.46	30.91	36.35	41.80
18	17.68	23.13	29.19	34.03	40.09

TABLE 10 - CONVERSION SURPLUS PER M BOARD FEET OF LUMBER, EIGHT-FOOT LOGS, MILL 3

Log Diameter (Inches)	Log Length, 8 Feet
	Dollars
8	-3.47
10	-2.47
12	2.65
14	9.90
16	16.90
18	21.60
20	24.20

TABLE 11 - CONVERSION SURPLUS PER M BOARD FEET OF LUMBER BY LOG DIAMETER AND LENGTH, MILL 4

Log Diameter (Inches)	Log Length (Feet)				
	8	10	12	14	16
			Dollars		
8	-7.96	-2.63	3.06	8.76	14.43
10	-1.58	4.48	10.15	15.14	20.82
12	7.37	13.77	19.10	24.44	30.13
14	16.52	22.56	27.89	33.59	39.62
16	23.23	28.56	34.96	39.95	45.63

marginal log. However, the use of such average prices does not recognize that operators of superior sales ability can receive higher incomes. For example, if the owners of these two mills received an average of $55.00 to $60.00 per M board feet, the marginal log would be confined to logs 8 inches in diameter.

Marginal log sizes at all mills were large. Average value of lumber sawed from 10-inch and 12-inch logs was less than that of 8-inch logs because, according to our grade-yield data, they contained less Number 1 Common lumber and more Number 3 Common lumber. Had lumber values increased progressively from $50.00 for 8-inch logs, rather than decreasing for 10-inch and 12-inch logs, logs of these sizes would have yielded a positive conversion surplus.

Conversion surplus for all mills followed the same relationship found in the regressions of sawing time over log diameter. Because logs of large diameter and length take less time to saw per M board feet, low variable costs were incurred and a greater conversion surplus was earned. For any given length of log the three mills that operated with edgers earned the greatest conversion surplus from sawing logs approximately 16 inches in diameter. The log returning the greatest gain for the mill without an edger was approximately 20 inches in diameter.

Mill Investment and Output

The influence of initial investment in equipment on hourly lumber output and variable cost of production was examined to determine the relationship of these factors. A skillful bargainer may purchase new equipment at a low cost, while a less competent one might pay an excessive sum for used equipment. To investigate the buyer strength of the mill owners, the replacement cost of comparable equipment was obtained for 1961 from mill equipment manufacturers. Table 16 shows the initial investment in each mill and the list price of comparable equipment.

When mills were ranked as to initial investment in equipment from the lowest to the highest value, Table 12, replacement cost of the equipment in 1961 exceeded the initial investment for each mill, but the order of the mills remained unchanged. Mill owners apparently exercised equal buyer strength. Mill 3 had the smallest investment and Mill 1 had the largest investment.

Production Rate: Hourly output for each mill was computed by the proportion:

$$\frac{M}{t} = \frac{m}{T} \qquad \text{where}$$

M = one M board feet
m = the unknown, board feet
T = one hour, minutes
t = average time to saw one M board feet, minutes

TABLE 12 - EFFECTS OF INVESTMENT IN EQUIPMENT ON HOURLY PRODUCTION RATE AND VARIABLE COST OF PRODUCTION

Mill	Initial Investment in Equipment	List Price of New Comparable Models, 1961	Lumber Output M Bd. ft.	Variable Cost per M Board Feet
3	$ 5,152	$ 7,863	306	$43.06
4	6,068	10,229	500	42.67
2	7,518	12,792	892	40.71
1	17,919	21,107	985	44.98

The relationship between investment in equipment and hourly output showed that a greater investment in sawmill equipment was accompanied by a higher production rate (Table 12).

Mill 1 had more than twice as large an investment as Mill 2 (the mill with the second largest investment), but its hourly lumber production exceeded that of Mill 2 by only 93 board feet. A fork-lift truck constituted over half of the investment at Mill 1. While the log deck and lumber yard were served more efficiently, the fork-lift truck did little to increase sawmill output.

Sawmills with the basic equipment--headsaw, carriage, edger, trim saw, and power unit--produced approximately one M board feet per hour. No doubt accessory equipment would increase output, but it is questionable whether additional investment in accessories greater than that at Mill 1 would raise hourly output significantly. Production rates probably could be raised only by investing in a larger, faster mill, or by adding a sash gang resaw to saw cants.4/

Production Costs: Average variable costs of production were obtained at each mill by multiplying the average time required to saw one M board feet by the hourly mill rate. Greater investment in equipment resulted in lower variable costs of production per M board feet, with the exception of Mill 1 (Table 12). Though Mill 1 had the largest investment in equipment, it also had the highest variable cost of production. Hourly direct cost for this mill exceeded that of other mills because of the large expenditures for fuel and overhead. All fuel expenses for the fork-lift and dump truck were charged to sawing operations since there was no way to allocate their operating costs to the other functions they performed. Overhead costs were larger for Mill 1 than for the other mills, probably because the owner kept more complete records. The range from the lowest to the highest average variable cost of production among the mills is rather narrow, $4.28 per M board feet.

As initial investment increased, labor costs per M board feet were reduced, indicating that labor was being used to better advantage in the larger mills:

4/ Logs slabbed on one or more sides by the headsaw; sawed into lumber by another saw in the same mill.

Initial Investment in Equipment	Labor Cost per M Board Feet of Lumber
$ 5,152	$12.07
6,068	10.10
7,518	9.74
17,919	9.74

The average direct cost of production also is affected to a great extent by an owner's efficiency and the type of product sawed. Numerous small sawmills with little investment continue to stay in business. Mills that shut down when lumber prices lag, regardless of size of investment, are those run by entrepreneurs who are unable to hold down production costs.

Return on Investment

To indicate the return to invested capital, gross income was obtained by multiplying lumber output from each mill during 1960 by the average price received by Ozark mills.5/ Total variable costs were computed by multiplying 1960 output by the variable cost per M board feet. Fixed cost components are shown in Table 13. Depreciation of equipment

TABLE 13 - ANNUAL FIXED EXPENSES

Type of Expense	Mill 1	Mill 2	Mill 3	Mill 4
		Dollars		
Rent	1,200[1]	--	--	--
Interest	--	36	--	--
Taxes	180	106	30	100
Insurance	600	19	--	200
Other	--	--	--	146
Totals	1,980	161	30	446

[1] Owner paid $100 per month rent for mill yard. Mill was located near a town and was served by a main highway.

5/ Unpublished data, Project 406, Marketing Timber Products, Mo. Agr. Expt. Sta. Mills with an annual output of 100 to 499 M board feet received an average price of $45.00 in 1959. Mills with an annual output of 500 to 999 M board feet received $49.56.

was not included in determining the return to capital because of the difficulty in setting a reasonable rate. The average depreciation period of 20 years indicated by the Internal Revenue Service (7) may be realistic for new equipment, but many sawmill owners in the Ozark Region purchase used equipment whose life is highly uncertain.

Net income of the two larger mills was more than 11 percent of the initial investment in equipment, Table 14. Mill 1 had the highest output, which offset its narrow margin of profit. Mill 2, with 3.5 times less production than Mill 1, returned more than 11 percent of the initial investment because of a wide margin of profit. Return to invested capital for the two smaller mills was 5.6 and 7.1 percent. A narrow margin of profit and lower total production, caused by part-time operation, accounted for the lower return.

TABLE 14 - RETURN ON INITIAL INVESTMENT BEFORE TAXES, 1960

Item	Mill 1	Mill 2	Mill 3	Mill 4
		Dollars		
Gross income	43,018	10,980	6,210[1]	15,210
Less:				
Variable cost	39,043	9,933	5,813	14,422
Fixed cost	1,980	161	30	446
Net income, before income taxes	1,995	886	367	342
		Percent		
Return on investment[2]	11.1	11.8	7.1	5.6

[1] Includes $135 for owner's labor
[2] Net income/initial investment

Analysis of Non-Work Time

The total non-work time averaged 21.3 percent of a normal eight-hour day for all mills combined, Table 15. Delay time 6/ accounted for the greatest portion, 17.0 percent of a work day. Sawing stopped most frequently to allow workers to file the headsaw, remove chips and slabs, and chop dirt from the bark. The average delay time for these work stoppages for all mills combined was 13.3 percent. Average lost time 6/ was 4.3 percent of an eight-hour day.

The non-work periods were similar to those reported for mills in the Tennessee River Valley (9). Almost one hour each day was needed for saw filing, changing saws, and log and lumber delays. The time required for saw filing is similar in both regions because circular saws are used and operators use essentially the same filing procedures.

6/ See definition, page 23.

TABLE 15 - ANALYSIS OF NON-PRODUCTIVE TIME IN AN EIGHT-HOUR DAY, AVERAGE OF FOUR SAWMILLS

Classification	Minutes	Percent
Delay Time		
Filing headsaw	51.1	10.6
Minor adjustments to equipment	2.1	0.4
Lubrication	1.3	0.3
Remove, chips, slabs, sawdust	7.7	1.6
Moving logs on yard or deck	4.2	0.9
Chopping dirt from bark	5.1	1.1
Instructing workers	2.0	0.4
Talk to customers and suppliers	2.9	0.6
Rest periods	5.3	1.1
	81.7	17.0
Lost Time		
Repairs	11.9	2.5
Metal object struck in log	8.4	1.8
	20.3	4.3
Total	102.0	21.3

Sawmills in the Eastern Ozark Region normally start each work period with a sharp saw. The sawyer files the saw, on the mandrel, before work in the morning and during the noon hour. In addition, the mill is shut down for approximately 25 minutes at mid-morning and mid-afternoon to file the saw. During this period, mill workers usually spend 15 minutes cleaning debris from the mill and greasing moving parts. Thus, the loss of operating time for filing saws, in addition to that needed for cleaning debris and lubrication, is approximately 20 minutes per day.

Five minutes of the non-work time was used to clean logs. To prevent the saw from dulling too fast, sawyers frequently stopped the carriage and used an axe to chop dirt and gravel from the log in the path of the saw. Sawing time could be increased if some system for cleaning logs were installed. Without a water supply for washing logs, a router head driven by a small electric motor mounted to remove bark immediately ahead of the headsaw would serve the purpose.

The greatest opportunity for increasing productive time is to reduce the 20.3 minutes of lost time. Preventive maintenance to detect weakness before a part fails during mill operation will reduce costs. If hidden embedded metal objects frequently are struck, logs should be scanned with a metal detector before sawing.

HOW THE STUDY WAS MADE

Field Measurements

An initial contact was made at each mill to discuss the proposed study and obtain general information.

Each piece of equipment was described--make, model, horsepower rating, size, year of purchase, and initial cost. Costs of equipment provided by mill owners were, with one exception, quoted from memory. Description of equipment was used to determine replacement cost of comparable new models if purchased in 1961.

Each owner supplied cost data which could be classified as fixed or variable. The following costs were classified as fixed: buildings, land, taxes, insurance, interest, rentals, and losses. Variable costs included labor, supplies, mill repairs, office and overhead expense, and cost of logs delivered to the mill. Information on total production and number of days of operation in 1960, type of products produced, and number of men regularly employed at the mill was obtained.

To analyze costs and returns and to observe production methods, a time study was made at each sawmill. Two men observed sawing operations for one or two days and timed from 85 to 198 logs at each mill.

One observer positioned himself near the log deck to take log measurements and time each log through the headsaw. The second man was stationed at the green end of the mill to tally lumber cut from each log.

Log Measurements: The species, scaling diameter at the small end in inches, and log length in feet were recorded. The gross volume of lumber in each log was scaled according to the International 1/4-inch saw kerf log rule. Scaling practices recommended by the Forest Service (4) for use on the national forests were followed in estimating gross scale, amount of cull, and net scale volume. Logs were numbered with lumber crayon to prevent accidental remeasurement and to provide the second man with the number of each log to be sawed.

Time Measurements: The speed of other operations in the mill is governed by the headsaw operation. The time required to break down each log on the headsaw was measured with a snap-back stopwatch.7/ Time periods were measured in minutes to two decimal places. Timing began for each log when the carriage moved toward the headsaw and continued until the last board was taken from the carriage. Non-operating time, as distinguished from work time, was determined with a second stopwatch. It was broken down into the following categories:

7/ A split-hand watch used to record continuous readings. One hand may be stopped to allow recording time measurements, while the second hand resets and begins timing the next element to prevent a break in continuity of the timing operation.

1. Delay time -- frequent delays normal to operation, such as removing branch stubs from logs, saw filing, refueling power unit, and short periods of rest.
2. Lost time -- non-productive time resulting from unusual, infrequently occurring events such as major breakdown of equipment and striking metal in logs.

Lumber Tally: The number of pieces of rough lumber from each log was tallied by width in inches, thickness in inches, and length in feet. Measurements were used later to compute the volume in board feet.

Analysis of Data

The objective in analysis of sawing time was to estimate by multiple regression technique the mean time required to saw one M board feet of lumber from logs of various diameters and lengths. The cost of operating the mill for one hour was multiplied by mean sawing time in hours to derive the variable cost of producing one M board feet of lumber by log diameter and length. The marginal log was obtained by subtracting the direct cost of production from the estimated income per M board feet.

To place computations on a basis of one M board feet, the unit of volume in common use, productive or work time to saw each log in minutes, was divided by its volume in thousands of board feet. The conversion, equivalent to the time required to saw one M board feet of lumber from logs of the same size, is expressed by the ratio:

$$\frac{t}{v} = \frac{T}{V}$$ where

v = volume of lumber produced from each log, board feed
t = work time to saw the log, minutes
V = one M board feet of lumber
T = work time per M board feet of lumber, minutes; the unknown

The work time required to saw one M board feet of lumber was adjusted by apportioning total delay time at each mill to obtain total sawing time per M board feet as follows:

$$M = T\left(1 + \frac{D}{W}\right)$$ where

M = total sawing time per M board feet
T = work time per M board feet
D = total delay time for each mill, minutes
W = total work time for each mill, minutes

Lost time was not included in total sawing time because it would have distorted data based on short periods of observation.

The adjusted sawing time per M board feet for individual logs was plotted over log diameter on cross section paper to study the relation of the two at each mill. A curvilinear relationship appeared to exist between sawing time and log diameter for each of the mills. From the graphs, the effect of log length seemed sufficient to justify separating log lengths. An analysis of variance revealed that log length was significant at all mills at the 1 percent level. Log length was excluded from the analysis at Mill 3 because 80 of the 85 logs studied were 8 feet long.

A multiple regression, using the data from each mill, was computed by the Burroughs 204 Datatron computer at the University of Missouri computer center. The regression expressed the relation between sawing time and the two variables of log diameter and length. Estimated sawing time was determined from the formula:

$$Y = a + bD = cD^2 + dL \qquad \text{where}$$

Y = computed mean time required to saw one M board feet of lumber (work time plus delay time), minutes
D = log diameter, inside bark at small end, inches
L = log length, feet
a,b,c,d, = coefficients to be determined

A curvilinear formula was applied to the data for Mill 3, but variable log length was not included. The term dL, then, was omitted from the formula.

An "F" 8/ test was used to determine whether the regression curves significantly fit the data. The curves for all but Mill 3 were significant at the 1 percent level; Mill 3 was significant at the 10 percent level. At Mill 3, edging was done on the headsaw; an edger was used at the other three mills. By introducing a new variable, edging time on the headsaw, the significance of the curve at Mill 3 apparently was reduced.

Average sawing time by log diameter and length was plotted over the regression curves (Fig. 1, 2, 3, and 4) to check for fit. By using miltiple regression techniques, the effect of log diameter on sawing time was assumed to be linear for all diameters. However, it appeared that log length had a greater effect on sawing time at smaller log diameters than at larger diameters. Since computations for the marginal log involve the relative values of average logs, multiple regression techniques were considered satisfactory to express the relationship between sawing time, log diameter, and length.

8/ A test of significance: Calculated "F" value equals mean square regression divided by mean square residual.

DESCRIPTION OF MILLS

Mill 1

Operation: Mill 1 produced from 7 to 9 M board feet of lumber per day. In 1960, it operated 46 weeks and produced 868 M board feet of lumber. The principal product manufactured was 1-inch lumber; this lumber was used mainly in the construction of pallets. The mill also produced lumber for local consumption, timbers for bridges and heavy construction, and a small amount of flooring stock.

Mill Setup and Equipment: The mill had burned in 1953. It had been completely replaced by a new building and equipment. The sawmill was constructed on a concrete floor and was covered by a well-built, metal-roofed shed which was open on all sides. The mill was well managed and stayed in business despite fluctuations in price and buyer activity in the lumber market.

Mill 1 was equipped with a Corley No. 440 mill which had a 52-inch circular, inserted-tooth saw. A 24-inch Corley edger and friction log turner gave the mill added production capacity. A 24-inch home-made swing trim saw was also located at the rear of the shed on the green chain. The mill was powered by a General Motors 150 horsepower Diesel engine.

Of the four mills, this one had the greatest investment in sawmill accessories. A chain conveyor carried sawdust up a ramp to a bin. The bin was built to dump sawdust by gravity into a truck. A 1 1/2-ton General Motors dump truck was used to haul sawdust to a nearby dump. Another chain conveyor and ramp was located near the trim saw. All edgings and slabs were cut into one foot lengths and were moved on the ramp to a large truck trailer. These residues were sold to a nearby charcoal plant at a small profit, and the hazard of fire caused by burning was eliminated.

Dead rolls extended from the green end of the mill into the yard to better enable the crew to sort and stack the lumber. A Clark Ranger 60, four-wheeled, rubber-tired, fork-lift truck was used to keep the log deck supplied with logs; it also was used to move and load lumber in the yard.

Manpower: Seven men were normally employed in the mill. One man did the sawing, and an assistant on the log deck helped turn logs and operated the rear dog on the carriage. Another man served as both off-bearer and edgerman. A fourth worker trimmed ends and passed the lumber along the dead rolls to two lumber stackers and graders. The mill foreman kept the log deck loaded, moved and loaded lumber in the yard, dumped sawdust periodically, and graded and tallied incoming logs.

Mill 2

Operation: The owner of Mill 2 also operated an adjacent stave mill. Normally, the sawmill operated 50 weeks per year and produced 7 to 9 M board feet of lumber per day. In 1960, the mill produced only 243,514 board feet of lumber, 60 percent of the usual output. The owner stated that, at the time of the study, he was operating only because he had contracts to purchase timber stumpage that were about to expire.

The main products handled by the sawmill were 1-inch lumber, ties, and flooring stock.

Mill Setup and Equipment: The mill was housed under an open shed with a wooden floor; it was in need of repair. Sawing was done on a Corley 20 sawmill with a 54-inch circular, inserted-tooth saw. The carriage had three dogs, but the two at the rear of the carriage were seldom used. A Tower edger had a 30-inch width capacity. A small electric table saw at the green end of the mill was used as a trim saw. The power unit operating the mill was a Minneapolis-Moline 90 horsepower engine that had been converted to use propane gas fuel.

Sawdust at the mill was transferred to a sawdust pile by a Phelps 25K sawdust blower through a metal pipe. Although a blower of this type is an excellent piece of equipment, it needed repairs. Several times during the study the mill had to be shut down to repair the blower. The sawdust pile, surrounded by a fence built from used metal roofing, was kept burning.

Slabs and edgings were taken from the headsaw and edger and loaded into the back of an old dump truck parked at the side of the mill. Periodically, they were dumped into a shallow depression in the ground near the mill and burned. Mill 2 operated a low cost, fork-lift truck that had been converted from a used truck chassis. It was used to supply logs to the log deck and move other wood products around the stave mill.

Manpower: The sawyer, assisted by one man on the log deck, loaded the carriage and turned the logs. One man served as both off-bearer and edgerman. Another man trimmed lumber and, with a helper, passed it to two men at the side of the mill who graded and stacked lumber. The trim saw operator and his helper also loaded slabs and edgings into the dump truck. An eighth man operated the fork-lift truck, kept the log deck supplied with logs, and did odd jobs around the stave mill.

Mill 3

Operation: Mill 3 was a small mill, producing only 2.5 M to 3.5 M board feet per day. Total production of lumber in 1960 was 135 M board feet. The owner operated the sawmill half time and worked on his farm the rest of the time.

The mill produced a variety of products--including oak squares, crating, flooring stock, ties, and lumber for local construction. From incomes reported by the owner it appeared that he was receiving top prices for his lumber.

Mill Setup and Equipment: The sawmill was mounted on concrete piers. It was covered by an open shed with a metal roof. However, non-essential equipment, tools, and other items cluttered the mill and created a hazard to safe operation.

The sawmill was a Fisher-Davis No. 0 with a 52-inch circular, inserted-tooth saw. The carriage had three knees, but only one dog was used to hold the logs on the carriage. All sawing and edging was done on the headsaw. If boards required edging, they were held until an entire log was sawed. Then, boards from one log were edged, several at a time or wide ones separately.

The mill was powered by a Cummins Diesel engine of approximately 150 horsepower. The unit was closely coupled to the mandrel by six V belts.

This mill had no accessory equipment. Sawdust was removed from beneath the mill with a shovel and scattered nearby on the mill lot.

Manpower: Only two men operated the mill. One sawed and loaded the logs onto the carriage. The other served as off-bearer and also stacked lumber. When a load of lumber was sold, the owner and both workers loaded the truck.

Mill 4

Operation: Mill 4 produced between 4.5 M and 5.5 M board feet of lumber per day. The total output of lumber for 1960 was 338 M board feet. The owner operated the mill half time when farm duties were not pressing. Lumber produced at the mill was sold mainly for pallets, crating, local construction, and flooring stock.

Mill Setup and Equipment: The mill was well located on a steep hill and had a sound wooden foundation. It was enclosed on two sides by a wooden shed. An elevated walkway extended from one side of the mill, near the headsaw, approximately 25 feet to a slab burning area which was enclosed by metal sheeting. Lumber was transported on dead rolls from the headsaw to the end of the mill. Approximately 60 feet of track extended from the end of the mill shed into the yard. As lumber was removed from the dead rolls, it was loaded onto a small flat car which was pushed down the track to the yard. Lumber was stacked on both sides of the track.

The sawmill was a Corley No. 1 with a 52-inch circular, inserted-tooth saw. The carriage had three dogs. However, only the front dog was used to hold the logs on the carriage. Lumber was edged on a Corley 22-inch-width edger. The mill was powered by a 150 horsepower Cummins Diesel engine. Sawdust was removed by a Phelps 25K sawdust blower.

Manpower: The owner acted as sawyer and turned the logs on the carriage. The second man worked as off-bearer and edgerman. A third man removed slabs to the burner, moved lumber on the flat car, and stacked lumber according to length on both sides of the track in the yard.

The cost of equipment for each mill and its replacement value are given in Table 16.

TABLE 16 - INITIAL INVESTMENT IN EQUIPMENT AND LIST PRICE IN 1961 OF COMPARABLE NEW EQUIPMENT

Type of Equipment	Mill 1 Initial	Mill 1 New	Mill 2 Initial	Mill 2 New	Mill 3 Initial	Mill 3 New	Mill 4 Initial	Mill 4 New
				Dollars				
Main sawmill equipment:								
Sawmill	3,015	3,210	2,100	2,810	1,952	2,540	2,000	2,730
Edger	1/	1,285	500	1,455	--	--	700	1,000
Trim saw	1/	363	150	100	--	--	--	--
Power unit	4,904	5,085	1,800	2,600	2,900	4,500	2,000	4,500
Accessory equipment:								
Fork-lift truck	10,000	9,500	2,000	4,000 2/	--	--	--	--
Miscellaneous items	--	1,664	118	957	--	523	118	749
Land and buildings	--	--	850	850	300	300	1,250	1,250
Total investment	17,919	21,107	7,518	12,792	5,152	7,863	6,068	10,229

1/ Included in sawmill costs.

2/ Fork-lift converted from used truck chassis, replacement cost is for used fork-lift truck of approximately the same size.

RELATED MILL STUDIES

Missouri

Quigley (13) determined the time required to saw one thousand board feet of lumber from logs of various diameters at four Ozark sawmills in 1949. Delay time was not considered, and logs were grouped by diameter regardless of length. He found that the time required to saw one M board feet from logs larger than 15 inches in diameter was relatively constant. Generally, high grade lumber was produced from logs of this size--increasing the operator's profit. Sawing time for logs from 9 to 15 inches in diameter increased moderately (20 percent). The sawing time increased sharply for logs 4 to 9 inches in diameter.

In study of two mills, Hunt 9/ analyzed sawmilling costs as affected by species, log size, and defect. Of the factors studied, Hunt concluded that log diameter had the greatest effect on sawing time. Sawing time increased rapidly for logs with diameters smaller than 12 inches and larger than 28 inches. The amount of defect in a log and the difference in hardness of wood of two species groups affected sawing time to a lesser degree. He found that work stoppage for sawmill repair exerted a pronounced affect on sawmilling costs.

Tennessee Valley Authority

Problems similar to those found in Missouri exist in the sawmilling industry in the Tennessee Valley. Many small mills in this area use circular saws to manufacture hardwood lumber from logs of small diameter. Results of a ten-year study of 58 mills are contained in several reports.

If sawmilling were to contribute its maximum to the economic development of the area, Darwin and Thurmond (3) concluded that more precise knowledge of factors which affect costs and returns would be needed, principally:

1. How can labor and equipment be balanced to produce more and better lumber?
2. What are the chief causes of lost time?
3. What is the effect of log size and grade on lumber quality and production rates?
4. How can the average mill operator reduce his operating costs and increase total production and profits?

Subsequent reports (3, 14) indicated operating practices which resulted in high production costs:

1. Average operating time was six hours per day--25 percent lost time.
2. On the average, mills were operated only one-half of the year.
3. Average diameter of logs sawed was less than 12 inches.

9/ Ellis V. Hunt, Jr., Analysis Of Sawmilling Costs, unpublished Master's thesis, The University of Missouri, Columbia, 1952.

Several suggestions were made to increase production and lower cost. Because in the average mill the headsaw was actually sawing logs only 34 percent of the operating time, King (9) suggested mechanization of the log deck and green chain to reduce unnecessary log and lumber moving tie-ups. Darwin and Thurmond (3) recommended that mill operators buy a second saw and hire a saw filer. By changing saws, rather than filing a saw in position on the mandrel, idle time for the entire mill crew could be reduced. The second saw could be filed while the mill was in operation.

To encourage the adoption of sound operating practices and the purchase of equipment to improve mills, the T.V.A.--in cooperation with sawmill equipment companies--conducted 34 conferences for mill owners and employees. The conferences may have influenced several improvements that were observed later. The number of mills in the Tennessee Valley was reduced in a ten-year period; but the remaining ones increased daily production from 5,824 to 6,726 board feet (9), and productive time increased by 22 minutes per day (11). Increases in mill efficiency were offset to some extent by a reduction in the average diameter of logs from 11.9 inches to 11.2 inches.

Determining the Marginal Log

A simplified method described by Creighton (2) was directed only at logs with diameters near the anticipated zero margin. The marginal log was determined graphically by plotting unit cost and income over diameter.

Herrick (6) simplified computation by using the number of logs per M board feet as the independent variable rather than log diameter. Straight-line linear regressions were substituted for complex functions of log or tree diameter. With an electronic computer available, however, the advantage is largely lost.

A study of pine sawmilling costs by log size (1) provided small sawmillers in the South Carolina Piedmont area with a simple method of calculating sawing costs at individual mills. Data from several mills were combined and analyzed by multiple regression and graphic techniques. The slope of the curve representing sawing time over log diameter was found to be nearly the same for all mills, so that the average sawing time for each log diameter could be made applicable to individual sawmills by expressing each as a ratio. To estimate sawing time at a mill, an operator could time one size of log and apply the ratios to determine the expected time required to saw logs of other sizes. He could obtain sawing cost by applying his hourly operating cost to sawing time.

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