COST ANALYSIS
IN
FOREST MANAGEMENT

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COST ANALYSIS IN FOREST MANAGEMENT

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by

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FOREWORD

This report on Cost Analysis in Forest Management is submitted to partially fulfill requirements for a degree of Master of Forestry from the University of Michigan. The study was made under the direction of Professor D. M. Matthews of the School of Forestry and Conservation, University of Michigan, to whom I am indebted for the suggestion of the problem and for helpful advice during the preparation of the report.

Allen Bruce Spike.

CONTENTS

COST ANALYSIS IN FOREST MANAGEMENT

INTRODUCTION

"The primary objective of management on the part of the private forest owner is the business objective."[1] The success of a business venture depends largely upon the ability of the managers of that business to analyze costs and make financial forecasts.

Financial plans based upon sound technical data and recommendations are an outstanding need of forest industries today. Accurate records of cost and cost relations made available when needed and so constructed that they may be accurately and quickly analyzed and applied to measured quantities of work are requisite to financial forecasting.

In spite of the elaborate detail in respect to operating divisions, the cost systems generally used by lumber companies fail to give any indication of differences in costs of converting trees of different diameters and species into lumber. It is impossible to obtain such information even with the most painstaking analysis of the cost sheets used. Hence, they furnish no valid basis for the solution of a great many internal operating and management problems.

There are some items of the total expense which can be allocated from the usual company records. These expenditures include items of annual expense such as taxes, insurance, supervision and salaries which can be reduced to a per M basis by dividing total expense by total production. There are other costs such as railroad construction and maintenance which are valuable aids to economic planning if the cost records show costs per mile.

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[1] D. M. Matthews, "Management of American Forests." McGraw-Hill Book Co.

There are a great many costs which vary with conditions and methods of operation. These cost relations are of prime importance in industrial management and can best be obtained from time and cost studies, properly analyzed to present the basic information in the most useful form.

The United States Forest Service and other investigating agencies have published a wealth of data on the relative cost of production and values of lumber from trees of different sizes, but they have not developed methods of applying these data to make them of the greatest use to the industry.

PRINCIPLES OF COST

Before presenting any methods of applying cost data it is thought best to discuss briefly the elements of cost and variations in cost. In analyzing costs it is necessary to break down total cost into its major parts and then make a separate analysis of each major part.

Elements of Cost

The most natural primary divisions of cost are labor, materials, transportation, rights, interest and contingencies.

Labor includes all expenditures for wages, salaries, fees, commissions, brokerage, premiums and profits.

Materials includes the raw material used in the manufactured product and all supplies used to keep the operation going.

Transportation expenditures are incurred in the moving of materials, men, domestic animals, supplies, manufactured parts, messages and so forth. Costs of transportation are dependent upon the facilities for transportation and the distances over which things must be transported.

Rights includes expenditures for charters, franchises, permits, licenses, rights of way over land, and so forth. Rents paid for the use of land and buildings, taxes and insurance are also included in this class.

Interest is the cost of capital tied up in the business and is computed from the date of first having the money on hand.

To cover errors in estimating an arbitrary figure called contingencies is added which may include any of the foregoing items of expense.

Costs in the lumber industry can be divided into three major groups, namely: logging cost, milling cost and selling and distribution costs, Figure 1.

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                           ( Logging cost
                           (      +
        Cost of Lumber     ( Milling cost
                           (      +
                           ( Selling and distribution cost
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Figure 1. Analysis of Cost of Lumber

Further analysis of costs must proceed along these lines. The diagram, Figure 2, will show more clearly the items upon which data are necessary to make a thorough-going analysis of cost.

TOTAL COST	COST GROUPS	CLASSES OF COST	ITEMS OF COST
COST OF LUMBER	Total Logging Cost	Direct Logging Cost	Felling and bucking
			Bunching
			Wagon haul
			Loading on cars
			Railroad operation
		Indirect Logging Cost	Depreciation - wagons, tools, equipment
			Railroad construction cost
			Railroad maintenance cost
			Supplies
		General Expenditures	Supervision
			Scaling
			Miscellaneous - Insurance, taxes, etc.
	Total Milling Cost	Direct Milling Cost	Operation
		Indirect Milling Cost	Repairs
			Idleness
			Depreciation
			Supplies
		General Expenditures	Supervision
			Insurance, taxes, interest
	Selling and Distribution Costs	Direct Cost	Salaries and expenses - salesmen
			Advertising
		Indirect Cost	Clerical
			Supplies
			Freight

Figure 2. Analysis of Costs in the Lumber Industry

Variations of Costs

The items of cost may be divided into two broad groups, namely: fixed costs and variable costs.

There are certain costs that are relatively fixed for any operation and that must, therefore, increase as the cut per acre decreases. These costs include main-line railroad construction, depreciation on all plants and equipment, taxes on timber and selling cost of lumber.

Such costs will vary from one operation to another because of differences in:

a. Size of timber tract being operated.

b. Character of the operation - liquidation or sustained yield. The length of the liquidating period will have an important bearing on depreciation and taxes.

c. Type of operation.

(1) Size and design of mill.

(2) Plan of management.

No analysis of costs can be made without first obtaining definite information on all of the above points. Since under a definite plan of management there will be no subsequent variation, these costs may be treated as fixed charges which vary as a cost per M inversely with the amount of timber cut.

The variable costs can be classified according to the factors controlling their variation:[1]

I. Varies with time per M feet.

1. Felling and bucking.

2. Bunching and skidding.

[1] Virginia Forest Service Publication No. 43. P. 20. 1931.

3. Loading on cars.

4. Sawmilling, pond and green chain.

II. Varies with capacity of cars or wagons when loaded with logs of different sizes.

1. Wagon haul.

2. Railroad operation.

3. Freight (camp to mill, common carriers).

III. Varies with total logging costs.

1. Supplies (woods).

2. Depreciation (woods equipment).

3. General expenses (woods).

IV. Varies with milling time.

1. Railroad maintenance.

2. Sawmilling supplies.

3. General expense - office and office salaries, taxes, insurance and depreciation on plant.

V. Varies with price of lumber.

1. Discount and allowances.

2. Insurance and taxes on lumber.

VI. Varies with number of pieces per M board feet lumber tally.

1. Dry kiln. 2. Yards and timber docks. 3. Rough shed. 4. Rip mill.	) Labor, materials and supplies.

VII. Varies with spacing.

1. Spur construction cost on per M basis.

2. Skidding and wagon haul.

Milling and selling costs have been generally standardized on a fairly uniform and efficient operating basis. As shown in the previous classification of cost items, milling cost varies with the time required to produce a thousand board feet of lumber from logs of different sizes. The quality of logs which come into the mill and the kinds of lumber cut also have a direct effect on milling time.

The big variable in lumbering costs is in logging costs, which differ with every logging chance and local conditions. The determination of the best methods, equipment and personnel to be used is of prime importance. Transportation costs amount to from 60 to 78 per cent of the total logging cost. Therefore, much of the success of the operation depends upon the selection of the cheapest method or combination of methods of bringing out the logs. The determination of minimum transportation costs consists of finding the correct balance between minor and major transportation methods.

The items of logging cost may be divided into three general classes:

1. Log making (marking, felling and bucking).
2. Minor transportation (hauling logs from stump to railroad or other means of general transportation).
3. Major transportation (transportation by railroad, waterway or highway).

Marking charges are incurred only when the timber is logged selectively. The cost of marking is a very small item and is relatively constant per acre regardless of the degree of marking; i. e., whether it is a light or heavy cut.

Felling and bucking costs vary as the time required to produce a thousand board feet of logs. The time per M board feet varies with the following factors:

1. Size of timber.
2. Density of the stand.
3. Cut per acre.
4. Log lengths as determined by:
    a. Market demands.
    b. Methods of logging in that particular region.
5. Topography, amount of windfall and density of undergrowth.
6. Amount of defect or per cent of cull.
7. Breakage.
8. Overrun.
9. Contract or day work.
10. Effective hours per day.

The determination of felling and bucking costs must therefore be based upon time studies or motion timing.

The elements of felling time may be grouped into three classes for the purpose of making observations.

Class I - Those items varying with stump diameter.

a. Planning

b. Barking

c. Undercutting

d. Sawing

e. Wedging

Class II - Items independent of diameter.

a. Travel time from tree to tree } Constant per tree.

b. Swamping time }

Class III - Rests and delays - assumed to be proportional to the time spent in working. Prorated on basis of the total of Class I and Class II items for the tree in question.

The elements of bucking time may be grouped into three classes for the purpose of making time studies.

Class I - Items dependent on diameter of the bucking cut.

a. Propping

b. Undercutting

c. Chopping

d. Sawing

e. Wedging

Class II - Items independent of log diameter.

a. Travel time from cut to cut

Class III - Items to be prorated.

a. Rests

b. Delays

The marking of logs, usually done by the buckers, varies with the length of the bole or the number of logs produced.

Time in minutes per M for trees and logs of different sizes can be converted to cost per M by application of costs per minute as calculated from current wage rates and miscellaneous expenses chargeable to each item.

Transportation Costs

The cost of minor and major transportation varies with the logging plan. For every operation the factors determining the selection of a plan must be carefully reviewed. The special features and characteristics of an area to be logged suggest certain plans.

The size and character of the timber, the topography of the area, the climatic conditions and distance of haul will all affect the operating efficiency of different methods. Silvicultural and management policies may be such that it will be impossible to use certain methods of power skidding because of their harmful effects upon young growth and reproduction.

The outstanding factors which should be reviewed in selecting the method or combination of methods best suited for a particular logging operation are:

1. The total stand of timber available with stands per acre and by species and diameters.
2. The size of sawmill or market to be served daily and the annual volume of logs required.
3. Topography of the tract with natural outlets for the timber.
4. Available transportation facilities such as common carrier railroads, highways, streams and climatic factors influencing their use.
5. The relation of adjacent timber resources and logging operations.
6. Availability of capital for both the initial investment and carrying charges as well as the general financial program.

Because of the general conditions existing in different logging regions, there are various combinations of transportation methods which have become more or less characteristic. These are illustrated in Brown's "Logging Transportation," as follows:

California pine region

Minor Transportation	Major Transportation
Tractor and cable skidding	Railroad haul
Cable skidding	Railroad haul

California pine region (con.)

Minor Transportation	Major Transportation
Tractor skidding	Railroad haul
Horse skidding	Truck haul
Douglas fir region	
Cable skidding	Railroad haul - rafting
Cable skidding	Railroad haul
Tractor skidding	Railroad haul
Tractor skidding	Railroad haul - rafting
Cable skidding	Motor truck haul
Redwood region	
Cable skidding	Railroad haul
Tractor skidding	Railroad haul
Northern Rocky Mountain region	
Horse skidding	Railroad haul, stream drive, floating and rafting
Cable skidding	Railroad haul
Horse skidding	Chutes, stream drive
Horse skidding	Flume, railroad haul
Tractor skidding	Railroad haul
Horse skidding	Sled haul, railroad haul
Horse skidding	Chutes, motor truck haul
Northeastern region	
Horse skidding	Chutes, railroad haul
Horse skidding	Sled haul, railroad haul
Horse skidding	Stream drive

Northeastern region (con.)

Minor Transportation	Major Transportation
Horse skidding	Motor truck haul
Horse skidding	Sled haul, stream drive
Tractor skidding	Railroad haul

Southern pine region

Horse skidding	Motor truck haul
Horse skidding	Rafts on streams
Horse skidding	Wagon haul, railroad haul
Tractor skidding	Railroad haul
Cable skidding	Railroad haul

Cost, measured in charges per thousand board feet, is the controlling element in choosing the method to be used.

To analyze the cost of any method it is necessary to break down total operation time into its separate elements.

Total major transportation cost is composed of construction cost, maintenance cost and operating cost.

Construction cost may vary considerably depending upon the difficulties of construction (topography and general land characteristics) over which the operator has little control except in the location of rights of way. Under given conditions then, the cost per M will vary with the spacing of spurs and the cut per acre.

Maintenance cost will vary with the length of period of use and the quantity of logs hauled.

Operating cost varies with the capacity of cars when loaded with logs of different sizes, and the distance of haul. Loading cost may be considered a part of cost of operation and varies with different sized logs.

The elements of Minor Transportation time can be classified as fixed and variable according to their behavior under given conditions.

Class I - Fixed time.

a. Hooking

b. Unhooking

c. Delays

Class II - Variable time.

a. Outhaul

b. Inhaul

c. Loading

d. Unloading

COST DETERMINATION

Use of Time Studies

Actual costs must be determined by making time studies in the field; the object of such studies being to determine operating efficiency under various conditions of logging.

It has been said that the yarding or skidding operation occupies the key position in the intensive application of management principles. The importance of data on the operating efficiency of various methods of skidding under different conditions of logging cannot be overstressed. It becomes even more important in the selective cutting of sustained yield operations. Such data should be expressed in time per 100 feet per M under various operating conditions.

The typical logging operation is a series of operations or activities which are so related that cost studies of any particular one are not conclusive. The operation as a whole must be considered. Interdependent activities must be balanced between one another. The function of management is to select the methods which separately or in combination with others will perform the operation most efficiently and to combine these with proper planning into the most profitable operation. Time and cost studies of individual activities furnish the basic information for economic planning.

To translate time in minutes per M into cost per M, it is necessary to multiply by the machine rates expressed in dollars per minute. Changes in money values involve only a change in machine rates; the basic data remains unchanged.

Determination of Minimum Cost

The rule for securing minimum costs states that the sum of the units of cost must be a minimum. In the evolution of scientific cost analysis five kinds of units were successively developed:[1]

1. Time units.
2. Sale units.
3. Dimension units.
4. Work units.
5. Formula units.

The time unit of cost is the cost per unit of time, as the day, week, month or year. All interest costs and most depreciation costs are time costs. Many other "fixed costs," such as taxes, protectiom costs, supervision, and so forth, are time costs; that is, they are a function of time rather than output. Hence, time units will always remain useful as measures of certain costs of production.

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[1] Gillette and Dana, "Construction Cost Keeping and Management." McGraw-Hill Book Co. p. 34, 1922.

Since it is not commonly the case that the number of units of product is constant per unit of time, it early became the practice to express costs in terms of sale units.

A <u>sale unit</u> is the unit of product in which selling prices are expressed; as, the board feet of lumber, cord of pulpwood, and so forth.

While the sale unit is still more commonly used than any other, with the possible exception of the time unit, and while the sale unit possesses merit, it is a very imperfect criterion for judging the cost of many products and operations.

A <u>dimension unit</u> is a unit of length, area, or volume. Railroad construction, railroad maintenance, hauling, skidding, and others can all be expressed in dimension units.

In selecting dimension units that are better criteria of costs than sale units, the aim is to choose a dimension unit that will measure directly the approximate amount of labor required to produce the unit and that will lend itself readily to mathematical treatment. The next step in the evolution of costs was to select a cost unit which would measure the labor required in production with more scientific precision.

A <u>work unit</u> is a unit that directly measures the approximate cost of labor involved in its production.

The work unit is the product of some weight or force and the distance through which it moves. In selecting a work unit for hauling or transportation costs, one should be chosen that will be approximately a function of distance multiplied by tractive resistance.

The latest development in unit cost analysis is the <u>formula unit</u>. A formula unit is a composite cost unit made up of simple cost units, each of which measures approximately or exactly the cost of a certain part of the total.

Nearly every satisfactory formula unit is a composite of the three classes of units that have been discussed; namely, (1) time units, (2) dimension units, and (3) work units. A formula unit may be itself a sale unit, or it may be some arbitrary unit that merely serves to sum up all the sub-units of a given kind, or several kinds.

The cost of certain sub-units is often a function of the cost of other sub-units or of the total unit cost, so that comparisons of percentages become very effective. Frequently, however, the functional relation is such that when one sub-unit cost goes up another sub-unit cost goes down. Thus, a moderate increase in the cost of management usually results in a decrease in the cost of direct labor. So, too, a decrease in spur construction cost due to wider spacing results in increased skidding cost because of greater skidding distance.

The manager, who is fully informed as to scientific methods, will study the quantitative relation between sub-unit costs that vary inversely, one to the other. If the quantitative relationship can be established, it can be expressed in the equation that gives the formula-unit cost. Then it becomes possible to apply the science of mathematics to this unit-cost equation and solve for minimum unit cost.

Minimum cost problems are problems in economic engineering and consist, in final analysis, of deriving, first, a correct curve of unit costs and then in finding the lowest point on that curve. Thus, they are problems of minima, in which differential calculus offers the most direct and speedy method of solution.

The rule of minimum costs states that the sum of the items of cost must be a minimum. We can, therefore, express the cost per M in the basic formula: <u>Cost per M = Fixed Cost + Variable Cost</u>. The factors of fixed and variable cost have already been discussed and shown to vary with the plan of logging.

In order to base our discussion of minimum cost upon something concrete, it is necessary to assume certain conditions with regard to a logging operation:

The logging plan is to bunch logs with horses and to haul to railway spurs with Butler wagons. The total merchantable volume is to be cut.

Procedure:

Fixed costs:

F - Felling and bucking cost, fixed for present diameter limit of cutting.

B - Bunching cost, fixed for present average log size.

L - Loading and unloading cost per M, fixed for average load.

$$\frac{\frac{\text{Average time to load and unload (minutes)}}{\text{60 minutes}} \times \text{rate}}{\text{Load in M board feet}} = \text{cost per M}$$

Sw - Cost of swamping for roads, fixed for present volume cut per acre.

Variable costs:

S - Spacing between spurs in hundreds of feet, variable at will (Average road haul is 1/4 S).

R - Cost of spur construction per unit of 100 foot spacing on a per acre basis:

Area of a strip 100 feet wide x 1 mile in length is

$$\frac{100 \times 5280}{43560} = 12.1 \text{ acres} \qquad R = \frac{\text{cost per mile}}{12.1}$$

Therefore; R varies per M with spacing and cut per acre.

(V = volume cut per acre.)

C - Hauling cost per 100 feet of road, fixed for present average loads.

$$\frac{\frac{\text{Time per 100 feet (minutes)}}{\text{60 minutes}} \times \text{rate}}{\text{Average load in M board feet}} = \text{Cost per M per 100 feet}$$

Total cost per M varies with average hauling distance.

M - Total cost per M.

We can now rewrite the basic formula given above.

(1) $M = F + B + L + Sw + C\frac{S}{4} + \frac{R}{S \times V}$

This equation gives the total cost per M in terms of known constants and the spacing (s).

Using this equation of the cost curve, we can solve for minimum cost by placing the differential coefficient equal to zero, which is equivalent to finding the point of the lowest point in the cost curve, the point where the tangent is horizontal.

The same result can be arrived at by substituting various values for S until, by successive approximations, a minimum value for the total cost is derived. However, that is a crude - though not uncommon - method of solving such problems.

The differential calculus used in solving for minimum values is exceedingly simple, and it has the advantage of enabling us to derive general formulas for quickly ascertaining the most economic combination in any given case.

Since M and S are the only two variables, any increase in S by a distance of $\triangle S$ will cause a corresponding increase in M of $\triangle M$.

(2) Therefore, $M + \triangle M = F + B + L + \frac{C(S + \triangle S)}{4} + \frac{R}{V(S + \triangle S)}$

Subtracting equation (1) from equation (2),

$$(3) \quad \Delta M = \frac{C\Delta S}{4} - \frac{R\Delta S}{V(S^2 + S\Delta S)}$$

The average increase in M due to the increased distance ΔS is then:

$$(4) \quad \frac{\Delta M}{\Delta S} = \frac{C}{4} - \frac{R}{V(S^2 + S\Delta S)}$$

The limit of $\frac{\Delta M}{\Delta S}$ as ΔS approaches zero is the derivative of M with respect to S or $\frac{dM}{dS}$.

$$(5) \quad \text{Therefore, } \frac{dM}{dS} = \frac{C}{4} - \frac{R}{VS^2}$$

To find the point of minimum cost, i. e., the point where the curve has a horizontal tangent, the slope $\frac{dM}{dS}$ must equal zero.

$$\text{Therefore, } \frac{C}{4} - \frac{R}{VS^2} = 0$$

$$\frac{C}{4} = \frac{R}{VS^2}$$

$$S^2 = \frac{4R}{VC}$$

$$\text{or} \quad S = \sqrt{\frac{4R}{VC}}$$

This equation gives, in the most general form, the most economic spacing of spurs, for it is this value of S that satisfies the condition of minimum cost in equation (1).

APPLICATION OF COST DATA TO CUTTING LIMITS

Liquidation Operation

The determination of economic cutting limits can best be demonstrated by an illustrative case. For convenience and also to show comparisons, the assumed case used by Matthews, "Management of American Forests," page 314, is used here.

The average stand per acre of this assumed loblolly pine forest is shown in the stand and stock table, Table I.

TABLE I. - Stand and Stock Table

Loblolly pine forest, typical acre.

Diameter, Inches	Number of Trees	B. A., Sq. Ft.	Volume in Ft., B.M.	Per Cent of Volume per Diameter Class
7	5.5	1.47	104	0.70
8	10.6	3.70	386	2.70
9	10.3	4.55	422	2.90
10	11.0	5.99	628	4.35
11	9.3	6.14	706	4.90
12	10.1	7.93	1,010	7.00
13	9.5	8.75	1,216	8.40
14	8.9	9.50	1,415	9.80
15	6.5	7.97	1,274	8.80
16	5.7	7.95	1,345	9.30
17	4.2	6.62	1,176	8.15
18	4.6	8.11	1,495	10.40
19	2.1	4.14	784	5.40
20	1.2	2.62	508	3.50
21	0.9	2.16	429	3.00
22	0.7	1.85	373	2.60
23	0.3	0.85	177	1.20
24	0.4	1.26	261	1.80
25	0.3	1.02	215	1.50
26	0.2	0.74	156	1.10
27	0.2	0.79	170	1.20
28	0.1	0.42	92	0.60
29	0.1	0.46	99	0.70
	102.7	94.99	14,431	100.00

The total area of the timber tract is 40,000 acres, carrying a total stand of 577,240 M feet, B. M., which is to be liquidated during a period of 20 years. The fixed investment and depreciation, exclusive of spurs, is as follows:

Total average annual depreciation -		$ 43,280
Total fixed investment -	$ 356,520	
Working Capital, figured on total direct costs to 7" limit turned 4 times = $\frac{\$16.62}{4}$ x 28,000 M or $116,430, approximately	115,000	
Total profit-bearing Investment -		$ 471,520

Margin required per M feet, B. M., of annual cut when a 7" limit applies:

Annual depreciation charge -	$ 43,280
15 % x $471,520 (allowance for profit and risk)	70,720
Total annual margin over and above direct costs of operation	$ 114,000

Margin per M -

$$\frac{\$114,000}{28,862\ M} = \$3.95$$

The foregoing calculated indirect cost of $3.95 per M for an annual cut of 28,862 M will rise as the cut falls below this amount. The cost of railroad spurs per M will, of course, vary with the number of miles of railroad per acre and the volume of timber cut per acre.

The cost per mile is as follows:

	Initial Cost	Years in Use	Per Cent of Deprec.	Residual Value	Average Annual Depreciation	Fixed Investment
Grade	500					
Laying	150					
Ties	200					
Total per Mile	$850	1	100	- - -	850	850
Spur steel	$3000	5	20	- - -	600	1800
Total					1450	2650

Annual Cost per Mile -

Annual depreciation	$1,450
15% x $2,650 =	398
TOTAL	$1,848

The per acre cost on the basis of a 100 foot spacing would therefore be:

$$\frac{1848}{12.1} = \$152.60$$

In determining wagon haul costs the total cost to a 7" limit ($1.03 per M) was used as a basis and with the spacing of 2360 feet used by Matthews, the hauling cost per 100 feet per M was found to be $0.0762. (Found by substitution in the spacing formula as follows:)

$$S = \sqrt{\frac{4R}{VC}}$$

$$23.6 = \sqrt{\frac{4 \times \$152.60}{14.4 \times C}}$$

$$557 = \frac{\$611}{14.4\ C}$$

$$C = \$.0762$$

For a spacing of 2360 feet, the average wagon haul would be 590 feet. Therefore, the total cost per M is $0.45, which leaves $0.58 as a fixed charge. The fixed charges have been considered to be the same for all diameter limits. These and the computed costs per 100 feet per M appear in Table II.

TABLE II. - Comparison of Wagon Haul Costs

on a Fixed Spacing of 2360 Feet
and Those when the Economic Spacing is Used.

Diameter Limits	Hauling Cost if Average Haul is 590 feet *	Wagon Haul Cost per 100 feet	Economic Spur Spacing (feet)	Total Wagon Haul Cost on Economic Spur Spacing
7	$ 1.03	$ 0.0762	2,360	$ 1.03
8	1.03	0.0762	2,365	1.03
9	1.01	0.0729	2,455	1.03
10	1.00	0.0712	2,520	1.03
11	0.98	0.0678	2,650	1.03
12	0.96	0.0644	2,820	1.03
13	0.95	0.0627	2,960	1.04
14	0.93	0.0594	3,220	1.06
15	0.92	0.0576	3,530	1.09
16	0.91	0.0560	3,880	1.12
17	0.90	0.0542	4,370	1.17
18	0.89	0.0525	4,950	1.23
19	0.88	0.0509	6,070	1.35
20	0.87	0.0491	7,080	1.45
21	0.86	0.0475	8,085	1.54
22	0.86	0.0475		
23	0.85			
24	0.86			
25	0.84			
26	0.83			
27	0.84			
28	0.85			
29	0.86			

* Computed from wagon haul costs,
D. M. Matthews, "Management", Page 316, Schedule A, line 3.

TABLE III. - Average Wagon Haul Costs per M

if Stand is Cut to Various Diameter Limits.

1	2	3	4	5	6	7	8
D.B.H. Limits	Hauling Cost per 100' per M	Economic Spacing (feet)	Average Wagon Haul Cost per M	Fixed Charges (Loading) (Unloading) (Delays)	Total Cost per M	Volume cut per Acre	Per cent of Total Volume
7	$ 0.0762	2,360	$ 0.45	$ 0.58	$ 1.03	14.40	100.00
8	0.0762	2,365	0.45	0.58	1.03	14.30	99.30
9	0.0729	2,455	0.45	0.58	1.03	13.90	96.60
10	0.0712	2,520	0.45	0.58	1.03	13.50	93.70
11	0.0678	2,650	0.45	0.58	1.03	12.87	89.35
12	0.0644	2,820	0.45	0.58	1.03	12.15	84.45
13	0.0627	2,960	0.46	0.58	1.04	11.15	77.45
14	0.0594	3,220	0.48	0.58	1.06	9.94	69.05
15	0.0576	3,530	0.51	0.58	1.09	8.52	59.25
16	0.0560	3,880	0.54	0.58	1.12	7.25	50.45
17	0.0542	4,370	0.59	0.58	1.17	5.92	41.15
18	0.0525	4,950	0.65	0.58	1.23	4.75	33.00
19	0.0509	6,070	0.77	0.58	1.35	3.26	22.60
20	0.0491	7,080	0.87	0.58	1.45	2.48	17.20
21	0.0475	8,085	0.96	0.58	1.54	1.97	13.70

The economic spur spacing at various diameter limits has been computed and is shown in column 3 of the above table. The figures for the volume cut per acre (column 7) are given in M feet, B. M.

The data as computed has been put into a combined schedule, A and B, which follows.

(Part 1)

COMBINED SCHEDULE, A AND B,
showing Production Costs and Computed Surplus,
Margin, Stumpage Value per M feet
and Stumpage Revenues per Acre at Various Diameter Limits.

	Diameter Breast High, in inches											
	7	8	9	10	11	12	13	14	15	16	17	18
Sawing (Felling and bucking)	$2.10	$1.85	$1.66	$1.47	$1.32	$1.17	$1.02	$0.89	$0.81	$0.76	$0.71	$0.66
Bunching	1.62	1.50	1.36	1.20	1.05	0.86	0.68	0.55	0.48	0.42	0.35	0.31
Railroad Operation (Including loading, unloading and supplies)	2.43	2.24	2.02	1.81	1.59	1.41	1.24	1.12	1.04	0.96	0.90	0.85
Supplies (Camp and logging)	2.22	2.03	1.84	1.65	1.47	1.29	1.13	1.01	0.93	0.87	0.81	0.76
General Expense (Supervision, scaling)	3.90	3.57	3.23	2.90	2.58	2.27	1.98	1.77	1.63	1.53	1.41	1.35
Railroad Maintenance	0.78	0.74	0.70	0.64	0.59	0.56	0.53	0.50	0.47	0.44	0.42	0.40
Freight (Camp to Mill)	1.64	1.55	1.42	1.31	1.20	1.11	1.02	0.98	0.95	0.91	0.89	0.88
Sawmill Operation	8.64	8.14	7.62	7.07	6.55	6.13	5.73	5.38	5.05	4.76	4.52	4.29
General Expense (Main office, insurance and taxes on plant, and discounts and allowances)	2.99	3.01	2.87	2.69	2.52	2.41	2.29	2.19	2.09	1.99	1.91	1.84
Taxes and Insurance on Lumber and Selling Expenses	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
Total Cost per M - for various diameters	27.83	26.14	24.23	22.25	20.38	18.72	17.13	15.90	14.96	14.15	13.43	12.85
Percentage of Total Volume per diameter class	0.70	2.70	2.90	4.35	4.90	7.00	8.40	9.80	8.80	9.30	8.15	10.40
Cost of Producing Lumber from each diameter class of stand per M bd. ft.	0.19	0.71	0.71	0.97	0.98	1.31	1.44	1.56	1.32	1.32	1.09	1.34
Cost per M to various limits exclusive of wagon haul	15.59	15.49	15.19	14.91	14.55	14.22	13.92	13.41	12.98	12.66	12.32	12.05
Wagon Haul Costs to various limits	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.06	1.09	1.12	1.17	1.23
Total Cost to various diameter limits	16.62	16.52	16.22	15.94	15.58	15.25	14.96	14.47	14.27	13.78	13.49	13.28
Value per M - (Schedule B)	26.19	26.25	26.42	26.57	26.78	27.00	27.23	27.50	27.88	28.22	28.58	29.02
Surplus per M	9.57	9.73	10.20	10.63	11.20	11.75	12.27	13.03	13.81	14.44	15.09	15.74
Margin Required	4.40	4.43	4.54	4.66	4.87	5.13	5.56	6.20	7.18	8.38	10.19	12.61
Stumpage Value per M	5.17	5.30	5.66	5.97	6.33	6.62	6.71	6.83	6.63	6.06	4.90	3.13
Stumpage Revenue per acre	74.70	76.00	78.90	80.80	81.66	80.75	74.80	68.20	56.80	44.10	29.10	14.92

(Part 2)

COMBINED SCHEDULE, A AND B,
showing Production Costs and Computed Surplus,
Margin, Stumpage Value per M feet
and Stumpage Revenues per Acre at Various Diameter Limits.

	Diameter Breast High, in inches										
	19	20	21	22	23	24	25	26	27	28	29
Sawing (Felling and bucking)	$0.62	$0.60	$0.58	$0.56	$0.55	$0.55	$0.54	$0.55	$0.55	$0.56	$0.58
Bunching	0.27	0.26	0.24	0.22	0.19	0.19	0.17	0.13	0.13	0.13	0.13
Railroad Operation (Including loading, unloading and supplies)	0.81	0.78	0.75	0.73	0.71	0.72	0.71	0.68	0.67	0.67	0.67
Supplies (Camp and logging)	0.73	0.70	0.69	0.67	0.65	0.65	0.64	0.62	0.62	0.62	0.64
General Expense (Supervision, scaling)	1.28	1.24	1.21	1.17	1.14	1.14	1.11	1.08	1.08	1.09	1.12
Railroad Maintenance	0.38	0.37	0.35	0.35	0.34	0.33	0.33	0.32	0.32	0.32	0.31
Freight (Camp to Mill)	0.86	0.86	0.86	0.84	0.84	0.86	0.86	0.86	0.86	0.86	0.86
Sawmill Operation	4.14	4.01	3.89	3.80	3.72	3.66	3.61	3.58	3.55	3.55	3.50
General Expense (Main office, insurance and taxes on plant, and discounts and allowances)	1.80	1.75	1.73	1.70	1.68	1.66	1.64	1.64	1.65	1.64	1.64
Taxes and Insurance on Lumber and Selling Expenses	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
Total Cost per M - for various diameters	12.40	12.08	11.81	11.55	11.33	11.27	11.12	10.97	10.94	10.95	10.96
Percentage of Total Volume per diameter class	5.40	3.50	3.00	2.60	1.20	1.80	1.50	1.10	1.20	0.60	0.70
Cost of Producing Lumber from each diameter class of stand per M bd. ft.	0.67	0.42	0.35	0.30	0.14	0.20	0.17	0.12	0.13	0.07	0.08
Cost per M to various limits exclusive of wagon haul	11.66	11.45	11.34	-	-	-	-	-	-	-	-
Wagon Haul Costs to various limits	1.35	1.45	1.54	-	-	-	-	-	-	-	-
Total Cost to various diameter limits	13.01	12.90	12.88	-	-	-	-	-	-	-	-
Value per M - (Schedule B)	29.85	30.45	30.88	-	-	-	-	-	-	-	-
Surplus per M	16.84	17.55	18.00	-	-	-	-	-	-	-	-
Margin Required	18.26	23.81	-	-	-	-	-	-	-	-	-
Stumpage Value per M	-	-	-	-	-	-	-	-	-	-	-
Stumpage Revenue per acre	-	-	-	-	-	-	-	-	-	-	-

The stumpage revenues per acre as computed in the combined schedule were found to be identical with those as shown by Matthews[1] for the diameter limits, 7 to 11 inches.* For limits above 11 inches, stumpage revenues per acre rise.

This seems to indicate that the spacing formula would be found of greatest use in the planning of selective cutting. Brown[2] makes the statement that experienced loggers can readily determine the extent to which spur tracks on a logging railroad must be built to obviate the necessity of disproportionately long-distance power or tractor skidding hauls. However, most loggers are not experienced in selective cutting and therefore, their judgment cannot be totally relied upon to fix spur spacings.

As indicated by the schedule, the most satisfactory financial diameter limit is one of 11 inches. The revenue per acre obtainable at that limit may be taken as the basis for valuation under a 20-year liquidating plan. With such a plan, 2,000 acres would be cut annually. Total annual revenue would be 2,000 x $81.66 or $163,320. If we use 6 per cent interest in our calculations, the present worth of the property before taxes will be

$$P.\ W. = \frac{\$163{,}320(1.06^{20} - 1)}{0.06 \times 1.06^{20}}\ \text{, or } \$1{,}873{,}000$$

Sustained Yield Operation

Investigations into the possibilities of sustained yield on a 60-year rotation and 20-year cutting cycle have shown that by cutting to a 16" diameter limit an annual cut of 15,000 M can be obtained during the first cycle and 15,600 M during the second and subsequent cycles.

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* Probably due to the fact that cost values were rounded off to the nearest cent.

1 D. M. Matthews, "Management of American Forests"; McGraw-Hill Book Co. Page 321.

2 N. C. Brown, "Logging Transportation." John Wiley & Sons, Inc., New York, 1936.

Annual income during the first cycle -

15,000 M x $6.06, or $91,000.

Income during the second cycle -

3,550 feet, B. M., or 45.5% will come from timber averaging 15.6" in diameter and having a value of $26.18 per M. The balance of the cut, 4,250 feet, B. M., will come from timber averaging 18.1" in diameter, having a value of $27.27 per M.

Average value of lumber produced -

45.5% at $26.18 per M -	$ 11.92
54.5% at $27.27 per M -	14.88
Average value per M -	$ 26.80

Direct Costs:

45.5% at $15.58 per M -	$ 7.09
54.5% at $14.08 per M -	7.68
Total direct costs per M -	$ 14.77

Indirect Costs:

Cut per acre, 54% of stand to 7" limit

Margin - $\frac{\$3.95}{54\%}$ =	$7.31	
Spurs -	.54	7.85

Total Direct and Indirect Costs - $22.62 per M

Net value of stumpage - $4.18 per M

Annual income from stumpage:

15,600 M x $4.18 = $65,208

Capital value, exclusive of taxes:

P. W. of incomes during first cycle - $\frac{\$91,000(1.06^{20}-1)}{0.06 \times 1.06^{20}}$ = $1,042,000

P. W. of incomes during subsequent cycles - $\frac{\$65,208}{0.06 \times 1.06^{20}}$ = 338,600

Total present worth before taxes - $1,380,600

By increasing the spacing of spurs from 2,360 feet to 3,880 feet, the total wagon haul cost to a 16" limit was increased from $0.91 per M to $1.12 per M, but due to lower depreciation and investment charges in railroad construction the capital value increased from $1,354,800 to $1,380,600 or $25,800.

When compared to the capital value under the 20-year liquidation plan, $1,873,000, the sustained yield plan is most unfavorable. This is due to the lack of balance between the productive capacity and the annual production under sustained yield.

If the investment in plant and equipment is brought into balance with an annual cut of 15,000 M, as shown by Matthews[1], we can show the value of sustained yield in its true light.

The fixed investment and depreciation exclusive of spurs is as follows:

Total average annual depreciation -		$ 19,720
Total fixed investment -	$ 256,760	
Working Capital:		
Total direct costs at $16 turned 4 times: $\frac{\$16}{4}$ x 15,000 M -	60,000	
Total profit-bearing investment -		$316,760
Stumpage Revenue, first cycle:		
Value of lumber to 16" limit -		$ 28.22 per M
Direct costs to 16" limit	$ 13.78 per M	
Indirect Costs:		
Depreciation - $\frac{\$19,720}{15,000\ M}$ =	1.31	
Margin - $\frac{\$316,760 \times 15\%}{15,000\ M}$ =	3.17	
Spurs -	.54	
Total Costs		18.80 per M
Net stumpage value before taxes		$ 9.42 per M

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1 D. M. Matthews, "Management of American Forests." McGraw-Hill Book Co. p. 359.

Stumpage value, second cycle:

Value of lumber produced - $ 26.80 per M

Direct costs: (As previously calculated) - $ 14.77

Indirect Costs:

Depreciation - $\frac{\$19,720}{15,600 \text{ M}}$ = 1.26

Margin - $\frac{\$316,760 \times 15\%}{15,600 \text{ M}}$ = 3.05

Spurs - .52

Total Costs - 19.80 per M

Net stumpage value before taxes - $ 7.00 per M

Net Annual Stumpage Incomes:

First cycle - \$9.42 x 15,000 M = $ 141,300

Second and subsequent cycles - \$7.00 x 15,600 M = $ 109,200

Present capital value of these incomes at 6%:

First cycle - $\frac{\$141,300(1.06^{20}-1)}{0.06 \times 1.06^{20}}$ = $ 1,620,000

Second and subsequent cycles - $\frac{\$109,200}{0.06 \times 1.06^{20}}$ = 567,500

Total Capital Value - $ 2,187,500

Capital value when spurs were spaced

2,360 feet - 2,130,900

Increase in capital value due to economic

spacing of spurs - $ 56,600

TABLE IV. - Decrease in Surplus Available for Margin and Depreciation due to Increased Wagon Haul Cost.

Diameter Limits	Surplus per M, Schedule B *	Surplus per M, after economic spacing	Net Decrease per M
7	$ 9.57	$ 9.57	$ 0.00
8	9.73	9.73	0.00
9	10.22	10.20	0.02
10	10.66	10.63	0.03
11	11.25	11.20	0.05
12	11.82	11.75	0.07
13	12.36	12.27	0.09
14	13.16	13.03	0.13
15	13.98	13.81	0.17
16	14.65	14.44	0.21
17	15.36	15.09	0.27
18	16.08	15.74	0.34
19	17.31	16.84	0.48

* D. M. Matthews, "Management of American Forests;" McGraw-Hill Book Co. Page 321.

TABLE V. - Decrease in Margin Required due to Economic Spacing of Railroad Spurs.

Diameter Limits	Margin Required per M Schedule B*	Margin Required per M, after Economic Spacing	Net Decrease per M
7	$ 4.40	$ 4.40	$ 0.00
8	4.43	4.43	0.00
9	4.56	4.54	0.02
10	4.69	4.66	0.03
11	4.92	4.87	0.05
12	5.21	5.13	0.08
13	5.68	5.56	0.12
14	6.37	6.20	0.17
15	7.43	7.18	0.25
16	8.72	8.38	0.34
17	10.70	10.19	0.51
18	13.33	12.61	0.72
19	19.48	18.26	1.22

* D. M. Matthews, "Management of American Forests;" McGraw-Hill Book Co. Page 321.

TABLE VI. - Increase in Stumpage Values per M after Economic Spacing of Railroad Spurs.

Diameter Limits	Stumpage Values on Fixed Spacing	Stumpage Values on Economic Spacing	Increase in Stumpage Value per M
7	$ 5.17	$ 5.17	$ 0.00
8	5.30	5.30	0.00
9	5.66	5.66	0.00
10	5.97	5.97	0.00
11	6.33	6.33	0.00
12	6.61	6.62	0.01
13	6.68	6.71	0.03
14	6.79	6.83	0.04
15	6.55	6.63	0.08
16	5.93	6.06	0.13
17	4.66	4.90	0.24
18	2.75	3.13	0.38

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