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OBTAINING LOWER UNIT COSTS IN PULPWOOD PRODUCTION

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by

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PREFACE

During the past year bills for the state regulation of timber cutting have been introduced in both Michigan and Wisconsin, and although the Michigan bill has been defeated, the swing of the pendulum of public opinion in the Lake States is clearly indicated, and eventually the pulpwood operator is going to be cutting to a minimum diameter limit, whether by choice or by compulsion. In time regulation will prove beneficial, for it will force the adoption of improved practices upon an industry that has lagged behind in increasing production per man-hour and in adequate production planning.

The principal objection of the operator to selective logging has been that increased costs of production brought about by taking a smaller volume of wood would tend to force him out of business. To the uninformed this argument is plausible, and it is admitted that production costs would rise if operators cut selectively using common practices in wage payment and transportation planning.

The total direct costs of pulpwood can be held to reasonable levels in selective logging. To accomplish this, a revision of the method of wage payment and proper planning of the transportation system are necessary. The methods to be discussed are not confined to selective cutting only, but are equally applicable to clear-cutting situations. The purpose of this paper is to show that reduced costs and increased production per man-hour are possible through a sound incentive wage payment plan for pulpwood cutters and through adequate planning of the transportation system whether the operator is clear-cutting or logging selectively.

The writer wishes to acknowledge his deep appreciation to Professor D. M. Matthews of the School of Forestry and Conservation for guidance and helpful criticism in the preparation of this thesis.

SUMMARY

1. The combined total cost per cord for cutting and transporting pulpwood may be even less under a selective cut than when the entire merchantable volume is removed.

2. Time study data indicate that cutting costs in pulpwood production may be reduced by not cutting small diameter trees. The small volume of wood that can be cut per hour from 4- 5- and even 6-inch trees in comparison with the production per hour from larger diameters makes the cost of felling and bucking small trees excessive.

3. The stick piece-rate method of wage payment in its present form hinders the reduction of cutting costs because it allows cutters higher hourly earnings when cutting small timber than when cutting selectively.

4. Incentive wage rates that are fair to both the cutter and the operator would give cutters equivalent hourly earnings regardless of the size of the timber they worked in and permits the operator to obtain the maximum volume of wood per hour. Any wage payment plan that rewards on the basis of the volume of wood produced in a given length of time must be based on time study data to

avoid inequalities and criticism.

5. In order to obtain satisfactory costs in transportation pulpwood from the stump to the mill, branch road spacing and road standards that permit reasonable travel speeds must be in balance and adjusted to the volume of timber on the area.

6. Adequate planning of the road system enables the operator to cut reduced volumes without serious increases in transportation costs.

CUTTING COSTS

Cutting the sticks is the first phase of the production problem upon which an operator should concentrate in order to effect reduced costs in his operations. The cost of making the wood usually represents from 20 to 40 percent of the total cost of pulpwood at the mill and is a fertile field for cost reduction.

Pulpwood cutting under present methods is done strictly by hand labor and includes the steps of felling, bucking, peeling in some cases, and assembling the wood for draying. Since this work involves manual labor almost exclusively, the only savings possible are those obtained through increased labor efficiency and equitable wage payment based on a knowledge of how the cost of producing wood is affected by the size of the trees cut.

The use of mechanical saws for felling and bucking in the woods and the skidding of tree-length logs with mechanical bucking at the landings are methods being introduced on large operations to increase production per man-hour, but manual labor is not eliminated and the discussion of wage payment that follows is still applicable.

The Stick Piece Rate Method of Wage Payment

The stick piece rate method of wage payment for cutting pulpwood is the most widely used plan in the Lakes States, although occasionally men are paid for cutting by hourly rates or by the cord.

The piece rate system of payment has certain definite advantages. First, it is simple for both the cutter and the operator to compute the amounts earned. Second, the direct labor cost per unit or job is easily determined in advance on the basis of the number of sticks per cord. Third, the direct monetary gain which a worker realizes from his increased production makes him work efficiently and he is rewarded in direct proportion to his industry and acquired skill. Fourth, cutters tend to produce at full capacity without the necessity of increased supervision on the part of the operator. Fifth, fair piece rates tend to attract skilled and more efficient labor.

Although the stick piece rate plan is widely used in the Lake States, it presents one serious problem--the setting of fair rates based on the time required to produce a given quantity of wood in stands of varying volume and size. This disadvantage manifests itself in the fact that there is, in many instances, considerable "haggling" over the piece rate offered and a large labor turnover on pulpwood operations owing to dissatisfaction over earnings. If labor is scarce, operators make frequent increases in piece rates to attract cutters without accurate knowledge of how the cost of wood is affected or how the cost of pulpwood per cord can be held down in the face of raises in rates by not cutting small diameter trees. When woods labor is abundant, the provisions of the Wages and Hours Act must be considered and piece rates adopted that will allow the cutters at least the legal minimum wage.

The customary application of the piece rate system under which the cutter receives a fixed rate for all sticks over 8 inches is not the most satisfactory to either the worker or to the operator. Unless the rate is adjusted to fit the working conditions and tree diameters of the stand, the cutter will not earn a uniform hourly rate. If rigid cutting specifications are not enforced by the operator, cutters will "run away" with the rate by cutting all available small trees to obtain the maximum number of sticks per hour. This latter practice is common today in the second-growth stands and is one reason why the cutter is able to earn higher hourly wages under clear cutting and why the cutting costs per cord are unnecessarily high. Four-inch top diameter sticks contribute comparatively little to cord volume; yet the cutter is paid the same rate for these sticks as for larger sticks until an 8-inch top diameter is reached.

When the common stick piece rate plan was first adopted by operators, it was reasonably fair to both cutters and operators because in virgin pulpwood stands the average diameter was larger and the diameter range more uniform. Consequently, the practice of doubling the rate for sticks over 8 inches gave adequate compensation. At present, virgin pulpwood stands are virtually non-existent in the region and cutters are working in stands that are, for the most part, immature with a predominance of smaller-sized trees. To locate two jobs of any size in present Lakes States stands with identical working conditions and distribution of tree sizes would be a nearly impossible task; and yet an operator, in paying for the cutting of a stand under the piece rate plan, ordinarily chooses a rate that other operators are paying and offers it to the piece cutters on his job. Such a practice is certainly to lead to labor difficulties and variations in cutting costs.

Basis For Satisfactory Rates

In setting wage rates, it is obvious that as the trees increase in diameter, it takes fewer bolts and fewer trees to make a cord of pulpwood, but not so obvious that the length of time required to produce a unit of wood from large trees is materially less than the time required to produce the same amount of wood from small trees. If cutters are paid on the basis of volume of wood that can be produced in a given length of time, the cutters' earnings will be more uniform. At the same time, the operator will have lower cutting costs per cord when producing from larger trees because the cubic foot contents increase more rapidly with trees of larger diameter than the time required to produce a unit of volume from larger trees increases.

On the basis of the above facts pertaining to the relationship of the tree to the time required to produce pulpwood, it is evident that standards are necessary that permit estimation of the hours required to cut a cord of wood from trees of various diameters in order to establish fair wage payment systems. An accurate knowledge of the time it takes to cut a unit volume of wood and the factors affecting this time is necessary for the establishment of production standards.

Time Studies

Time study data are the basis for setting any fair production standards. However, time studies for woods work are far more difficult to obtain and apply than for factory work. In a factory, working conditions and operations are readily standardized and put under strict control; whereas in the woods, working conditions vary considerably from stand to stand and from season to season. Variations in tree volumes and sizes complicate the problem even more. A time study in the woods must necessarily cover a wide range of working conditions, tree sizes, weather, and workers to be of significant value. If a sufficient number of time records is obtained for cutting pulpwood of a particular species by diameters and heights under customary cutting practices, production standards and fair wage rates for given localities can be established.

Results of time study data will be expressed in time per unit of volume. However, in analysing the breakdown of total time for certain steps or elements of the operation, it is apparent that the time to perform these steps depends on characteristics of tree size and that a relationship exists between time consumed and one characteristic that actually controls the time change of the step as the size of the tree changes. For example: in felling a tree, the diameter is the factor that most influences the time consumed and is convenient to measure. For other phases of the cutting operation, such as walking to and from work, swamping and fitting tools, the time consumed remains relatively constant regardless of the tree size.

When the time for each distinct step of the cutting operation that is dependent on tree size is correlated with the factor that controls variation in the rate of production and then plotted over the size range, the resulting curves accurately describe the changing values and reliable synthetic, or "office" time studies for an entire operation can be made up for tree sizes not covered in the original study. The time steps that vary with the tree size as obtained from the time curves together with the times for steps that remain relatively constant for the operation give the total time to produce a unit volume of wood from a tree of a specified height and diameter under the local working conditions.

Application of Time Study Data to a Production Table

The time and motion analysis from a field study of typical spruce and balsam fir operations of Canadian pulp and paper companies at twelve different locations as prepared by Koroleff[1] is the source of the basic information used in working up the time curves and the production table presented in this paper.

The cutting steps presented in Table I that could be correlated with tree size were treated in the following manner. The average time for moving to the tree was combined with time for felling the tree and plotted as "seconds per tree" for each diameter class. The resulting curve is shown in Figure 1. The time for the steps of limbing and measuring was correlated with the average merchantable length of the trees in Koroleff's data and plotted as "seconds per linear foot" for each diameter

[1]A. Koroleff, Pulpwood Cutting--Efficiency of Technique. Montreal: Woodlands Section, Canadian Pulp and Paper Association, 1941.

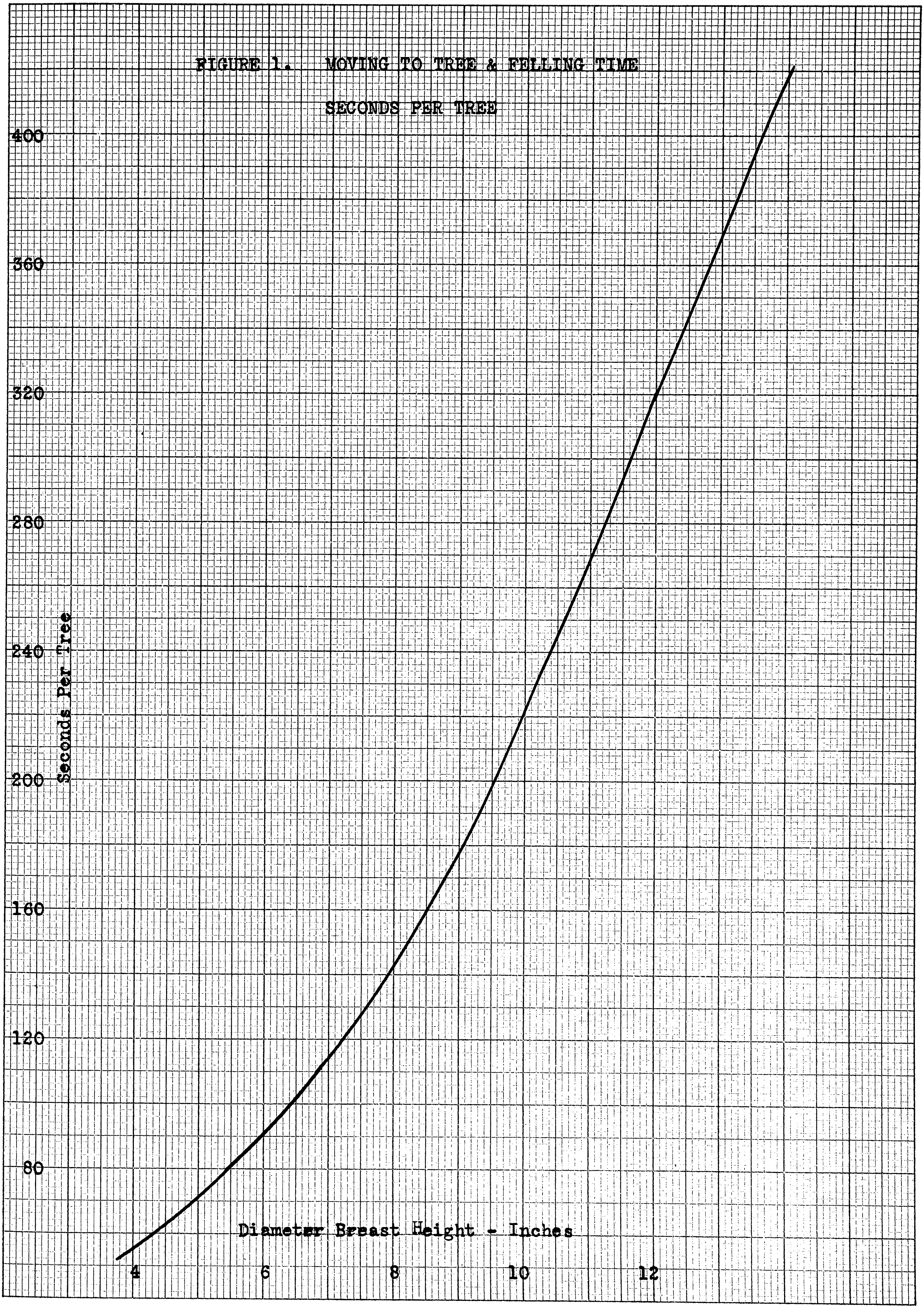

FIGURE 1. MOVING TO TREE & FELLING TIME
SECONDS PER TREE
Seconds Per Tree
Diameter Breast Height - Inches
400
360
320
280
240
200
160
120
80
4
6
8
10
12

Table I

Distribution of Cutters' Total Time in
Canadian Pulpwood Operations

Steps of the Operation	Distribution of Time for the Average Tree	
	Seconds per Cubic Food	Percent
Working time:		
Moving to tree	3.95	2.21
Felling	17.26	9.70
Limbing	26.71	15.03
Measuring	3.82	2.15
Bucking	40.61	22.87
Butting for defect	.83	.46
(Total actual cutting time)	(93.18)	(52.42)
Swamping and removing obstacles	12.71	7.15
Fitting tools	5.48	3.07
Assembling and piling	33.36	18.80
Non-working time:		
Walking to and from work	18.31	10.30
Resting	13.21	7.42
Waiting for bad weather	1.49	.84
Total time (working and non-working)	177.74	100.00

Source: A. Koroleff, Pulpwood Cutting--Efficiency of Technique. Montreal: Woodlands Section, Canadian Pulp and Paper Association, 1941.

Weighted averages of the itemized time of 120 cutters by steps of the operation from continuous stop watch readings for the total working day. Spruce and balsam 4-foot wood.

class as shown in Figure 2. The time for bucking and butting for defect was combined for each diameter class and plotted as "seconds per cut." Figure 3 presents the time curve for bucking and butting for defect. In this way the time study data for the actual cutting steps was reduced to a form that could be applied to any combination

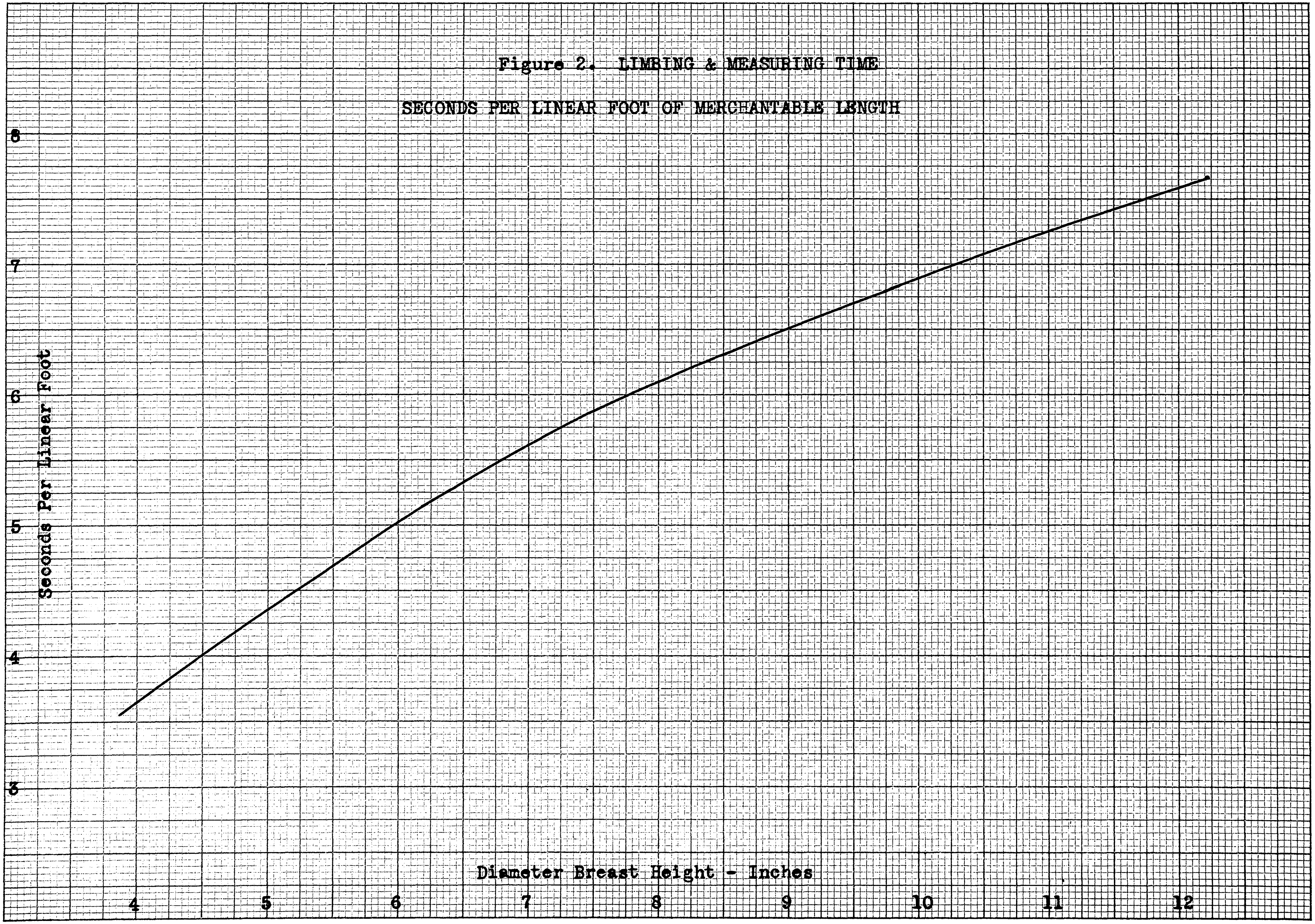
Figure 2. LIMBING & MEASURING TIME
SECONDS PER LINEAR FOOT OF MERCHANTABLE LENGTH
Seconds Per Linear Foot
8
7
6
5
4
3
Diameter Breast Height - Inches
4
5
6
7
8
9
10
11
12

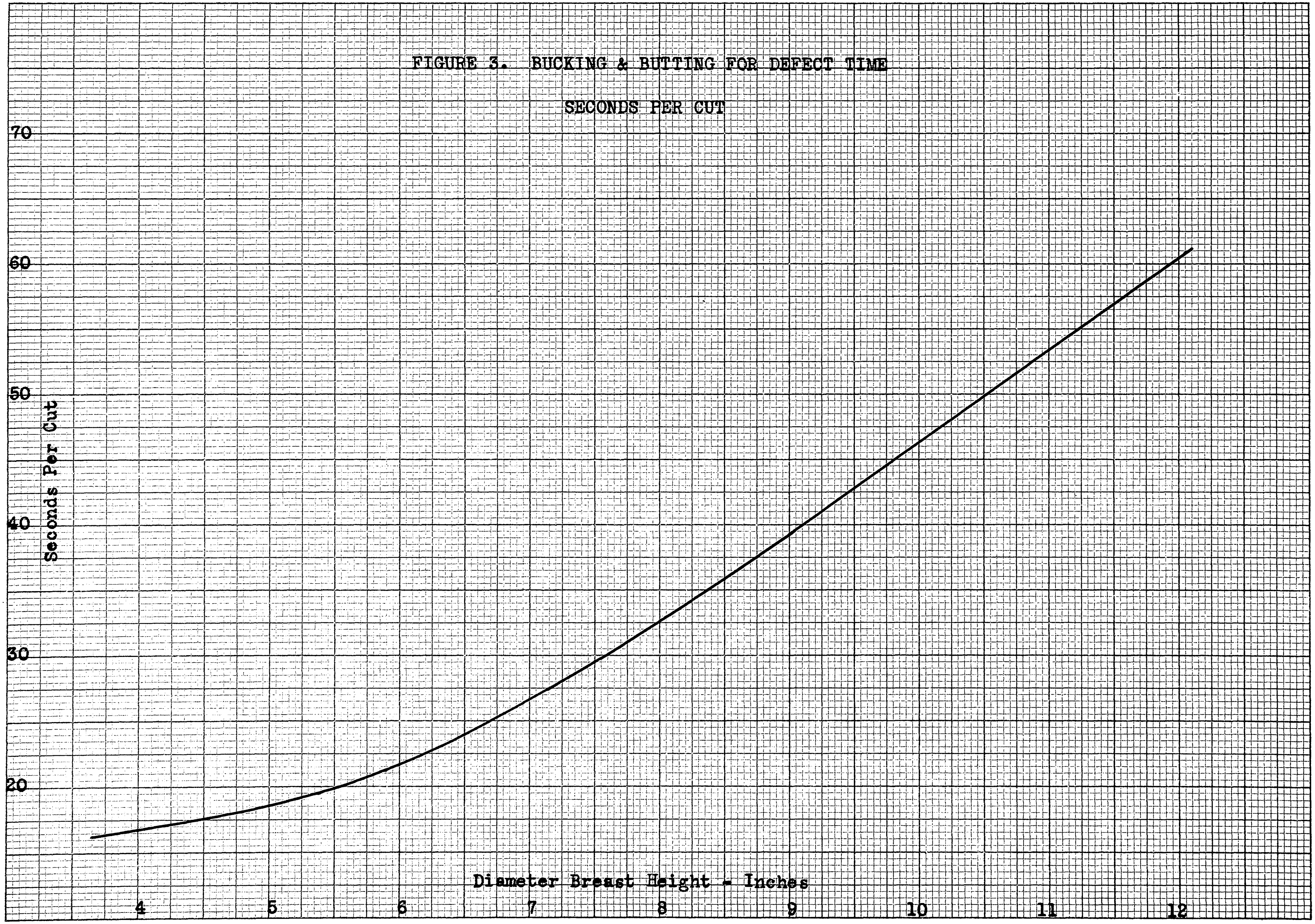
FIGURE 3. BUCKING & BUTTING FOR DEFECT TIME
SECONDS PER CUT
Seconds Per Cut
70
60
50
40
30
20
Diameter Breast Height - Inches
4
5
6
7
8
9
10
11
12

of tree heights, diameters and bolt lengths.

In Figure 1 it will be noted that the time to fell a tree increases rather sharply with increases in diameter. The felling time for larger diameters varies directly proportional to the square of the diameter, increasing at a compound rate. With small diameters (up to 8 inches) the increase is somewhat less than directly proportional to the cross-sectional area because the resistance to the saw offered by the cutting surface is influenced more by the diameter than by the cross-sectional area.

The time required for limbing and measuring as shown in Figure 2 is dependent on merchantable height. This time curve follows the general trend of a height curve based on diameter. The tree diameter has an indirect influence on the limbing time in that trees of larger diameters have larger branches.

The time for bucking and butting for defect per cut also varies as the square of the diameter in larger trees. The tendency of the curve in Figure 3 to fall into a linear function of diameter above 6 inches is due to the fact that the time per cut is an average figure for the total number of cuts for each diameter class.

To apply the time curve data to a specific locality for the average working conditions and trees found there, it is necessary to know the percentage of actual cutting time to total working time and the average heights of the trees in each diameter class. Table I shows the distribution of the average worker's total time for the operations studied by Koroleff. It will be noted that on these operations the cutter spent 52.42 percent of his time performing actual cutting steps, while swamping, fitting tools, assembling and piling, walking to and from work and resting took up the remainder of the time. The percent of actual cutting time to the total working time for any locality and cutting procedure may be determined by a study of a few average workers for a period long enough to obtain a reliable figure.

In working up the production table, Table II, for trees 5 to 12 inches in diameter the following assumptions were made:

1. The actual cutting time takes up 50 percent of the worker's total time.

2. The average merchantable heights of the trees for each diameter class are as indicated in column 2 of the table.

The time per tree for felling, limbing and bucking, shown in column 5 of Table II, was calculated for the average tree of each diameter class from the time curves given in Figures 1, 2 and 3. The production per hour in column 6 was obtained by multiplying the number of seconds in one hour by the volume per tree and dividing the product

Table II

Production Table Giving the Production Per Hour and Supplementary Data for the Average Tree of Each Diameter in an Assumed Locality. Spruce and Balsam Pulpwood

1	2	3	4	5	6	7	8	9
					Production Per Hour			
DBH	Average Number of Sticks per Tree	Volume per Tree	Sticks per Cord at 90 cu. ft. per Cord	Time per Tree-- Fell, Limb and Buck Only	Fell, Limb and Buck Only	Total Cutting Time	Number of Sticks Cut	Hours Required per Cord
inches		Cu. Ft.		Seconds	Cu. Ft.	Cu. Ft.		Hours
5	1.6	1.85	78	158.7	42.0	21.0	18.2	4.28
6	2.4	3.18	68	241.8	47.4	23.7	17.9	3.80
7	3.0	4.95	55	329.5	54.0	27.0	16.4	3.33
8	3.5	7.13	44	428.5	60.0	30.0	14.7	3.00
9	4.0	9.60	38	540.0	64.0	32.0	13.3	2.82
10	4.4	12.48	32	665.5	67.6	33.8	11.9	2.66
11	4.7	15.40	27	794.0	70.0	35.0	10.7	2.57
12	5.1	19.20	24	936.0	74.0	37.0	9.8	2.43

by the figures in column 5, or $\frac{3600 \text{ seconds x Column 3}}{\text{Column 5}}$.

The production per hour for the total operation, column 7, was then obtained by assuming the actual cutting time to be 50 percent of the total working time. In calculating the production figures, a volume of 90 cubic feet per standard 128-foot cord was assumed. The volume table presented in Table III is the source of the tree volumes used in computing the production table.

Table III

Volume Table for Spruce and Balsam in the Upper Peninsula of Michigan

DBH inches	Number of 100-inch Sticks Per Tree							Basis Trees
	1	2	3	4	5	6	7	
	(Cubic feet of peeled merchantable wood)							
4	0.80							11
5	1.31	2.20	3.00					65
6	1.58	2.70	3.90	5.10				90
7	2.25	3.60	4.95	6.25	7.60			50
8	3.40	4.90	6.40	7.85	9.35	10.8		30
9	4.80	6.40	8.00	9.60	11.2	12.8		15
10		8.30	10.00	11.8	13.5	15.2	17.0	8
11			12.1	14.0	16.0	17.9	19.8	5
12			14.8	16.9	19.0	21.2	23.3	
13			17.5	20.0	22.4	25.0	27.4	1
14			20.6	23.6	26.4	29.4	32.2	
15				27.7	31.0	34.4	37.6	
16				32.4	36.0	39.6	43.0	
								275

Source: W. S. Bromley, Unpublished data.

The basic time study data used in developing Table II are comprehensive and reliable. Since Koroleff reported that 90 percent of the cutters observed in the study, which ran for a period of eight months, worked on a "straight piece" basis, it is reasonable to assume that the "production per hour" figures for the steps of felling, limbing, and bucking represent production standards for each diameter class that can be achieved by the average worker without undue physical exertion.

A comparison of the time required to produce a cord of pulpwood from 5-inch trees in Table II with the time required for larger diameter classes will bear out the statement that an operator cannot afford to pay for cutting bolts from small trees if fair hourly earnings are provided the cutter. Table II also indicates that cutters are able to produce the greatest number of sticks per hour from small trees.

Job Standards

Lack of accurate knowledge of what should constitute a job and how long it should take is one of the basic causes of labor difficulties in woods work. The chief purpose of the production table presented in Table II is to provide the operator with a knowledge of how the number of sticks per cord and the time required to produce a cord of pulpwood vary with the diameter of the tree. Because the range and distribution of diameters varies in practically every stand, the production table as presented has little practical application in setting job standards.

<u>The Job Standard Table</u>: To enable an operator to set a job standard for a spruce-balsam pulpwood stand of from 5 to 12 inches in diameter from the values given in the production data, a job standard table is presented in Table IV. This table is simply a breakdown of the hours required to produce a cord of pulpwood for any diameter into proportional times based on the percent of trees in the stand contained in each DBH class.

Table IV

Job Standard Table Giving the Number of Hours Required to Produce One Cord of Wood for the Percent of Trees Found in Each DBH Class

Percent of Total Number of Trees in Stand	DBH Class, Inches							
	5	6	7	8	9	10	11	12
	(hours required to cut one cord)							
100	4.28	3.80	3.33	3.00	2.80	2.66	2.57	2.43
90	3.85	3.42	3.00	2.70	2.54	2.39	2.31	2.19
80	3.42	3.04	2.67	2.40	2.25	2.13	2.05	1.94
70	2.99	2.66	2.33	2.10	1.97	1.86	1.80	1.70
60	2.57	2.28	2.00	1.80	1.69	1.60	1.54	1.46
50	2.14	1.90	1.67	1.50	1.42	1.33	1.29	1.22
40	1.71	1.52	1.33	1.20	1.13	1.06	1.03	.97
30	1.28	1.14	1.00	.90	.85	.80	.77	.73
20	.86	.76	.67	.60	.56	.53	.51	.49
10	.43	.38	.33	.30	.28	.27	.26	.24

In applying the table to a given stand, the percent of trees in each DBH class is found to the nearest 10 percent. Information as to the number of trees can be obtained from the cruise data or from sample plots when tallying is done by diameter classes. Then the percentage hours required to produce a cord of pulpwood for the percent of trees in each class is taken from Table IV. The sum of these percentage hours will be the job standard for any stand based on the production per hour figures given in Table II.

An illustration of the use of Table IV in setting a job standard follows. Assume the cruise data of a stand indicates an average of 173 trees per acre to be cut with the tree distribution into diameter classes as indicated below.

DBH	Number of Trees per Acre	Percent of Trees by DBH Classes (to Nearest 10 Percent)	Hours to Produce One Cord
5	48	30	1.28
6	42	20	.76
7	30	20	.67
8	25	10	.30
9	14	10	.28
10	9		
11	4	10	.26
12	1		
Totals	173	100	3.55

The sum of 3.55 hours in the above illustration is the job standard for the stand used in the example.

Values in Table IV may be interpolated to closer than 10 percent if it is desired, but repeated checks by interpolating with the exact percentages has given less than 0.1 hour differences in all but extreme cases. Furthermore, it is doubtful that the percent of trees in each DBH group will be obtained closer than 10 percent. When only a few trees per DBH group are found, as is usually the case in the larger diameters, it is convenient to group the number of trees to make up approximately 10 percent. The difference in percentage hours to produce a cord of wood in the 10 percent line of the table is so small for the larger diameter classes that it makes practically no difference in the job standard figure.

The job standard for any stand serves to provide the operator with a knowledge of what to expect from his cutters and is a basis for estimating the number of men required and costs of production. Its most important function, however, is in providing a base for setting wage rates.

Adjustment of Job Standards for Divergent Stands: A job standard table similar to the one set up in Table IV would be based on the average trees and stands of a locality and on the usual working procedure employed by the operator. In any wide application of the table an operator would be confronted with occasional situations where the job standard would have to be adjusted up or down in order to be used for setting wage rates.

The job standard table will not provide a basis for fair wage rates when the general working conditions vary from stand to stand. Situations will arise when the average cutter in a stand, working at normal capacity, is unable to attain, or is able to exceed the job standard as determined from Table IV. This may be due to one or more factors that vary the average times for the steps of the cutting operation, such as: physical ability, skill or experience of the average workers, quality of the timber, character and composition of the stand, job specifications, ground conditions, or season of the year. Deviations from the average in any of the above factors will tend to increase the standard time set to produce a cord of pulpwood, decrease it, or deviations in several factors may tend to offset each other with no total variation in the job standard.

If the average cutter exceeds or falls short of the job standard as determined for the stand from Table IV and is paid under an incentive wage plan, his hourly earnings will be affected. That is, if a cutter earns 60 cents per hour on one location, he might average only 50 cents per hour on the new job if the cutting conditions were less favorable than before and rates set without an allowance for the unfavorable situation. However, if only the diameters and the diameter distribution of the two standa differed, application of the job standard table would provide equitable earnings in both stands.

The job standard for the divergent stand may be adjusted in one of two ways to set a new standard for uniform hourly earnings. The first method is only approximate, but can be used successfully by the keen observer. Observation or experience may indicate that the job standard should be raised or lowered a certain amount to conform with the cutting conditions of the stand, or that the job requirements should be altered enough to make the task set by the table fair to the cutters. The second method is more reliable and involves a short time study. To secure a fair standard it is necessary to time an average worker or two, preferably by steps of the operation, for a long enough period under the new conditions to obtain a dependable new number of hours required to cut a cord of pulpwood. Records of these simple production studies would provide percentage figures for future adjustments that would eliminate the necessity of timing. To illustrate, assume that heavy brush occurred in a scattered pulpwood stand. The operator could increase the time allowed to produce a cord of wood arbitrarily to compensate for the additional effort required in swamping, or he may decide to have workers other than the cutters perform the swamping. While experience alone may enable him to make an adequate decision regarding the adjustment of the standard, a short time study would provide a more dependable basis for adjustment.

Incentive Wage Plans Based on Job Standards

The character of woods work makes an incentive form of wage payment more desirable than straight day rates, and fair wage plans necessitate reliable job standards. Work tasks and incentive wage payment plans necessarily deal with the average cutter and any task set, to be effective, must be easily attainable by the average cutter working at normal capacity. In any group of workers, some are certain to produce at a faster rate than others because of greater skill, experience and ability. For lack of the same qualities, others will not be able to attain any work standard unless it is designed to meet the production of the porrest worker. If the standard is fair, it will reward each man directly according to his ability to produce and provide an incentive for all the workers to increase their skill and efficiency.

The proposed method of time study application for determining job standards provides management with a foundation for setting fair wage rates based on the volume of wood the average worker can produce. The stick piece rate, the cord piece rate, and the task and bonus systems of incentive wage payment described on the following pages are all very applicable to pulpwood cutting. The choice of the plan which best fits his particular needs rests with the operator.

<u>Equitable Stick Piece Rate Plan</u>: The unpopularity of selective cutting among piece cutters working under the common piece rate plan is due largely to the fact that their hourly earnings are less than when they are allowed to clear-cut. It is contended that if a piece cutter could obtain equivalent hourly earnings, regardless of the size of the timber he worked in, there would be no objection on his part to selective cutting or to leaving the high cost trees of small diameter.

An equitable piece rate, therefore, would be one that gives cutters an approximately uniform rate whether they work in predominately small timber, or in comparatively large timber, and at the same time reduces the operator's cutting costs when producing from larger diameters.

The equitable piece rate plan requires setting a new rate for each job based on the number of hours required to produce the average cord of wood in the stand under consideration. It differs from the common piece rate in that a uniform rate per stick is applied to the job, regardless of the stick size. To set the equitable rate for a stand, the following information is necessary.

1. The hours required to produce the average cord of

wood. This may be obtained by an application of the job standard table, keeping in mind that the job standard must be adjusted if the cutting conditions vary considerably from the average.

2. The average number of sticks per cord. This information is most readily obtained from observation, but may be more accurately obtained by estimating the total number of sticks per acre and dividing by the estimated number of cords.

3. The hourly wage to be paid.

The piece rate may then be calculated by multiplying the job standard by the rate per hour and dividing the product by the number of sticks per cord. To illustrate, assume the calculated job standard is 3.5 hours, the average number of sticks is 46, and a fair local hourly rate is 60 cents per hour. Then, 3.5 hours x 60¢ = $2.10 which is the cost per cord. $2.10 ÷ 46 sticks = 4.57¢, or the piece rate paid would be 4.5¢ per stick.

Strictly enforced rules regarding the tree diameters to be cut must accompany any stick piece rate payment plan to prevent the cutter from "running away" with the rate by cutting all possible small trees in order to earn a high hourly rate and thus increase the cost per cord.

Cord Piece Rate Plan: The cord piece rate plan is an incentive form of piece rate payment with the cord as the unit for measuring instead of the stick. This method is not widely used in the Lake States despite the fact that it is easy to use and predetermines the cost per cord.

In setting a rate per cord for pulpwood cutting in a particular stand, the job standard, or time required to produce a cord of wood may be calculated from Table IV and the piece rate set on the basis of an hourly rate. For example, if the job standard for producing the average cord of wood in a stand is 3.5 hours and 60 cents per hour is considered a fair hourly wage, the cord piece rate would be 3.5 hours x 60¢, or $2.10 per cord.

This plan is the simplest form of piece rate payment to adopt, since a consideration of the number of sticks per cord is eliminated. The fact that the piece rate per cord decreases when the worker moves into larger timber, if set by the job standard, may not make it particularly desirable to stick piece cutters, The stick piece rate has an advantage in that the rate increases as the average diameter of the trees increases. If this objection from the cutter's standpoint could be overcome, the cord piece rate would be very advantageous to use. With a cord piece rate, cutters will tend to favor cutting larger trees because of the larger volume of wood produced per unit of time. The necessity of stricter piling requirements will decrease the production per hour to a slight extent, but administrative time is reduced when production is measured by the cord rather than by counting sticks.

<u>Task and Bonus Plan</u>: Task systems of wage payment with a reward for production above the task are common in manufacturing industries and have been applied to woods labor to a limited extent. In pulpwood cutting they have not been too satisfactory, either to the operator because of the difficulty of setting a fair task, or to the cutter owing to his resenting the fact that his fellow worker may be receiving a higher rate per hour or per piece for the same kind of work.

With an effective method of setting the job standard, or task, for any given stand as provided by Table IV, an adaptation of the task and bonus system[1] to pulpwood cutting will adequately guarantee the cutter a minimum wage rate and provide an incentive for increased production.

The bonus to be paid for production at and above task is determined by the operator according to his particular needs and ordinarily varies from 20 to 50 percent of the task rate. The task is set on the basis of the number of cords the average worker can produce in a work week of 40 hours. The formulas for computing wage payment under the task and bonus system are as follows:

(1) For earnings up to, but not including task: $E = RT$

[1]For a detailed discussion of the task and bonus system, see: Charles W. Lytle, <u>Wage Incentive Methods</u>. New York: Ronald Press Company, 1938, pp. 209-16.

(2) For earnings at and above task: E = 1.opSNR

Where: E = earnings for the week

R = hourly rate

T = actual hours spent on the job

S = job standard per cord

N = number of cords cut in the period

.op = bonus percent to be paid.

To illustrate the computation of earnings under this plan, assume the job standard for a stand is 3.33 hours per cord. This translated into a task for the forty-hour work week is 12 cords. Since 33 1/3 percent is a common bonus paid under this plan, it will be used in this case. If cutters A, B and C produce 10, 12 and 14 cords respectively in forty hours, and the minimum hourly rate to be paid is 45 cents, then their earnings would be as follows:

Cutter	Weekly Earnings	Wages per Hour	Cost per Cord
A (below task) 45¢ x 40 hours	$18.00	45¢	$1.80
B (at task) 1.33 x 3.33 x 12 x 45	24.00	60	2.00
C (above task) 1.33 x 3.33 x 14 x 45	28.00	70	2.00

From the illustration above it is apparent that the cost per cord at and above task are uniform for the job and that the weekly and hourly earnings of the cutter increase steadily after the task has been attained and exceeded. The sharp jump in wages at task point tends to make the worker want to reach the task and the system provides enough incentive to induce those capable of doing so, to go beyond the task. In substance, this system provides a day rate for substandard workers and a cord piece rate for those who are capable of reaching or exceeding the standard.

The plan is fair to the cutter in that he is guaranteed a minimum wage if he fails to meet the task, and amply rewards the cutter who excels in ability to produce. The task can easily be adjusted to allow for adverse weather conditions during any period, or for below average cutting strips by simply decreasing the task. The system is not too difficult for the cutter to understand or to compute his earnings, and the fact that all cutters receive the same basic hourly wage rate should overcome their objection to a differential wage scale.

There are several decided advantages to the operator who uses this system. First, the job standard is easily set and the minimum wage guarantee insures compliance with the Fair Labor Standards Act of 1938. Second, the sharp increase in wages at task assures the operator of a reliable minimum output and provides a basis for production planning and the correlation of the pre-hauling and hauling equipment with the cutting. Third, since the cost per cord at and above task is uniform, and since the sub-standard worker is penalized for his failure to reach task, cost predetermination is simplified. Fourth, because workers are induced to increase their efficiency in order to produce at task or better, the task and bonus system reduces the overhead cost of woods supervision and any mechanical equipment on the job. Fifth, the cutters will tend to avoid small trees in order to obtain the maximum volume per unit of time involved. Sixth, the task and bonus system offers an outright hourly rate which is easier to adjust to the community wage scale than when the stick piece rate is used. Seventh, in comparison with the cord piece rate, when operating in larger timber it is less likely to create dissatisfaction among the cutters to increase the task and maintain the hourly rate than to lower the cord piece rate in order to obtain the reduced cost per cord to which the operator is entitled.

While the task and bonus system appears to be generally advantageous, resistance to a change in the method of wage payment is almost certain to occur in the Lake States where the stick piece rate system is so well established.

Responsibilities of Management in Wage Payment

The proper application of an incentive wage payment system, whether it takes the form of a piece rate or bonus plan, places a serious responsibility upon management. A job and time study provides the facts that aid management in setting proper job standards and effective wage rates, but even a time study requires judicious application in order to avoid labor difficulties and provide reliable cost estimates. Job standards must allow the average worker to meet them consistently while working at normal efficiency.

The operator is obliged to pay a fair wage based on community levels, and it is essential that he do this in order to obtain satisfactory workers and avoid costly labor turnover. In order to pay fair wages without increasing the cost of pulpwood, waste effort must be reduced and production increased. An incentive wage plan is not sufficient to increase production in itself for economy in production is largely dependent on the efficienty of the worker. The mere use of an incentive may supply the motive, but it cannot increase production appreciably if the cutter does not have the correct conceptions of cutting technique and of planning his work.

Pulpwood cutters, even though experienced are often decidedly inefficient. In commenting on this fact, Koroleff[1] points out:

> Through experience, most lumberjacks learn only how to do their work, but not how to do it best. . . . It is obvious that many, perhaps most, woods workers cannot gain sufficient proficiency in pulpwood cutting through merely spontaneous effort and experience; that they definitely need guidance to gain adequate efficiency in planning and execution of this work.

There is a little explored field in pulpwood cutting covering proper instructions and education in cutting technique, standard tools, proper conditioning of tools, standardization of methods, and sound employee relations wherein even a small amount of effort is bound to increase the productivity of woods labor with economic benefits to both the worker and the jobber. There is a crying need for adequate organization of pulpwood production to provide wood at minimum costs and still pay reasonable wages. Pulpwood operators can successfully meet the competition of other industries for the labor supply if high wage rates are accompanied by increased efficiency of the cutter and it rests with the operator to assist the cutter in attaining this efficiency.

Operators deplore the independence of the modern piece cutter, but their failure to assist him in his job, the stress placed upon cheap labor in an effort to keep

[1] A. Koroleff, Pulpwood Cutting--Efficiency of Technique. Montreal: Canadian Pulp and Paper Association, 1941, p. 2.

costs down, the blind application of the common piece rate method of wage payment, and the infrequent contacts with the cutter at his job have made the piece cutter what he is. It may not be easy to introduce new techniques of wage payment and cutting efficiency, but management must do just that in order to improve the situation.

The stick piece rate system of the Lake States is firmly established and in its present form is a serious hinderance to the adoption of selective cutting practices. The customary stick piece rate allows the cutter larger earnings when he produces from small trees because he can cut more sticks from them in a given length of time. It is up to management to provide a wage plan that is satisfactory to labor under cutting practices that will reduce the cost per cord and at the same time reserve an adequate growing stock. A minimum cutting diameter limit of at least 6 or 7 inches, together with a wage plan that offers the cutter equivalent earnings for cutting larger trees and assistance to the cutter in building up his productive efficiency will give an operator ample returns for his effort.

TRANSPORTATION COSTS

The second major phase of controlling direct costs of pulpwood production lies in recognition of the factors influencing costs of transporting pulpwood from the stump to the mill and proper planning to secure maximum economy in this field. The axiom that one must spend money to make money is as applicable to the field of forest transportation as to other industrial enterprises. This statement does not necessarily intend to give the impression that in order to log economically one must have the latest and most modern equipment, but rather, that through the proper understanding of certain facts regarding the use of available transportation equipment and its proper application to the specific logging chance, appreciable economies may be obtained, both in direct transportation savings and in increased production.

The three outstanding measures subject to control under adequate planning are: road spacing, truck hauling costs, and service standards of logging roads. It will be developed that these considerations are all interrelated and that all must be considered for greater transportation economy. Logging is essentially a transportation problem and the operator who is able to control his transportation costs and secure maximum production for his equipment is in an advantageous position.

Road Spacing

Proper branch road spacing is dependent upon balancing the cost of road construction with the variable cost of skidding or draying and the volume of timber to be removed.

Road construction costs are generally expressed in terms of a unit of distance such as a station or a mile, but for cost comparison purposes, they must necessarily be expressed as a cost per sale unit of volume such as the cord. To express the cost of roads in terms of a cord, the cost per mile must be divided by the volume available to be moved over the unit distance of road. The volume of timber available depends on the volume per acre to be removed and on the area served by the road. The area tributary to a road, however, varies directly with the spacing of the roads and is inversely proportional to it. That is to say, if given a forty acre tract, one road through the center would serve forty acres, and with two roads through the forty spaced 660 feet apart and 330 feet in from the boundaries, each road would serve an area of 660 feet by 1320 feet, or 20 acres. With this in view, the cost of roads expressed in terms of the volume unit would be $\frac{r}{VS}$ where r = the cost of the road per station of 100 feet, V = the volume per acre, and S = the road spacing in stations. If roads were spaced 100 feet apart with the road cost expressed in terms of 100 foot stations, then each 100 foot station would serve an area of 100 by 100 feet, or 10,000 square feet. In acres this would be 10,000/43,560 or 0.229 acres. The road cost per acre when spacing has not been determined is r/0.229, and to express the road cost per cord in terms of the road spacing, the formula is $\frac{r/.229}{VS}$.

The cost of skidding or draying is usually expressed as a cost per cord for a specific operation, but to be of utmost value in cost estimation, the total draying cost must be broken down into its fixed and variable components. Any hauling cost is essentially a time cost representing the hourly cost of the men and equipment involved in moving the product, and a portion of any hauling cost is not dependent on distance, but remains constant, regardless of how far the product is moved. This fixed or constant cost for draying is the time cost of loading the dray in the woods and unloading it at the road. The variable component of the draying cost is the cost of moving the load from the woods to the landing. It varies directly with the distance and is usually expressed as a cost for draying one cord a distance of one station of 100 feet. The average number of stations the wood is drayed is directly dependent on the spacing of the branch roads and for moving directly to the roads is one-fourth the road spacing. The variable cost of draying may be expressed as $C \frac{S}{4}$ when C = the variable cost of draying a cord one station, and S = the road spacing in stations. The total draying cost is then $F + C \frac{S}{4}$ if F represents the fixed cost of draying.

By combining the formulas for draying and for road construction into a total cost formula, we have: Total cost $= F + C \frac{S}{4} + \frac{r./0.229}{VS}$. A situation is apparent where one element of the total cost, variable draying, varies directly with the road spacing, and another element, road construction, varies inversely with the spacing. A formula that solves for the road spacing necessary to make the costs that vary directly equal to the costs that vary inversely and thus give the minimum total cost has been developed by Matthews[1] and is $S = \sqrt{\frac{17.4\ r}{V\ C}}$, where S = the spacing of roads in stations of 100 feet, V = volume per acre to be removed, C = variable cost of skidding one cord a distance of 1 station, and r = cost of road construction per station.

The effect of the factors affecting the road spacing

[1]For a complete discussion of road spacing see: D. M. Matthews, Cost Control in the Logging Industry. New York: McGraw-Hill, 1942, pp. 119-27.

is apparent from the formula. The volume per acre is inverse in its effect; that is, as the volume rises, the road spacing is reduced. The variable cost of draying also has an inverse effect. The cost of road construction, however, has a direct effect on the spacing and as this cost is increased, the road spacing is increased. Changes in any of these factors will affect the road spacing and unless the draying and construction costs are brought into balance for each logging chance, minimum costs will not be achieved. To follow a set plan of road spacing that gave satisfactory results on one chance may seriously increase the total cost of draying and road construction in a situation where the volume or road costs change. Road costs can be held down by wide road spacing, but in such an event draying costs become excessive. A tabular presentation of the effect changes in road spacing has on these two costs when the costs are calculated separately and then totaled as in Table V indicates that it is not necessary to hold exactly to the spacing as determined by the formula. A range of up to 30 percent on either side of the spacing that gives minimum costs will be satisfactory and allow for the adjustment of the road plan to the topography and shape of the area.

Table V

Effect of Road Spacing on Costs

Spacing, Hundreds of Feet	$C \frac{S}{4}$ Skidding Cost per Cord (Cents)	$\frac{R/.229}{V\ S}$ Road Cost per Cord (Cents)	$C \frac{S}{4} + \frac{R/.229}{V\ S}$ Total Cost per Cord (Cents)
2	5	65.5	75.5
4	10	32.75	42.75
6	15	21.9	36.9
8	20	16.4	36.4
10	25	13.1	38.1
12	30	10.9	40.9
14	35	9.36	44.36
16	40	8.2	48.2

Illustration of effect of changes in road spacing on variable skidding cost and road construction cost when V = 10 cords per acre, C = 10 cents per station, and r = $3.00 per station.

Truck Hauling Costs

The unit cost of truck hauling expressed as a cord-mile cost depends primarily on three factors: namely, the machine rate or cost of owning and operating the truck, the safe speed at which the truck is able to travel, and the number of cords in the load.[1] The cost of fuel per mile is also a factor affecting hauling costs and to a limited extent varies inversely with the safe travel speed. However, fuel cost at different speeds is so

[1]For a detailed discussion of machine rates and hauling costs see: D. M. Matthews, Cost Control in the Logging Industry. New York: McGraw-Hill, 1942, Chapters 3 and 6.

negligible a factor as compared with the hourly cost of truck operation per mile at different speeds, that for practical purposes it may be included as an average figure in the machine rate for the truck.

Machine Rates: Truck machine rates are generally expressed in costs per hour, but for application to cost problems must necessarily be expressed as a cost per mile. Costs for truck operation may be divided into two classes. Fixed costs are proportional to time and will set up a constant time charge when the truck is stationary, and will fall per mile as the truck speed increases. Items normally included in this classification are:[1]

Driver's wages
Helper's wages (if he rides the truck)
Interest, licenses, taxes and insurance
Depreciation on the truck, less tires

The second class of costs are related to the speed of travel but cease when the truck is stationary, and include:

Tires
Oil
Repairs
Greasing and general maintenance

Regarding the expressing of the truck operation costs as a cost per mile, Matthews[2] states:

The foregoing items can be, and usually are, recorded as hourly costs. The justification for expressing them as a cost per mile based on the speed of operation is found in

[1]D. M. Matthews, Cost Control in the Logging Industry. New York: McGraw-Hill, 1942, p. 61.

[2]Ibid., p. 61.

the assumption that speed will vary in relation to the character of the road surface, alignment, and grade of the roads over which the trucks operate. If this assumption is correct--and under good management, it should be, for drivers should be instructed to operate at a speed considered safe for the road conditions encountered--then these costs will rise per mile as speed falls--that is, the truck will be doing about the same amount of work per hour at all speeds and will be wearing out tires, consuming oil and grease, and accumulating repair charges at a constant time rate.

Machine Rate for Standard 1 1/2 Ton Truck[1]

Based on an estimated life of two years of 25000 hours per year. (Data collected in Michigan.)

Initial Cost	$1000	
Less tires	250	
Net investment	750	
Trade-in value after 2 years	150	
Balance to be depreciated	$ 600	
Fixed Cost per Hour:		
Driver's wages	$0.50	
Helper's wages	0.40	
Ins. and Soc. Security at 15%	0.135	
Interest, license and insurance on truck at $150 ÷ 5000 hours	0.042	
Depreciation: $600 ÷ 5000 hours	0.120	
Total fixed cost per hour		$1.20
Operating Cost per Hour:		
Oil at $0.30, 9 qt. every 50 hours	0.054	
Repairs at $200 every 1000 hours	0.16	
Greasing and maintenance	0.026	
Fuel (average)	0.40	
Tires (estimated life of 1000 hours)	0.25	
Total operating cost per hour		0.89
Running cost per hour		$2.09

[1] D. M. Matthews, Hauling Cost Control and Increase in the Efficiency of Truck and Tire Use in the Pulpwood Industry. Washington: Pulp and Paper Division, War Production Board, December 9, 1942, 23 pages, mimeograph.

Average Speed of Truck: A unit truck hauling cost is essentially a time charge for the rental value or the cost of owning or operating a truck that is applied to the amount of work done by the truck. It follows then, that as the safe travel speed of the truck is increased, the production of the truck per unit of time will be increased and the hauling cost per cord will be reduced in proportion.

In cost estimating it is most convenient to deal with the round-trip mile and the average round-trip speed of a truck must be determined to express the cost in terms of a cord-mile unit. The truck will normally travel at one speed over the road when loaded and at a faster rate when returning empty. If this is the case, the average speed of travel for both ways cannot be calculated by simply adding the low speed and the high speed together and dividing by 2 because the time consumed by the truck in negotiating the distance differs for the outgoing and incoming trips. The formula used to calculate the average round-trip speed is:

$$\text{Average speed} = \frac{2\,(\text{high speed mph} \times \text{low speed mph})}{\text{high speed mph} + \text{low speed mph}}$$

To illustrate, assume a loaded truck is able to travel at 8 miles per hour over a stretch of road, and when returning empty makes 15 miles per hour. The correct average speed is $\frac{2\ (15\ mph \times 8\ mph)}{15\ mph + 8\ mph}$, or 10.4 mph; and not $\frac{15\ mph + 8\ mph}{2}$, or 11.5 mph.

Load of the truck: The load carried on the truck has the same effect on the hauling cost per cord per mile as does speed--that is, the cost decreases as the load increases. However, overloading to the extent that speed is sacrificed is poor economy as it will not reduce hauling costs and truck wear and the possibility of breakage is greatly increased.

Cord-Mile Cost Formula: The hourly cost of truck operation expressed as a volume unit per round-trip mile cost is dependent on the two factors discussed above, namely: the average safe travel speed at which the truck operates and the load carried by the truck. Both of these variables have an inverse effect on the cord-mile cost of truck hauling.

A formula that expresses the unit cost of hauling one cord of wood a round trip distance of one mile in terms of the factors affecting this cost is: $X = \frac{2\ Hc}{mph \times L}$, where X = the round trip hauling cost per cord per mile; Hc = hourly cost of truck operation; mph = average round trip speed; and L = number of cords in the load.

As has been stated previously, to be meticulously accurate, the hourly cost of fuel at the various speeds should be considered separately, but an average hourly cost for fuel consumption included in the machine rate is entirely satisfactory and simplifies the calculation.

Road Standards

The previous discussion of road spacing and unit hauling costs brings up the problem of road standards. It has been pointed out first, that one of the factors considered in branch road spacing is the cost of construction; and second, that the unit hauling cost of truck operation depends on the safe speed at which the hauling equipment is able to negotiate the distance and also on the load the truck is able to carry without excessive wear and damage. Obviously, then, a most important consideration in transportation economy is the type or quality of roads provided for truck hauling. Too often, the logging contractor, in shying away from heavy fixed charges, constructs the most primitive type of road over which to operate an expensive piece of equipment that depends on speed of travel to capitalize on its efficiency.

In actual practice there is no constant correlation between the cost of roads and the speed a truck can maintain on them, but it is readily apparent that, under given conditions of soil and topography, the more money spent for road construction in providing for adequate grade, alignment, drainage, and surfacing the higher an average speed trucks will be able to maintain. A classification of roads over which logging trucks operate in Northern Michigan was made by Bruce Spike of George Banzhaf and Company, Milwaukee, Wisconsin and is as follows:

Class I (Strip road)--Average round-trip speed 2 mph. Brushed out, stumps cut low, little or no hand grading, rough, no alignment. Usually made by piece cutter or trucker. Cost included in the piece rate or trucking rate.

Class II road--Pour haul roads--brushed out, stumps cut low, hand graded, not smooth. Average speed--2-4mph. Cost to construct in heavy soil--$3.00 per station. Cost to construct in sand or gravel--$1.50 per station.

Class III road--Fair to good haul roads. Machine graded, drainage provided for, dirt surface, fair alignment and gradient. Average speed--8 to 10 mph. Cost to construct in heavy soil--$5 to $7 per station.

Class IV Road--Good haul road comparable to the average township road. Alignment and gradient similar to Class III. Smooth and well maintained, dirt surface or lightly gravelled. Average speed--18 to 20 mph. Cost to construct in heavy soil--$7 to $9 per station. Maintenance after every 50 truck trips if not gravelled--25¢ per station.

An examination of the above classification indicates that the most significant economies can be obtained in the lowest classes of private logging roads when their length justifies a higher standard. In these classes only a comparatively small additional expenditure is necessary to raise the service standard and obtain a large percentage increase in the average speed that can be maintained.

Logging is essentially a transportation problem and with a classification similar to the above for the region, road standards to fit the particular logging chance can be adopted that will give the greatest economy. Regarding road service standards, Matthews[1] points out:

> The service standard of any hauling road may be progressively increased as long as such improvement induces a reduction in cost of hauling on that road that is greater than the cost of the improvement.
>
> This might be called a self-evident proposition. It is. What is not generally recognized is that the point of minimum cost is approached as total hauling cost and road construction cost are brought into balance. If this latter fact is kept in mind, mere comparison of total hauling costs and road-construction costs will suffice to determine when roads are being constructed to too low a standard or when too much money is being expended on their construction. Comparisons may be made in terms of total cost or in terms of the volume unit of the product.

If the average speed of trucks can be increased by spending more money on road construction and this added speed provides a savings in hauling cost that equals or exceeds the added cost of road improvement, the expense is justified because the hauling cost and construction cost will be brought into approximate balance and a minimum total cost will be approached.

The information necessary to make a correct decision as to the road service standard is as follows:

1. Volume of timber to be moved over the road.

2. Length of road when subject to control--this does not apply to the exterior main haul, or "tap" road since this length is fixed by the location of the timber.

[1] *Ibid.*, p. 162.

3. Cost of road construction per mile or station at various standards.

4. Hourly hauling cost per round trip mile or station to haul the product over roads of various standards.

When the cost of hauling a cord of pulpwood and the cost of road construction per cord per station is calculated for each class of road, a direct comparison will indicate the correct road standard to adopt.

It is evident that there must be a sufficient volume available to justify the cost of a high standard road if economy is to be obtained by constructing such a road. Ordinarily, logging roads are built to facilitate the transportation of the pulpwood to the mill and their cost must be charged against the volume removed as a cost per cord. Consequently, the greater the volume on an area served by a road, the lower the cost of construction per cord will be. A low standard road for a large volume of timber will give low construction costs per cord, but the total hauling cost for this large volume will be greatly increased if a fair rate of speed cannot be attained because of a poor road.

Exterior Main Haul Road Standard: The standard for any exterior main haul road may be easily determined, since the volume to be moved over the road is easily ascertained. a break-even formula that gives the volume necessary to bring about equality between any two classes of road is:

Volume to be hauled over the road = $\frac{R' - R}{H - H'}$; where R and R; are the costs of road construction per station, and H and H' are the hauling costs per cord per station for the two classes of road under consideration. For example, if the cost of road construction for a Class III road is \$6.00 per station, and \$10.00 per station for a Class IV road, and the respective hauling costs over these roads are \$.0035 and \$.0015 per cord per station, then:

$$\text{The volume required for equal costs} = \frac{\$10 - \$6}{\$.0035 - \$.0015}$$

$$= 2{,}000 \text{ cords.}$$

This indicates that with a volume of 2,000 cords, either a Class III or a Class IV road may be built and the hauling and construction costs of the two classes of road will be equal. However, if the volume to be hauled is less than 2,000 cords, a Class III road will give lower total costs, and if the volume is over 2,000 cords, a Class IV road should be built.

Interior Main Haul Road Standard: The construction of a high standard interior main road is warranted only if there is a sufficient volume available to haul over the road to give a saving in hauling costs that is equal to or greater than the increased cost of constructing the road to a higher standard. Since the volume of timber available to be moved over the interior main road decreases at a fairly uniform rate as the road penetrates the area, the tendency is to lower the standard as the road progresses into the tract. This practice is justified if the road is of considerable length serving a large volume of timber, provided the standard is lower in accordance with the amount of timber still available at various points along the road. In most cases, however, a single standard road will suffice to give satisfactory economy.

When a decision is to be made between any two standards of road in an area, the difference in cost to construct per station may be considered a cost of improvement to the next higher standard. The increase in travel speed permitted by this higher standard will reduce the hauling cost per cord. Therefore, the difference in hauling cost between the two standards under consideration is actually a saving brought about by an additional expenditure to improve the road.

For a unit distance of one station of road the total saving in hauling cost will be the saving per cord per station multiplied by the volume tributary to the unit distance of road; or, $s = V h$, where s = the total saving in hauling cost per station, V = the volume of timber tributary to each station of road, and h = the reduction in hauling cost per cord per station.

In moving over an interior road toward the exit of the area, the total saving for the length of road will increase at an arithmetic rate as the volume tributary to each station is added to the amount to be hauled over the road. The saving for "n" stations of road may be expressed as the sum of a typical arithmetic series, or, Total saving for the road = $\frac{n}{2}(s + ns)$, where s = the saving per station and n = the number of stations.

Matthews[1] has developed a break-even formula by equating the total cost of road improvement of "n" stations, expressed as "n r", against the total saving for "n" stations, $\frac{n}{2}(s + ns)$ to solve for the number of stations necessary to bring about equality between the cost of road improvement and the saving in hauling cost.

This formula is: $n = \frac{2r - s}{s}$, where n = the number of stations of road required to give equality between the improvement cost and the resulting saving, r = the cost of road improvement to the next higher standard, and s = the total saving in hauling cost per station.

To illustrate the use of this formula, assume an area one mile wide with a main haul road to go through the center of the property. The average volume per acre is 10 cords. A Class III road costing $7 per station to

[1]For a complete discussion of interior main haul standards see: D. M. Matthews, Cost Control in the Logging Industry. New York: McGraw-Hill, 1942, pp. 171-99.

construct and a Class IV road costing $12 per station are under consideration. The respective hauling costs for these roads are estimated at $.0035 and $.0020 per cord per station.

The volume tributary to each station is 12.1 acres x 10 cords, or 121 cords. The total saving in hauling cost per station by construction of a Class IV road is $.0035 - $.0020 = $.0015 x 121 cords, or s = $.1815. The cost of road improvement, r = $12 - $7 = $5.

Substituting in the formula: $n = \frac{(2 \times 5) - .1815}{.1815}$ = 54 stations.

This indicates that if the road is 54 stations long, the cost of road improvement just equals the saving in hauling cost that results from the improvement to a Class IV road, and that total costs for both roads are in equality. Therefore, if the interior main road is longer than 54 stations, a Class IV road will be more economical, and if shorter than 54 stations, a Class III road should be built.

Branch Road Standard: Branch roads are built primarily to keep the cost of skidding at satisfactory levels. In order to accomplish this, each road must necessarily serve a comparatively small volume and therefore expensive roads are not justified. If the operation is well planned and the topography permits, these roads will be of short length and the cost of hauling on them will be but a small portion of the total hauling cost. However, the cost of skidding, branch road construction, and hauling on the branch roads should be brought into balance for greatest economy. The lowest possible standard would be the most economical for the total cost of skidding and road construction as expressed by the formula $C \frac{S}{4} + \frac{r/.299}{V S}$, but when the cost of hauling, $H \frac{D}{2}$, is added, a higher type of branch road that reduces the combined total may prove more economical. This certainly will be the case if the branch roads are long enough to require a considerable portion of the truck travel time to negotiate them, or if they are of so low a standard as to require a sacrifice in load.

A calculation of the economical spacing for each branch road standard being considered and a direct comparison of the variable unit cost of draying with the unit hauling cost for each standard will indicate the service standard to adopt, for these two costs should be approximately equal to provide minimum costs.

Planning for Selective Logging

In selective cutting adequate planning of the transportation system assumes even greater importance than in clear-cutting because the operator is dealing with reduced volumes. It has been demonstrated that the volume to be cut is the controlling factor governing the spacing of branch roads and the service standard of the road system. Consequently, the fact that the road plan can be adjusted to allow the removal of a smaller volume of pulpwood without seriously increasing the total transportation costs is all-important for financial success in a selective cutting operation.

ILLUSTRATIVE CASE

To illustrate the application of the principles and methods of production control discussed in this paper, the following case will be assumed.

1. A tract of timber, two sections in area, is to be logged for spruce and balsam pulpwood. This tract lies one mile back from a high standard gravelled county road. An average round trip speed of 20 mph can be maintained on this road and the travel distance is 6 miles to a concrete highway. The travel distance on the highway is 10 miles to the mill and an average speed of 35 miles per hour can be maintained.

2. The cruise data of the area indicates the following average stand per acre:

Stand Table for the Average Acre of the Logging Chance

DBH	Number of 100" Sticks per Tree					Total Trees
	1	2	3	4	5	
5	26	33				59
6		23	14			37
7			32			32
8			8	12		20
9			2	10		12
10				6	2	8
11				2	2	4
12					3	3
						175

The average volume per acre (from Table II) is 9.5 cords.

3. The following equipment is available for use on the job:

Standard 1 1/2 ton trucks:

Machine Rate:	Fixed cost per hour	$1.20
	Operating cost "	.89
	Running cost per hour	$2.09

Average load: 3 cords of 128 cu. ft. per cord.

Horses and drays:

Machine Rate:	Fixed cost per cord	$0.40
	Variable cost per cord per station	$0.05

4. Loading and unloading time requires 1 hour per trip.

5. Available data regarding woods road standards is as follows:

Road Class	Average Speed	Cost to Construct per Station
I	2	$1.50
II	4	3.00
III	8	6.00
IV	18	10.00

6. The job standard table, Table IV, may be applied to the stand without adjustment. The cutting cost will be estimated for an average worker at an assumed wage for pulpwood cutters of $0.60 per hour.

The total direct production costs for this case will be estimated, first, for a plan to clear-cut the entire area, taking all pulpwood 5 inches and up; and second, under a plan to remove only trees 8 inches and up.

PLAN I--CLEAR CUT

A. Cutting Costs

DBH	Number Trees per Acre	Percent of Total Trees (to nearest 10 Percent)	Hours Required to Cut 1 Cord
5	59	30	1.28
6	37	20	.76
7	32	20	.67
8	20	10	.30
9	18	10	.28
10	8		
11	4	10	.26
12	3		
	175	100	3.55

The job standard is 3.55 hours.

Calculation of Rates to be Paid for Cutting.

a. Equitable stick piece rate plan:

Average number of sticks per cord is 48.5
Cost per cord is 3.55 hours x $0.60 = $2.13
$2.13 ÷ 48.5 sticks = 4.4¢, or pay 4.5¢ per stick for cutting all trees 5 inches and up.
New cost per cord = 4.5¢ x 48.5 sticks, or $2.18

b. Cord piece rate plan:

3.55 hours x $0.60 = $2.13 per cord, or pay $2.15 per cord for cutting all trees 5 inches and up DBH.

c. Task and bonus plan:

Bonus to be paid for performance at and above task = 33 1/3 percent.
Minimum wage guarantee is \$0.45 per hour.
Job standard for 40 hour week = 40 hours + 3.55 hours, or 11.3 cords.
Set the weekly task at 11 cords.

Formula for earnings at and above task: E = 1.op SNR
Weekly earnings of an average worker for 40 hour week = 1.33 1/3 x 3.55 x 11.3 x .45 = \$24.00
Cost per cord = \$2.13

B. Transportation Costs

1. Calculation of the hauling cost per cord per station for each class of road.

Formula: $X = \frac{2\ Hc}{mph \times L}$; Hourly cost = \$2.09; Load = 3 cords

Class I (2 mph) $\frac{2 \times 2.09}{2 \times 3 \times 52.8}$ = \$0.0132 per cord per station.

Class II (4 mph) $\frac{2 \times 2.09}{4 \times 3 \times 52.8}$ = 0.0066 per cord per station.

Class III (8 mph) $\frac{2 \times 2.09}{8 \times 3 \times 52.8}$ = 0.0033 per cord per station.

County Road (20 mph) $\frac{2 \times 2.09}{20 \times 3}$ = 0.0697 per cord per mile

Concrete Highway (35 mph) $\frac{2 \times 2.09}{35 \times 3}$ = 0.0398 per cord per mile

2. Determination of the standard for the exterior main road.

Calculate the volume necessary to bring about equality of hauling and construction costs between a Class III and a Class IV road.

$$V = \frac{R' - R}{H - H'} ; \quad V = \frac{\$10 - \$6}{\$.0033 - \$.0015} \text{ or } 2,222 \text{ cords.}$$

This calculation indicates that a Class IV road is more economical and should be constructed in preference to a Class III road, since the estimated volume to be hauled over the road is 12,160 cords.

3. Branch road standard and spacing.

To determine the most economical service standard and road spacing for the branch roads, it is necessary to calculate the spacing that brings about equality in the road construction cost and the variable skidding cost for each class of road by the formula $S = \sqrt{\frac{17.4\ r}{V\ C}}$ where r = the cost of construction for each class of road, V = 9.5 cords, and C = 5¢, the variable skidding cost per cord per station.

Class I (r = 150¢) $S = \sqrt{\frac{17.4 \times 150}{9.5 \times 5}} = \sqrt{55} = 7.4$ stations

Class II (r = 300¢) $S = \sqrt{\frac{17.4 \times 300}{9.5 \times 5}} = \sqrt{110} = 10.5$ stations

Class III (r = 600¢) $S = \sqrt{\frac{17.4 \times 600}{9.5 \times 5}} = \sqrt{220} = 14.8$ stations

Class IV (r = 1000¢) $S = \sqrt{\frac{17.4 \times 1000}{9.5 \times 5}} = \sqrt{336} = 19.1$ stations

Then estimate the cost of draying, road construction, and hauling for each class of road and compare the total costs. Since the spacing figure for each class of road makes the variable skidding cost and the road construction cost equal, the formula $2\ C\ \frac{S}{4} + H\ \frac{D}{2}$ may be used, where C = variable skidding cost of 5¢, S = economical spacing for each class or road, H = hauling cost for each class of road, and D = maximum hauling distance on the branch roads, or 26.4 stations.

$$\text{Class I:}\quad 2 \times 5 \left(\frac{7.4}{4}\right) + 1.32 \left(\frac{26.4}{2}\right) = 35.90¢$$

$$\text{Class II:}\quad 2 \times 5 \left(\frac{10.5}{4}\right) + .66 \left(\frac{26.4}{2}\right) = \underline{34.96¢}$$

$$\text{Class III:}\quad 2 \times 5 \left(\frac{14.8}{4}\right) + .33 \left(\frac{26.4}{2}\right) = 40.36¢$$

$$\text{Class IV:}\quad 2 \times 5 \left(\frac{19.1}{4}\right) + .15 \left(\frac{26.4}{2}\right) = 49.73¢$$

Class II roads give the lowest total cost for draying, road construction and hauling; therefore this standard for the branch roads should be adopted. The branch roads will be built to a Class II standard and spaced approximately 1050 feet apart.

4. Interior main road standard.

Estimate the saving in hauling cost available if the road is improved to each successively higher standard.

$$\text{Area served by each 100 feet of road} = \frac{100' \times 5280'}{43{,}560 \text{ sq. ft.}}$$

$$= 12.1 \text{ acres}$$

Volume tributary to each 100 feet of road = 12.1 x 9.5 cords = 115 cords.

Road Class	Construction Cost per Station	Cost of Road improvement to Next Class (r)	Hauling Cost per Cord per Station	Saving in Hauling Cost per 115 Cords per Station (s)
I	$1.50	----	$0.0132	-----
II	3.00	$1.50	0.0066	$0.759
III	6.00	3.00	0.0033	0.380
IV	10.00	4.00	0.0015	0.207

Calculation to determine the length of road necessary to justify the construction of a Class IV road vs. a Class III road.

$$n = \frac{2r - s}{s}, \quad n = \frac{2 \times 4 - .207}{.207} = 37.8 \text{ stations}$$

The interior main haul road will be approximately 101 stations in length, so a Class IV standard should be used.

5. Estimated transportation costs per cord:

Draying:

Fixed draying cost		$0.40	
Variable - $C\frac{S}{4}$,	$.05 \times \frac{10.4}{4}$	.131	$0.531

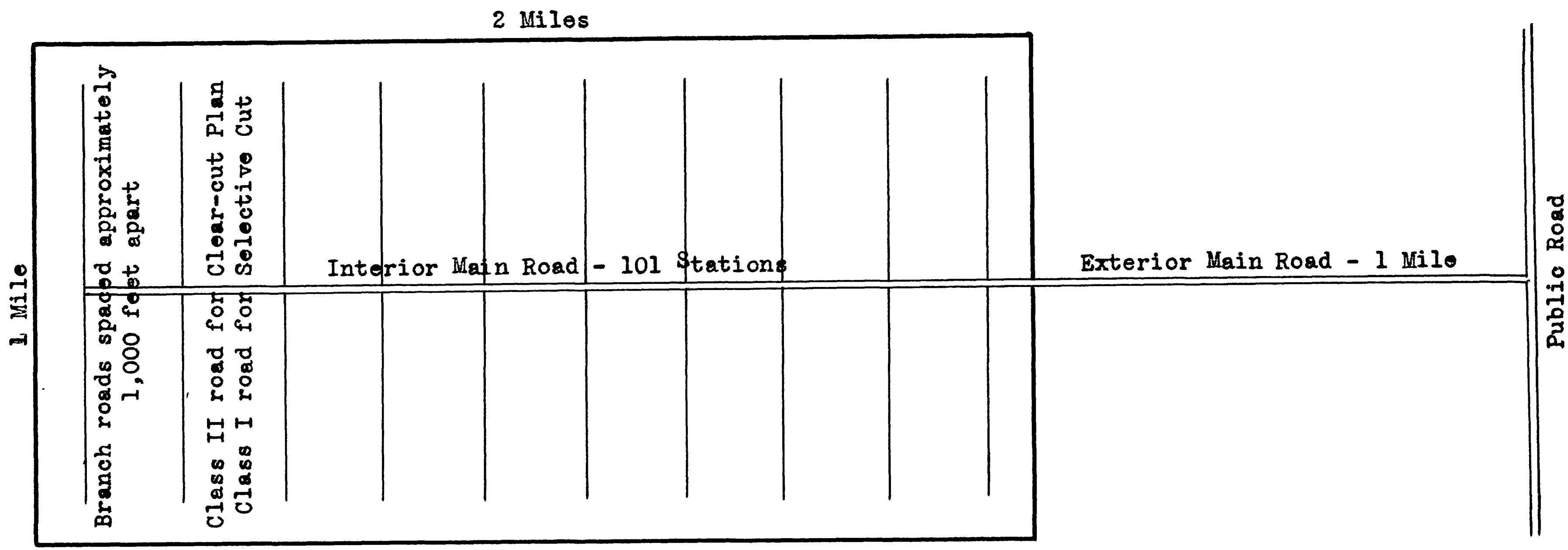

FIGURE 4. DIAGRAM OF LOGGING ROAD PATTERN FOR ILLUSTRATIVE CASE

Road Construction:		
Exterior main haul--Class IV, 1 mile \$528 ÷ 12,560 cords	\$0.043	
Interior main haul--Class IV, 101 stations \$1010 ÷ 12,560 cords	0.083	
Branch roads--Class II $\frac{4.356\ r}{V\ S}$, $\frac{4.356 \times \$3}{9.5 \times 10.5}$	0.131	\$0.257
Hauling Cost on private roads:		
Exterior main road--Class IV, 1 mile \$.0015 x 52.8 stations	0.077	
Interior main road--Class IV, 2 miles $H \frac{D}{2}$, $\$.0015 \times \frac{105.6}{2}$	0.077	
Branch roads--Class II, one-half mile $H \frac{D}{2}$, $\$.0066 \times \frac{26.4}{2}$	0.087	0.241
Hauling Cost on Public Roads:		
County road--6 miles (20 mph) \$0.0697 x 6 miles	0.418	
Concrete highway--10 miles (35 mph) \$0.0398 x 10 miles	0.398	0.816
Standby Cost on Trucks for Loading and Unloading:		
1 hour per trip, or \$1.20 ÷ 3 cords		0.40
Total transportation cost, 100 percent cut		\$2.245

PLAN II--SELECTIVE CUT, 8 INCHES AND UP

A. Cutting Costs

Calculation of the job standard from Table IV:

DBH	Number of Trees per Acre	Percent of Total Trees (to nearest 10 percent)	Hours Required to Cut one Cord
8	20	40	1.20
9	12	30	.85
10	8	20	.53
11	4	10	.26
12	3		
	47	100	2.84

The job standard is 2.84 hours.

Calculation of the rates to be paid for cutting:

1. Equitable stick piece rate plan:

The average number of sticks per cord is 35.5
The cost per cord is 2.84 hours x $.60 = $1.704
Piece rate = $1.704 ÷ 35.5 sticks = 4.8¢, or, pay 5¢ per stick
New cost per cord at 5¢ per stick = $1.77
Hourly earnings of average cutter = $0.62

2. Cord piece rate plan:

Cost per cord = 2.84 hours x $.60 = $1.704
Hourly earnings of average cutter = $0.60

3. Task and bonus plan:

Bonus to be paid for performance at and above task is 33 1/3 percent.
Minimum wage rate guarantee is 45¢ per hour.
Task for 40 hour week is 40 ÷ 2.84 = 14.1 cords, or 14 cords.

Formula for earnings at and above task: E = 1.op SNR
Cutters weekly earnings for 40 hour week
1.33 1/3 x 2.84 x 14.1 x .45 = $24.00
Cost per cord = $1.704
Hourly earnings = $0.60

B. Transportation Costs

1. Determination of the standard for the exterior main Road.

Class IV (same as for 100 percent cut)

2. Branch road standard and spacing.

Calculate the correct spacing for each road standard by the formula: $S = \sqrt{\frac{17.4\ r}{V\ C}}$; Volume per acre = 5.2 cords

Class I (r = 150¢) $S = \sqrt{\frac{17.4 \times 150}{5.2 \times 5}} = \sqrt{100.4} = 10$ stations

Class II (r = 300¢) $S = \sqrt{\frac{17.4 \times 300}{5.2 \times 5}} = \sqrt{201} = 14.2$ stations

Class III (r = 600¢) $S = \sqrt{\frac{17.4 \times 600}{5.2 \times 5}} = \sqrt{401.5} = 20.1$ stations

Comparison of total cost for draying, road construction, and hauling for each class of road

Class I: $2 \times 5 \left(\frac{10.0}{4}\right) + 1.32 \left(\frac{26.4}{2}\right)$ = 42.4¢ per cord

Class II: $2 \times 5 \left(\frac{14.2}{4}\right) + .66 \left(\frac{26.4}{2}\right)$ = 44.2¢ per cord

Class III: $2 \times 5 \left(\frac{20.1}{4}\right) + .33 \left(\frac{26.4}{2}\right)$ = 56.86¢ per cord

A class I road is more economical to use with the reduced volume. Therefore build branch roads to a Class I standard and space them approximately 1000 feet apart.

3. Interior main road standard:

Estimate the savings in hauling cost per station that is available if the road is improved to each successively higher standard.

Area served by each 100 feet of road = 12.1 acres

Volume tributary to each 100 feet of road = 12.1 x 5.2 cords = 63 cords. Tabulation of the cost of improvement and saving for each road class:

Road Class	Construction Cost per Station	Cost of Road Improvement to Next Class (r)	Hauling Cost per Cord per Station	Saving in Hauling Cost per 115 Cords per Station (s)
I	$1.50	----	$0.0132	-----
II	3.00	$1.50	0.0066	$0.416
III	6.00	3.00	0.0033	0.208
IV	10.00	4.00	0.0015	0.113

Calculation to determine the length of road necessary to justify the construction of a Class IV road

$$n = \frac{2r - s}{s}, \quad n = \frac{2 \times 4 - .113}{.113} = 69.7 \text{ stations}$$

The interior main road will be approximately 101 stations long, therefore, build to a Class IV standard.

4. Estimated transportation costs per cord:

Draying:		
Fixed draying cost	$0.40	
Variable draying - $C\frac{S}{4}$, $.05 \times \frac{10}{4}$	0.125	$0.525
Road Construction:		
Exterior main haul--Class IV, 1 mile $528 ÷ 6656 cords	0.079	
Interior main haul--Class IV, 101 stations $1010 ÷ 6656 cords	0.152	
Branch roads--Class I $\frac{4.356 \times 1.5}{5.2 \times 10}$	0.125	0.356
Hauling costs on private roads:		
Exterior main road--Class IV, 1 mile $.0015 x 52.8 stations	0.077	
Interior main haul--Class IV, 2 miles $.0015 x $\frac{105.6}{2}$	0.077	
Branch roads--Class I, one-half mile $.0132 x $\frac{26.4}{2}$	0.174	0.328
Hauling cost on public roads:		
Same as for clear-cut plan		.816
Standby cost on trucks for loading and Unloading:		
1 hour per trip, or $1.20 ÷ 3 cords		0.40
Total transportation cost, selective cut		$2.425

Comparative Cost Schedule

	Clear-cut	Selective Cut
Felling, bucking and assembling (task and bonus plan)	$2.130	$1.704
Draying		
Fixed cost	.400	.400
Variable cost	.131	.125
Road Construction		
Branch roads	.131	.125
Interior main haul road . . .	.083	.152
Exterior main haul road . . .	.043	.079
Hauling		
Branch roads	.087	.174
Interior main haul road . . .	.077	.077
Exterior main haul road . . .	.077	.077
Public roads	.816	.816
Loading and Unloading	.400	.400
Total direct production cost . .	$4.375	$4.129

The comparative cost schedule for the two plans indicates that a reduction of $0.246 per cord may be obtained by cutting only trees 8 inches and up, or 55 percent of the available volume. This reduction resulted from the adoption of a wage plan that permitted the saving of $0.42 in cutting costs.

While it is true that the cost of roads per cord increased $0.18 per cord, some increase is certain to occur when a smaller volume per acre is removed. This added cost need not be serious if the transportation system is properly planned. In the illustrative case, if the same road plan had been used for the selective cut as was used for clear-cut operation, the variable skidding, branch road construction, and branch road hauling costs would have been increased 3.3¢ per cord. In other words, a total saving of $220 was effected for the 6656 cords by reducing the average branch road spacing to 1000 feet and adopting a Class I standard. This comparatively slight change in the logging plan to adjust the roads to the new volume indicates what serious errors may occur when no comparative cost calculations whatever are used in making decisions.

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