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Economic analysis of a mechanized pulpwood operation. 1947.

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ECONOMIC ANALYSIS
of a
MECHANIZED
PULPWOOD OPERATION

Submitted by David L. Buell in partial fulfillment of
requirements for Master of Forestry degree.

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Until a few years ago the logging industry has always depended upon the "strong arm" method of cutting pulpwood. That is, the pulpwood loggers have depended mostly on a few strong backs, with practically no machines or methods which avaided or eliminated any of the "bull-work" in pulpwood.

However, during the past world war, various pulpwood producing companies have found that they could not find enough strong backs to produce the amount of pulpwood for which the industry had a demand. Thus they have been forced to look for methods machinery to replace the pulp cutters, or at least to make their work easier so that logging could attract more workers. To this end, various tools have been perfected that have eased the situation considerably. These tools, such as the power chain saws, power loaders, tractors, and the re-adapted jammers, have all helped to facilitate and speed up production. New methods in the paper mills have aided the lumberjacks, too. The old drum-barking methods have been partially replaced by the new hydraulic barkers. These new barkers eliminate a lot of the waste of the drum-barkers, and therefore make it more advisable to eliminate the sap-peeling methods in the bush.

The problem of these new methods is the extent to which the mechanization can be carried, and what financial benefits will be gained by specific equipment. The economics of mechanizing the logging industry is not the only consideration the pulpwood operators come up against, as they must also consider the effects of mechanization on the workers. Though this problem is difficult, it can be solved. However, this paper is not a consideration of the lumberjack's ideas as to the "new-fangled gadgets" coming into the woods, but a consideration of the economics of a machine which has been put into use recently, and a comparison of two types of pulpwood operation with emphasis on the costs and advantages of each. The two operations are: (1) a standard hand operation; and (2) the aforementioned machine operation. Both analyses are based on data collected from operations of the Patten Logging Company in Baraga County, Michigan.

The property under discussion is part of section 24, Town 47 North, Range 32 West, Baraga County. Of this section, I have taken one hundred acres of highland log timber as a representative section. Though this may seem a little incongruous for a treatise on pulpwood, not saw-log operations, The mechanization process under discussion was set up primarily to take care of big, scattered pulpwood which forms a considerable part of the Patton Company's holdings. The highland type on section 24 contains a large amount of big, scattered spruce and balsam.

This section, adjacent to the Patten Logging Company's railroad is about fifteen miles from Amasa, Michigan, where the company has its headquarters. From Amasa, the pulpwood is shipped to Northern Paper Mills, Green Bay, Wisconsin, about 150 miles distant, via the Chicago, Milwaukee, St. Paul and Pacific Railroad. The Patten Logging Company railroad is of standard guage, so there is no necessity for re-loading cars.

The land is level to rolling, with low hills scattered throughout. The soil is typical of the area, sandy loam mixed with a lot of glacial rock.

The stand on the area is composed mainly of yellow birch, sugar maple, spruce and balsam, with a few other varieties (elm, basswood, white pine, etc.,) scattered throughout. As we are not concerned with the log timber on the area, it will suffice to say that the stand averages about six thousand board feet per acre. The volumes of the spruce and balsam are given in Table I.

The Patten Logging Company, although it owns its own lands, figures stumpage values at $2.50 per cord for spruce, and $1.00 per cord for balsam. This charge for stumpage is charged only on the amount of wood cut. The sales values for these two species are $16.50 for spruce and $14.50 for balsam. These prices are for rough wood not peeled. To these prices, a sales commission is added, as the Patten Logging Company gets a commission for each cord of pulpwood purchased or produced and sold to the Northern Paper Mills. This sales commission need not necessarily be added to the sales price, but in this case it is paid on every cord of wood produced, so is included in the sales values.

The following detailed volume table was prepared from data supplied by Bruce G. Buell, forester for the Northern Paper Mills and the Patton Logging Company. As his volume tables were based on total height rather than merchantable height, I had to refer back to the data from which he drew his volume tables. This data was collected by him in western Ontario, but has been found to apply closely to the same species in Michigan. (See Table II.)

In these volume tables the following explanation will aid in showing calculations.

Columns 2, 3, and 4..................Based on B. G. Buell's volume tables.

Column 5 ....Based on curves drawn from data collected by B. G. Buell.

Column 6 ....Column 5 divided by 8 feet.

Column 7 ....Column 3 divided by column 6.

Column 8 ....Column 7 divided by 8 feet.

Column 9 ....Read from Basal Area tables and column 8.

Column 10 ....Computed from formula No. = $\left(\frac{45}{d}\right)^2$ when d is between 4 and 8"; and No. = $\left(\frac{46}{d}\right)^2$ when d is between 8 and 12"; and No. = $\left(\frac{47.3}{d}\right)^2$ when d is 12" and up. d is read from column 9.

Column 11.............................. Column 10 is divided by column 6. This shows comparison between B. G. Buell's figures and mine. Variations may be due to differences in curves of merchantable height and D.B.H.

Column 12.............................. Reciprocal of Column 11.

TABLE -

PULPWOOD VOLUME

Section 24, Township 47 North, Range 38 West, Baraga County, Michigan

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
DBH	SPRUCE				BALSAM				TOTALS			
	No. of Trees per 100 Acres	Volume (in Cords)			No. of Trees per 100 Acres	Volume (in Cords)			Volume (in Cords)		Percent of Total Volume D. and up.	
		Per Tree	Per class	D. and up.		Per Tree	Per class	D. and up	Per Class	D. and up	Spruce	Balsam
6	145	.0425	6.16	247.16	1873	.0333	62.40	354.50	68.56	601.66	41.1	58.9
8	173	.0832	14.40	241.00	1001	.075	75.10	292.10	89.50	533.10	45.2	54.8
10	189	.139	26.30	266.60	879	.128	112.50	217.00	138.80	433.60	51.0	49.0
12	144	.232	33.40	200.30	285	.189	53.40	104.50	86.80	304.80	65.7	34.3
14	115	.352	40.40	166.90	135	.278	37.50	51.10	77.90	218.00	76.5	23.5
16	77	.500	38.50	126.50	36	.378	13.60	13.60	52.10	140.10	90.4	9.6
18	64	.666	42.70	88.00					42.70	88.00	100.00	--
20	53	.855	45.30	45.30					45.30	45.30	100.00	--

Columns 3 and 7 from Table II

Column 10 is sum of columns 4 & 8

Column 12 equals $\frac{\text{column 5}}{\text{column 11}}$

Column 13 equals $\frac{\text{column 9}}{\text{column 11}}$

TABLE IIa

VOLUME TABLE

for Spruce

1 D. B. H.	2 Total Height (feet)	3 Volume per Tree (Cu. ft.)	4 No. of Trees per Cd.	5 Merch. Height (feet)	6 No. of Bolts per tree	7 Vol. of Av. Bolt (Cu. ft.)	8 Form Basal Area (Sq. ft.)	9 Middle Diam. of Av. Bolt (inches)	10 No. of Bolts per Cd.	11 No. of Trees per Cd.	12 Volume per tree (cords)
5	42	2.2	39	16	2	1.10	0.137	5.0	81	40.5	.0256
6	48.5	3.6	23.5	21	2.6	1.38	0.172	5.6	64.5	24.8	.0425
7	53	5.5	16.5	27	3.4	1.62	0.202	6.1	54.3	16.0	.0606
8	57	7.6	12	32	4.0	1.90	0.237	6.6	46.5	11.6	.0832
9	60.5	9.7	9	37	4.6	2.11	0.274	7.1	40.1	8.7	.111
10	63.1	12.5	7.2	42	5.25	2.38	0.298	7.4	37	7.05	.139
11	65.6	16.3	5.5	46.5	5.8	2.81	0.351	8.0	31.6	5.45	.182
12	67.8	20.9	4.3	52.5	6.6	3.17	0.396	8.5	29.3	4.45	.232
13	69.9	25.8	3.5	54	6.75	3.82	0.477	9.35	24.2	3.58	.286
14	71.8	31.7	2.84	57	7.25	4.37	0.546	10.0	21.2	2.92	.352
15	73.5	38.1	2.36	60	7.5	5.08	0.635	10.8	18.8	2.50	.424
16	75	45.0	2.00	62	7.75	5.80	0.725	11.5	16	2.06	.500
17	76.2	52.0	1.73	64	8.0	6.50	0.812	12.2	15	1.87	.578
18	77.4	60	1.50	65.5	8.2	7.31	0.914	12.9	13.4	1.63	.666
19	78.3	68	1.32	66.5	8.3	8.20	1.025	13.7	11.9	1.42	.756
20	79	77	1.17	67	8.4	9.16	1.147	14.5	10.6	1.25	.855

VOLUME TABLE

for Balsam

1	2	3	4	5	6	7	8	9	10	11	12
D. B. H.	Total Height (feet)	Volume per tree (cu.ft.)	No. of Trees per cord	Merch. Height. (feet)	No. of Bolts per Tree	Volume of Av. Bolt (cu.ft.)	Form Basal Area (sq.ft.)	Middle Diameter of Av. Bolt (inches)	No. of Bolts per cord	No. of Trees per cord	Volume per Tree (cords)
5	31	1.5	57.0	15.0	1.9	0.79	.099	4.3	105	55.3	.0181
6	39	2.9	30.0	20.5	2.6	1.12	.140	5.1	78	30	.0333
7	46	4.5	20.0	25.5	3.2	1.41	.176	5.7	62	19.4	.055
8	50	6.6	13.50	30.8	3.85	1.71	.214	6.3	51	13.3	.0751
9	54	8.7	10.20	35.5	4.4	1.98	.248	6.7	45	10.2	.098
10	57	11.3	7.96	40.0	5.0	2.26	.282	7.2	39	7.80	.128
11	60	14.0	6.43	44.0	5.5	2.54	.318	7.6	35	6.36	.157
12	62	17.3	5.20	47.2	5.9	2.92	.365	8.2	31.5	5.30	.189
13	64	21.4	4.20	50.6	6.3	3.40	.425	8.8	27.3	4.30	.233
14	66	25.7	3.50	53.2	6.65	3.86	.483	9.4	24	3.60	.278
15	67.5	30.2	2.98	55.7	7.0	4.31	.539	9.9	21.6	3.08	.325
16	69	35.1	2.56	58.0	7.25	4.85	.606	10.5	19.2	2.65	.378
17	70	40.5	2.22	60.7	7.6	5.33	.665	11.0	17.4	2.48	.403

The actual logging operation is usually run by a jobber or contractor who buys the stumpage from the company, does the cutting, hauling and loading. The jobbers generally do not own the heavy equipment, but rent it from the company. However, in this problem, I have assumed that the company owns and operates the camp and equipment.

The principles applied in this problem would not differ if applied to a jobbers' operation, rather than a company operation, though such things as cost of railroad, railroad hauling and protection would not be taken into account.

STANDARD HAND OPERATION

The cutting is done by men who cut"by the piece." That is, they cut the bolts and pile them along a strip road which they cut out as a part of their job. They are paid on a basis of nine cents per stick with doubles at eight inches and triples at twelve inches. That is, any stick eight inches on the top end is paid for at the rate of 18 ¢ and those twelve inches and up are paid at the rate of 27¢. An average pulp cutter will cut from 80 to 100 sticks of pulp per day.

From the strip roads, the pulpwood is loaded by a two man crew onto drays. These men are paid at the rate of 2¢ per stick with the same double and triple arrangement as in cutting. These crews use a team and haul the drays out to the main road and hook them up into a train for the tractor to haul to the landing. The cost per cord for loading is shown in Table III.

From this pay basis and the foregoing volume tables, we can now state the cost to the company to have this wood cut andd loaded.

In Table III, the first four columns are taken directly from the foregoing volume tables. The cost to cut is simply the rate times the number of sticks per cord, or per class, as the case may be. The rate is based on "d", or the middle diameter of the average bolt. This is not absolutely accurate as some of the butt sticks below the 12 inch D. B. H. class will be doubles, but the number of sticks so misplaced will be small and in all probability counteracted by the number of top sticks which will not be doubles in the 12 inch class and up. The same applies to the loading rate. The costs "D and up" are simply the total cost per class from that diameter class and up. That is, the cost "D and up" for the 10 inch class is the cost of the 10, 12, 14, 16, 18, and 20 inch classes; the cost "D and up" for the 14 inch class is the cost of the 14, 16, 18, and 20 inch classes, etc. The total cost per class is the sum of the cutting cost per cord and the loading cost per cord .

TABLE III

STANDARD OPERATION CLASS "A" COSTS

S P R U C E

Line	Diam. Breast High	6	8	10	12	14	16	18	20	
(1)	Volume D and Up	247.16	241.00	266.60	200.30	166.90	126.50	88.00	45.30	(from
(2)	Bolts per cord	64.5	46.5	37	29.3	21.2	16	13.4	10.6	(Tables
(3)	Bolts per class	397	669	973	978	857	616	572	480	(I and
(4)	Middle diam.av.bolt	5.6	6.6	7.4	8.5	10.0	11.5	12.9	14.5	(II
	Cost of Cutting (dollars)									
(5)	per stick	.09	.09	.09	.18	.18	.18	.27	.27	
(6)	per cord(line 2 x line 5)	5.80	4.18	3.33	5.27	3.82	2.88	3.62	2.86	
(7)	per class (lines 3 x 5)	35.75	60.10	87.50	176.00	154.20	111.10	154.50	129.60	
(8)	D and Up	908.75	873.00	812.90	725.40	549.40	395.20	284.10	129.60	
	Cost to load in bush (dollars)									
(9)	per stick	.02	.02	.02	.04	.04	.04	.06	.06	
(10)	per cord (lines 2 x 9)	1.29	0.930	0.740	1.172	0.848	0.640	0.804	0.626	
(11)	per class(lines 3 x 9)	7.94	13.38	19.46	39.12	34.28	24.64	34.32	28.80	
(12)	D and Up	201.94	194.00	180.62	161.16	122.04	87.76	63.12	28.80	
	Total Class "A" costs per cd.(dollars, lines 6 plus 10)	7.09	5.11	4.07	6.442	4.668	3.52	4.424	3.486	

B A L S A M

Line	Diam. Breast High	6	8	10	12	14	16	18	20
(1)	Volume D and Up	354.10	292.10	217.00	104.50	51.10	13.60	(from	
(2)	Bolts per cord	78	51	39	31.5	24	19.2	(Tables	
(3)	Bolts per class	4860	3830	4390	1680	900	261	(I and	
(4)	Middle diam.av.bolt	5.1	6.3	7.2	8.2	9.4	10.5	(II	
	Cost of Cutting (dollers)								
(5)	per stick	.09	.09	.09	.18	.18	.18		
(6)	per cord (lines 2 x 5)	7.02	4.59	3.51	5.67	4.32	3.46		
(7)	per class (lines 3 x 5)	438.00	345.00	395.00	302.00	162.00	47.00		
(8)	D and Up	1689	1251	906	511	209	47		
	Cost to load (dollars)								
(9)	per stick	.02	.02	.02	.04	.04	.04		
(10)	per cord (line 2 x 9)	1.56	1.02	0.78	1.26	0.96	0.768		
(11)	per class (line 3 x 9)	97.20	76.60	87.80	33.60	18.00	5.22		
(12)	D and Up	318.42	221.22	144.62	56.82	23.22	5.22		
(13)	Total Class "A" costs per cord (dollars, Line 6 plus Line 10	8.58	5.61	4.29	6.93	5.28	4.228		

These costs are the variable costs per cord. The cutting and loading costs vary with the size of the trees cut. This variation is rather obvious in that a large tree contains more volume than a small tree. Therefore; if a large bolt is cut for the same price as a small bolt, the cord of large blocks costs less, per cord, than a cord of small blocks. However, since the company pays for doubles and triples, this cost does not decrease in a regular curve, but in a series of increases and decreases.

There are other types of costs which are to be considered. Two other types will be considered in this case. These are the constant costs per cord, and the fixed costs per acre. The constant costs per cord are such things as hauling, loading on railroad cars, and in this case, stumpage. Stumpage can be classified as constant per cord only if stumpage charges are placed on each cord as it is cut. If the stumpage charges w ere charged on the cruised volume per acre, then it would be placed in the fixed per acre category.

In this case, the constant costs per cord are:

Tractor haul......................	$1.00	per cord.
Loading onto railroad cars........	.65	" "
Railroad haul.....................	1.00	" "
Overhead and margin for profit....	2.00	" "
Total constant costs..............	$4.65	per cord.

Stumpage: for spruce, $2.50 per cord, or a total of $7.15 constant cost per cord.
for balsam, 1.00 per cord, or a total of 5.65 constant cost per cord.

As for the fixed costs per acre in this case it is rather difficult to determine them, as they are also chargeable to the hardwood volume in the area. However, the following breakdown is what B. G. Buell considers an average on the Patten Logging Company operations:

Haul roads..................................	$2.00	per acre.
Camps......................................	1.00	" "
Railroad...................................	1.75	" "
Protection, taxes, cruise costs, etc........	.25	" "
Total fixed cost....................	$5.00	" "

On the haul a tractor is used as the motivating power. The tractors are used on roads generally spaced about twice through a forty, or about 660 feet apart. These roads are spaced thus mainly for the saw-log volume on the area, rather than the pulpwood, so I have disregarded the economic spacing of these roads.

From the above data concerning the variable costs and constant costs per cord, we can now make the following value calculations when cutting the entire stand of 6" and up.

	Spruce	Balsam
Sale Values	$17.50	$15.50
Class "A" or		
Variable costs per cord		
Cutting costs:		
Cost D and up $908.75 / Vol. D and up 247.16 cds	$3.68	$1689.00 / 354.50 cds ... $ 4.76
Loading costs:		
Cost D and up $201.94 / Vol. D and up 247.16 cds	$0.82	$318.42 / 354.50 cds ... $ 0.90
Balance after deducting Class "A" costs	$13.00	$ 9.84
Class "B" costs or		
Constant costs per cord:		
Tractor haul ... $1.00		
Loading on R.R.cars .65		
Railroad haul ... 1.00		
Overhead and margin 2.00	$ 4.65	$ 4.65
Balance	$8.35	$6.19
Stumpage	2.50	1.00
Balance	$5.85	$ 4.19
Class "C" or		
Fixed per acre costs:	$5.00 X .411 / 2.47 cds.per acre .83	$5.00 X .589 / 3.54 cds. ... $ 0.83
Total Net Balance	$ 5.02	$ 3.36

This method of analysis does not show whether there are any "zero margin" trees in the stand. To do this, we have to find the maximum amount that can be spent on the variable costs per cord. In doing this, the class "C" costs can be eliminated as these are fixed per acre costs and not really directly chargeable to the cordage cut. Therefore, by deducting Class "B" costs and stumpage, we may find the maximum amount which can be spent on Class "A" costs.

Sale values		Spruce		Balsam
		$17.50		$15.50
Class "B" costs,	$ 4.65		$ 4.65	
Stumpage	2.50	7.15	1.00	5.65
Balance for Class "A" costs		$10.35		$9.85

From the variable cost Table (III) we may now determine what diameter limit is the most practical. As the total cost per cord class at the six inch D.B.H. class is $7.09 per cord for spruce and $8.58 per cord for balsam, it is obvious that the maximum return per acre will be obtained by cutting down through the six inch class.

By so cutting we will obtain a return per acre of

2.47 cords spruce @ $5.02 per cord............$12.40

3.54 cords balsam @ $3.36 per cord............ 11.90

$ 24.30

If we only cut to a diameter limit of eight inches, the return per acre will be as follows:

		Spruce		Balsam
Sales values		$17.50		$15.50
Class "A" costs:				
Cutting	$873.00 / 241 cds.	$3.62	$1251 / 292.1 cds	$4.28
Loading	$194.00 / 241 cds	.80	$221.22 / 292.1 cds	.76

	Spruce			Balsam	
		$17.50			$15.50
Class "B" costs	$4.65			$4.65	
Stumpage	2.50			1.00	
Class "C" costs					
$5.00 X .452 / 2.41 cds	.94	$12.51	$5.00 X .548 / 2.92 cds	.94	11.63
Total Net Balance per cord		$ 4.99			$ 3.87

2.41 cords spruce @ $4.99 per cord..............$12.05

2.92 cords balsam @ $3.87 per cord.............. 11.30

Total net returns per acre..............................$23.35

The difference in total return on the area of 100 acres is,

$24.30 less $23.35 equals $0.95 X 100 acres equals $95.00

The actual value per tree is shown in the following tables (IV). These tables are useful in showing the comparison between pulpwood values and other utilizations such as saw logs or chemical wood. It is also useful in showing the increase in value per tree as it grows from one diameter class to another, when the operation is carried on in the same manner.

TABLE IVa

STANDARD OPERATION TREE VALUES

S P R U C E

Diameter Breast High	6	8	10	12	14	16	18	20
(1) Surplus after Class "B" costs per cord.	12.85	12.85	12.85	12.85	12.85	12.85	12.85	12.85
(2) Class "A" costs per cord (cutting & loading) (from Table 111a)	7.09	5.11	4.07	6.44	4.67	3.52	4.42	3.49
(3) Balance for Class "C" costs and stumpage. (line 1 - Line 2)	5.76	7.74	8.78	6.41	8.18	9.33	8.43	9.36
(4) Volume per tree in cords. (Table IIa)	.0425	.0832	.139	.232	.352	.500	.666	.855
(5) Net value per tree in cents	24.5	63.4	122.0	149.0	288.0	466.0	561.0	800.0
(6) Increase in value per tree in cents for each dollar of increase in stumpage per cord. (Line 4 x 1.00)	4.25	8.32	13.9	23.2	35.2	50.0	66.6	85.5
(7) Net value per tree in cents when balance for stumpage is $1.00 per cord at 6" d.b.h. (sum lines 5 and 6)	28.75	71.72	135.9	172.2	323.2	516.0	627.6	885.5

TABLE IVb

STANDARD OPERATION TREE VALUES

B A L S A M

Diameter Breast High	6	8	10	12	14	16
(1) Surplus after Class "B" costs per cord.	10.85	10.85	10.85	10.85	10.85	10.85
(2) Class "A" costs per cord. (cutting and loading) (From Table IIIb)	8.58	5.61	4.29	6.93	5.28	4.23
(3) Balance for Class "C" costs and stumpage (Line 1 - Line 2)	2.27	5.24	6.56	3.92	5.57	6.62
(4) Volume per tree in cords. (Table IIb.	.0333	.075	.128	.189	.278	.378
(5) Net value per tree in cents. (line 3 x line 4)	7.56	39.3	84.0	74.1	149.0	250.0
(6) Increase in value per tree in cents for each doller of increase in stumpage per cord. (Line 4 x $1.00)	3.33	7.5	12.8	18.9	27.8	37.8
(7) Net value per tree in cents when balance for stumpage is $1.00 per cord at 6" d.b.h. (Sum lines 5 and 6)	10.89	46.8	96.8	93.0	176.8	287.8

MACHINE OPERATION

The mechanized operation under consideration in based on the same area and general set-up as discussed under the standard land-labor operation. The difference occurs in the handling of the sawing and loading of the pulpwood before the haul to the railroad. The pulp-cutting machine was designed to eliminate the back-breaking handling of large pulpwood, at least as much as possible. To do this, a method was devised of handling the pulpwood in tree lengths until the machine is reached. The cutters only fell, limb and top the trees. They are paid at a rate of 1¼ ¢ per linear foot for spruce and 1¢ per foot for balsam. Though in B. G. Buell's opinion this is too high, I used this pay rate as it is the rate in use.

From the bush, these tree-length stringers are skidded with a D 4 Caterpillar tractor. The average load for the tractor is three stringers. Actually the capacity of the tractor is considerably more than three stringers, but as the skidding operation takes place in and among other trees, the difficulty in handling stringers is greatly increased. The tractor is serviced by one hooker and the operator, who are paid $0.80 and $1.00 per hour respectively. The $1.00 per hour for the tractor operator may be considered high, but it is here assumed that a good operator was obtained and was paid at that rate to keep him on the job. By a good operator, it is meant that the company desires a man who understands this machine keeps it in good repair and can maintain good production.

The tree length sticks are brought to the tail end of the sawing machine by the tractor. There they are unhooked from the tractor and then hooked to a cable run from a winch on the machine. The winch pulls the log up onto the machine until a short bull-chain catches onto the log. The cable is then unhooked and run back for another stringer. The bull-chain keeps the stringer moving through the machine until the proper length (eight feet, four inches) is past a circular saw. The saw operator then saws the bolt off by pulling the saw (set on a swinging arbor) toward him. The bolt drops onto the table which has four "dead rollers, and is rolled off the table onto an empty dray by the "tableman." The table is off the ground about 4½ feet, enough so that all the tableman need do is roll the bolts off until the dray is full. The problem of sorting is negligible as the table-man can roll the bolts to either side.

The machine, at the time my data was taken, was powered by a Chevrolet motor. The engineering done on the machine was also very poor and consequently there was considerable trouble with breakdowns. Since then, the machine has been changed from gas power to diesel-electric power. This change-over and subsequent rebuilding of the machine have eliminated most of the numerous shafts, pulleys and clutches used previously. It has also reduced the number of breakdowns on the job to practically none. Therefore, in the operating cost, very little allowance is made for repairs.

From the sawing machine, the operation is the same as the standard operation. The haul to the railroad is made with tractors and drays; the loading on the landing is done with jammers.

The cost breakdown in this mechanized operation is divided into three classifications as in the previous standard operation. The variable costs per cord, of Class "A" costs in this case, will be felling and limbing, sawing operation, and skidding. Skidding is variable because the average load is four stringers, regardless of size. (If the maximum hauling capacity, in weight, were obtainable in skidding these tree lengths, the number of logs per load would decrease as the size increased, but the cordage per trip would be almost constant which would put skidding in the constant cost per cord classification.) The constant per cord costs will be the same in this case as in the standard operation; that is, hauling.

loading and railroad haul. The fixed per acre costs will be roughly the same for camps, roads, protection, etc.

As stated before, the cutting consists only of felling and limbing, paid for at the rate of $1\frac{1}{2}$¢ per linear foot for spruce and 1¢ per foot for balsam. This will be the equivalent of 10¢ per stick for spruce and 8¢ per stick for balsam. Therefore, with the volume table given, we can calculate the costs as in the table below. The limit placed on the cutters is that they shall not cut any trees which cut less than three sticks per tree.

For the skidding cost per cord, we need the machine rate for the tractor, the average skidding distance, the speed of skidding per 100 feet and the average load per trip.

The machine rate for the tractor is calculated as follows:

Machine Rate for Caterpillar D 4 Tractor.

Fixed Charges	Per Day	Per Hour	Per Minute
Depreciation $\frac{\$3000}{600 \text{ days}}$	$5.00	$ 0.625	1.04 ¢
Average Investment Charges @ 10% *			
$\frac{\$3000 \text{ X } 4}{6}$ equals $2,000 per year **			
10% of $2000 equals $\frac{\$200 \text{ per year}}{200 \text{ days per year}}$	$1.00	0.125	0.21 ¢
Repairs. (Based on repair charges for three D 4 tractors in use by P.L.Co over a period of two years.)	$4.74	0.592	0.98 ¢
Total Fixed Charges.....	$ 10.74	$1.34	$2.23 ¢

* Includes charges such as interest on capital investment, insurance and taxes.
** From formula: average investment equals first cost (N plus 1) where N equals no. of years machine is in use.
D. M. Matthews, "Cost control in the Logging Industry" p. 56.

Operating Charges	Per Day	Per Hour	Per Minute
Operator's wages	$ 9.00	$ 1.00	$ 1.67 ¢
Hooker's wages	6.40	0.80	1.33 ¢
Insurance and Social Sec. @ 20%	3.08	0.385	0.631 ¢
Fuel, 15 gals. per day @ 10 ¢ per gal.	1.50	0.187	0.312 ¢
Gasoline and Grease	.20	0.025	0.042
Oil, 5 gal. in 12 days @ 60 ¢ per gal.	.25	0.033	0.055
Total operating Charges	$20.43	$ 2.43	$4.04 ¢
Total Fixed Charges	10.74	1.34	2.23
Total Charges	$31.17	$ 3.77	$6.27 ¢

This gives us the total operating and fixed charges per minute of operation. We now have to obtain the average load per turn and the times per turn. To get these figures, I timed the skidding operation several times.

In 53 turns, the average time for various steps were:

Bunching Time,	1 min.	56 sec.	or	1.93	minutes
Hooking time,	1 "	21 "	or	1.35	"
Unhooking time,		33 "	or	.55	"
Delay time,	1 "	39 "	or	1.65	"
Total Fixed Time per turn,	5 min.	29 sec.	or	5.48	minutes

Travel time per 100 feet round trip equals 51.3 sec. or 0.855 minutes.

The average load on these 53 turns was four trees. (Actually 3.87 trees, but as this was a summer operation instead of the usual winter operation, and the tractor can take a larger load, I think an average of four trees will be a safe figure). The average skidding distance was slightly over 200 feet on these trips. As we will see later, this distance is close to the most economical skidding distance.

The size of all the trees skidded out during this time were tallied, and the average D.B.H was found to be about twelve inches. To corroborate these measurements, a scale and count of the number of pieces per cord were made. In 75 cords, it was found that the average number per cord was 31 bolts. From the equation,- Number of bolts per cord equals $\left(\frac{46}{d}\right)^2$ * where d is the middle diameter of the average bolt, we can state that: 31 equals $\left(\frac{46}{d}\right)^2$ and

$$d \text{ equals } \sqrt{\frac{46^2}{31}} \text{ equals } \sqrt{\frac{2120}{31}} \text{ equals } \sqrt{66.5} \text{ equals } 8.15''$$

Then from the volume tables for spruce and balsam, we see that a d of 8.15" corresponds to a D.B.H. of between 11 and 12 inches for both species. This places them both in the 12" D.B.H. class as the classification used by the P.L. Co., is a 2 inch class.

Therefore, the average load per trip is:

Spruce: 4 trees X 0.232 cords per tree equals 0.928 cords.

Balsam: 4 trees X 0.189 cords per tree equals 0.676 cords.

Then at 0.855 minutes per 100 feet, the cost of moving a cord 100 feet can be determined.

0.855 minutes @ 6.27¢ / minute ÷ 0.9 cords of spruce equals 5.96¢ per cord.

0.855 minutes @ 6.27¢ / minute ÷ 0.7 cords of balsam equals 7.66¢ per cord.

As the percentage of the total volume (6 inches D.B.H. and up) is not equally divided between spruce and balsam, we must weight these costs to find the average cost of skidding a mixed cord 100 feet.

Spruce: 41.1% of the total volume @ 5.96¢ per cord equals 2.45¢

Balsam 58.9% of the total volume @ 7.66¢ per cord equals 4.51¢

Total cost to skid average mixed cord 100 feet is 6.96¢ or 7.0¢

* Developed by D. M. Matthews, Ann Arbor, Michigan.

We now come to the analysis of the machine operation. We must, of necessity, obtain a machine rate for the machine. This can be done in the same manner as the machine rate for the tractor was calculated.

Pulp Machine Rates.

	Per Day	Per Hour.	Per Minute.
Fixed Charges:			
Original Cost........$2,400			
Life.................. 600 days			
Depreciation.........$2400 / 600	$4.00	.... $0.500	......0.834 ¢
Interest charges on			
Average investment @ 10%			
$2400 X 4 / 6 equals $1600 per year.			
$1600 @ 10% equals $160 for 600 days	0.667	...... 0.83	......0.138
Repairs, $500 per year (200)	2.50	...... 0.313	......0.521
Total Fixed Charges....................	$7.167	......$ 0.896	......1.493 ¢
Operating Charges:			
Wages			
Operator................................	$7.60	...... $0.95	...... 1.58 ¢
Tail-man or hooker....................	6.40	...... 0.80	...... 1.33
Tableman............................	6.40	...... 0.80	...... 1.33
Insurance, social security and			
overtime @ 20%	4.08	...... 0.51	...... 0.85
Gasoline, 12 gals. per day @ 16¢..........	1.92	...... 0.24	...... 0.40
Oil, 1 quart per day @ 25¢	0.25	...... 0.032	..... 0.053
Grease..................................	0.20	...... 0.025	..... 0.042
Total Operating Charges...........	$ 26.85	......$ 3.357	..... 5.585 ¢

	Per Day	Per Hour	Per Minute
Total Operating Charges..........	$ 26.85	$ 3.357	$ 5.585 ¢
Total Fixed Charges..............	7.167	0.896	1.493 ¢
Total Charges..............	$ 34.017	$ 4.253	7.078 ¢

From a detailed time study of the machine operation the following curve can be drawn. From this graph, we can determine the time it takes to complete the operation on various size trees. (See next page).

As this machine is put on skids so that it can be moved from one position to another, it is necessary to find how often the machine should be moved. It is quite obvious that as the timber is skidded to the machine and the area around the machine is gradually cleared of pulpwood timber, the skidding costs will go upwards a s the distance becomes longer. If we move the machine every time the immediate area is cleared , the moving costs will be prihibitive, but the skidding costs will be low. To find the point at which the total of moving and skidding costs will be lowest, we first must find the cost of moving the machine.

From the time analysis made on the machine, the time and cost breakdown can be stated. The times for the various steps in moving the machine are as follows:

Breakdown (picking up pan, tools, and hooking tractor to machine)... 7.00 minutes

Moving (per 100 feet) .... 0.62 "

Set-up (setting pan, straightening table, brushing for room, etc.... 10.00 "

Total time to move 100 feet.......................... 17.62 "

The costs for this moving time can be calculated using the foregoing machine rates and times.

Cost for Tractor:

Breakdown, 100% of time, stand by and hook,- 7.00 min. @ 6.3 ¢ equals 44.10¢

Move,- 100% of time 0.62 min. @ 6.3 ¢ " 3.90¢

Set-up,- 25% of time (straightening table and unhooking, rest of time getting drays, logs)............................. 2.50 min @ 6.3 ¢ equals 15.75¢

Total Tractor Cost.. 63.75¢

Cost For Machine:

(Machine cost nothing as it is not in operation.)

Wages: operator @ 1.58¢ per minute

Hooker @ 1.33¢ " "

Tableman @ 1.33¢ " "

Insurance, etc., @ 0.85¢ " "

5.09¢ per minute X 17 minutes equals 66.90 ¢

5.09¢ per minute X 0.62 " " 3.16 ¢

Total cost for machine per 100 ft.of move ....70.06 ¢

plus " " " tractor " " " " " 63.75

Total cost to move 100 feet..... .... 133.81 ¢

Therefore, the fixed cost per move is, Tractor, 44.10¢ plus 15.75¢ ....59.85 ¢

Machine..................................66.90 ¢

Total Fixed Cost..................... 126.75 ¢

The fixed cost will be incurred every time the machine is moved, regardless of the distance involved. The variable cost (cost of actual moving) per 100 feet of move is:

Tractor........................ 3.90 ¢

Machine........................ 3.16 ¢

Total variable cost.......... 7.06 ¢ per 100 feet.

In this case the roads are spaced the same as in the standard, i.e. 660 feet apart. To find the most economical distance to move the machine, we will find the most economical combination of skidding and moving distances and costs. As there is more than one unknown quantity, it is best to use the trial method in conjunction with two cost formulae. These two formulae* are: skidding cost equals .P C S and moving cost equals

$$\frac{L}{\frac{.Z}{4.356} \quad S^2 \quad V}$$

where .P is the percentage relationship of thr average skidding distance to the road spacing; C is the variable cost of skidding a cord 100 feet; S is the spacing of roads; L is the cost of moving the machine; .Z is the percentage relationship of machine spacing to S; and V is the volume per acre. From the foregoing data, we know that C equals 7.0 ¢ per cord per 100 feet; S equals 660 feet; L equals $1.27 plus cost of moving the unknown distance; and V equals 5.3 cords per acre. If we assume a value for .Z we can calculate the cost for skidding and for the moving of the machine. For instance, if we assume .Z to be 50% of S, then we move the machine 330 feet (50% of 660) so L will be $ 1.27 plus 3.3 X $0.071 or $1.50. Then the following can be calculated.

* Developed by D. M. Matthews in "Cost Control in the Logging Industry" Chap. V.

When .Z equals	Skidding Cost X equals .P C S	Moving Cost $\dfrac{L}{\dfrac{.Z}{4.358}\ S^2 V}$	Total Cost
40%	.276 X 46.2 equals 12.75¢	$\dfrac{146¢}{0.092 \times 231}$ equals 6.88¢	19.63 ¢
50%	.289 X (7.0 X 6.6) equals 13.35¢	$\dfrac{150¢}{0.115 \times (6.6)^2 \times 5.3}$ equals 4.98¢	18.33 ¢
60%	.3038 X 46.2 equals 14.40 ¢	$\dfrac{155¢}{0.138 \times 231}$ equals 4.86¢	19.26 ¢

It can now be said that the economical spacing for the machine is about 50% of the road spacing, or 330 feet. Anything much less than this (250 feet) or more than this (400 feet) should not be considered unless another factor which is not taken into account here should interfere.

We have now arrived at the point where we can make an analysis of the skidding operation. The average skidding distance when the machine is set up at intervals of 330 feet will be 0.289 X 6.6 stations or 191 feet. The fixed time (hook, bunch, unhook and ordinary delays) was 5.5 minutes per turn, and the variable time was 0.855 minutes per 100 feet round trip, with an average load of four trees per turn.

Therefore, the fixed cost per turn will be 5.5 minutes @ 6.3¢ per minute equals 34.62¢
and the variable cost will be 1.91 stations X 0.855 minutes X 6.3¢ per min. " 10.28¢
per turn 44.90¢

or an average of 11¢ per tree. With this cost, the following skidding cost table can be made out. (Table V).

Machine Operation

Volume and Cost Table

Spruce

Line	Diam. Breast High	6	8	10	12	14	16	18	20
	No. of Trees:								
(1)	per cord (Table IIa)	24.8	11.6	7.05	4.45	2.92	2.06	1.63	1.25
(2)	per class (Table I)	145	173	189	144	115	77	64	53
(3)	D and Up	960	815	642	453	309	194	117	53
	Volume (Cords):								
(4)	per tree (Table IIa)	.0425	.0832	.139	.232	.352	.500	.666	.855
(5)	per class (Table I)	6.16	14.40	26.30	33.40	40.40	38.50	42.70	45.30
(6)	D and Up (Table I)	247.16	241.00	226.60	200.30	166.90	126.50	88.00	45.30
	No. of Bolts:								
(7)	per tree (Table IIa)	2.6	4.0	5.25	6.6	7.25	7.75	8.2	8.4
(8)	per cord (Table IIa)	64.5	46.5	37.0	29.3	21.2	16.0	13.4	10.6
(9)	per class(line 7 X line 2)	397	669	973	978	857	616	572	480
(10)	D and Up	5542	5145	4476	3503	2525	1668	1052	480
	Cutting Cost (dollars)								
(11)	per tree(1.25¢ X 8ft X line 7)	.26	.40	.525	.66	.725	.775	.82	.84
(12)	per cord(line 11 X line 1)	6.45	4.65	3.70	2.93	2.12	1.60	1.34	1.06
(13)	per class(line 11 X line 2)	39.70	66.90	37.30	97.80	85.70	61.60	57.20	48.00
(14)	D and Up	554.20	514.50	447.60	350.30	252.50	166.80	105.20	48.00
	Skidding Cost (dollars)								
(15)	per tree	.11	.11	.11	.11	.11	.11	.11	.11
(16)	per cord(line 15 X line 1)	2.73	1.279	0.775	0.490	0.321	0.227	0.179	0.138
(17)	per class(line 15 X line 2)	15.95	19.03	20.79	15.84	12.65	8.47	7.04	5.83
(18)	D and Up	105.60	89.65	70.62	49.83	33.99	21.34	12.87	5.83
(19)	Sawing Time per tree (min.)	1.80	1.87	2.13	2.60	3.15	3.67	4.00	4.15
	Sawing Costs (dollars)								
(20)	per tree (7¢ X line 19)	.126	.131	.149	.182	.221	.257	.280	.290
(21)	per cord (line 20 X line 1)	3.12	1.52	1.05	0.81	0.645	0.529	0.456	0.362
(22)	per class(line 20 X line 2)	18.27	22.65	28.15	26.20	25.40	19.75	17.91	15.40
(23)	D and Up	173.73	155.46	132.81	104.66	78.46	53.06	33.31	15.40
	Total Class "A" costs (dollars)								
(24)	per cord(sum lines 12, 16, 21)	12.30	7.45	5.62	4.23	3.09	2.36	1.98	1.56
(25)	D and Up(sum lines 14,18,23)	833.53	759.61	651.03	504.79	364.95	241.20	151.38	69.23

Machine Operation

Table Vb

Volume and Cost Table.

Balsam.

Line	Diam. Breast High	6	8	10	12	14	16
	No. of Trees						
(1)	per cord (Table IIb)	30	13.3	7.8	5.3	3.6	2.65
(2)	per class (Table I)	1873	1001	879	285	135	36
(3)	D and Up	4209	2336	1335	456	171	36
	Volume (Cords)						
(4)	per tree (Table IIb)	.0333	.075	.128	.189	.278	.378
(5)	per class (Table I)	62.40	75.10	112.50	53.40	37.50	13.60
(6)	D and Up (Table I)	354.50	292.10	217.00	104.50	51.10	13.60
	No. of Bolts						
(7)	per tree (Table IIb)	2.6	3.85	5.0	5.9	6.65	7.25
(8)	per cord (Table IIb)	78	51	39	31.5	24	19.2
(9)	per class (line 7 X line 2)	4860	3830	4390	1680	900	261
(10)	D and Up	15921	11061	7231	2841	1161	261
	Cutting Cost (dollars)						
(11)	per tree (1¢ X 8ft X line 7)	.208	.308	.40	.472	.532	.58
(12)	per cord (line 11 X line 1)	6.24	4.08	3.12	2.52	1.92	1.54
(13)	per class (line 11 X line 2)	389.00	306.00	351.00	134.50	72.00	20.90
(14)	D and Up	1273.40	884.40	578.40	227.40	92.90	20.90
	Skidding Cost (dollars)						
(15)	per tree	.11	.11	.11	.11	.11	.11
(16)	per cord (line 15 X line 1)	3.30	1.463	0.858	0.583	0.396	0.292
(17)	per class (line 15 X line 2)	206.03	110.11	96.69	31.35	14.85	3.96
(18)	D and Up	462.99	256.96	146.85	50.16	18.81	3.96
(19)	Sawing Time per tree (minutes)	1.80	1.87	2.13	2.60	3.15	3.67
	Sawing Costs (dollars)						
(20)	per tree (7¢ X line 19)	.126	.131	.149	.182	.221	.257
(21)	per cord (line 20 X line 1)	3.78	1.74	1.16	0.964	0.795	0.680
(22)	per class (line 20 X line 2)	236.00	174.30	130.90	51.80	29.80	9.25
(23)	D and Up	632.05	396.05	221.75	90.85	39.05	9.25
	Total Class "A" Costs (dollars						
(24)	per cord (sum lines(12,16,20)	13.32	7.28	5.14	4.07	3.11	2.51
(25)	D and Up (sum lines(14,18,23)	2368.44	1537.01	947.00	368.41	150.76	34.11

We now have all the data necessary to make up our analysis of Class "A" costs. The tables are self-explanatory. (Table V).

The Class "B" costs, next to come under consideration, will be much the same as in the standard operation with one addition, the cost of moving the machine. This will be a constant cost per cord as determined in calculating the economic spacing of the set-ups. Therefore, the constant costs per cord will be a s follows:

Tractor Haul................................	$1.00	per cord.
Loading onto Railroad cars................	0.65	" "
Railroad haul................................	1.00	" "
Overhead and margin for profit............	2.00	" "
Set-up cost....................................	0.05	" "
Total Class "B" costs......................	4.70	per cord.

Stumpage will be the same as before ($2.50 and $1.00), making a total for Class "B" costs of $7.20 per cord for spruce and $5.70 per cord for balsam.

The Class "C" costs fixed per acre charges will remain at the $5.00 per acre as itemized in the standard operation.

From this data, we may now make a calculation as to the value received from this area.

Sale Value	Spruce $17.50		Balsam $15.50
Class "A" costs:			
Cutting:	$554.20 / 247.16 cords equals 2.240		$1273.40 / 354.5 cords equals $3.59
Skidding:	$105.60 / 247.16 cds. equals 0.427		$ 462.99 / 354.5 cords equals 1.31
Sawing:	$173.73 / 247.16 cds. equals 0.703	$3.37	$ 632.05 / 354.5 cds. equals 1.78
			6.68

Balance after Class "A" costs, Spruce $14.13, Balsam, $8.82.

	Spruce.	Balsam.
(Balance)	$14.13	$8.82
Class "B" Costs.............	4.70	4.70
Balance................	$9.43	4.12
Stumpage..................	2.50	1.00
Balance................	$6.93	$3.12
Class "C" costs: $5.00 X .411 / 2.47 cds	.83	5.00 X .589 / 3.54 cds equals .... .83
Total Net Balance......	$6.10	$2.29

However, as in the previous case, this does not show any zero margin limit, and we have to use the same system of deducting Class "B" costs to find the maximum expenditure we can make per cord.

	Spruce.	Balsam.
Sale Values.....................	$17.50	$15.50
Class "B" Costs and stumpage.....	7.20	5.70
Balance(for Class "A" costs)	$10.30	$ 9.80

From a reference to the Total Class "A" costs (table V) we find that the variable cost for a cord of 6" spruce is $12.30, or $2.00 over the sum allowed for class "A" costs. The balsam variable cost per cord at 6 inches is $13.32, or $3.52 over the allowed sum. Thus, we will lose money on all 6 inch trees cut. The costs for the 8 inch class in both species are below the maximum allowable expenditures as above, so we can cut down through the 8 inch class (about a four stick limit) and eliminate undue costs incurred if the 6 inch class is included. Setting the minimum D.B.H. above the 8 inch class reduces the return per acre.

	Spruce		Balsam	
Sale Values	$17.50		$15.50	
Class "A" costs: $759.61 / 241 cds. equals	$ 3.15		$1537.01 / 292.1 cds ... $5.26	
Class "B" costs:	4.70		4.70	
Stumpage	2.50		1.00	
Class "C" costs: $5.00 X 462 / 2.41 cds.	0.94	$11.29	5.00 X .548 / 2.92 cds ... 0.94	$11.90
Total Net Balance		$ 6.21		$ 3.60

The difference in net balance from the area would be:

Cutting to 6 inch diameter: 2.47 Cds. spruce @ $6.10 on 100 acres..........$150.50

3.57 cds. balsam @$2.29 on 100 acres.......... 81.00

Total Net Recovery on 100 acres..........................$231.50

Cutting to 8 inch diameter: 2.41 cds. spruce @ $6.21 on 100 acres.....$149.50

2.92 cds. balsam @ $3.60 on 100 acres..... 105.10

Total Net Recovery on 100 acres....................$254.60

The net difference in recovery from the area is $254.60 minus $231.50 equals $23.10

Repeating the procedure on tree value calculations as we did in the standard operation, we obtain the following tables. (VI). With these tables and Table IV for comparison, we can draw our conclusions, using line 5.

Machine Operation Tree Values

Table VIa

Spruce

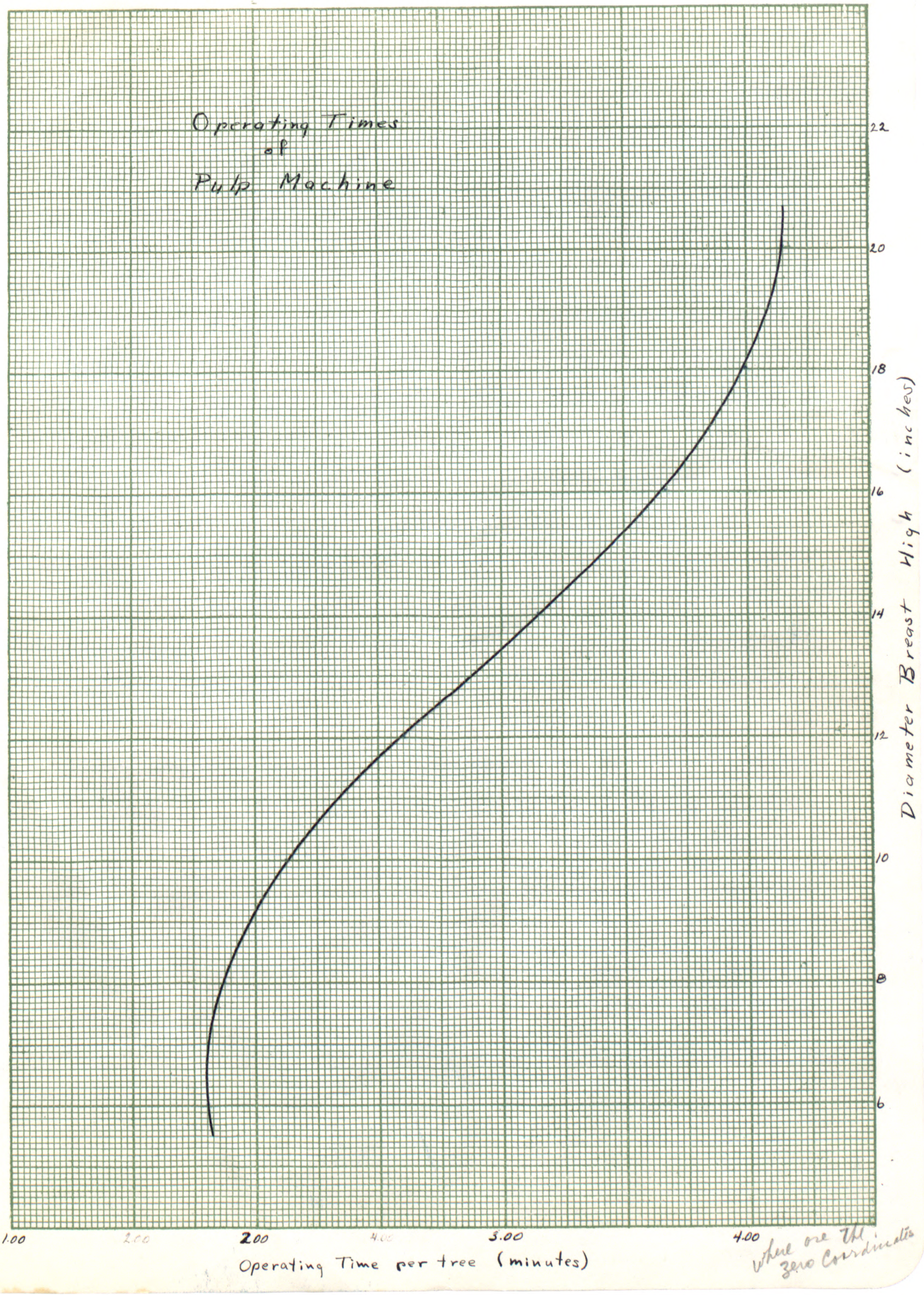
Diameter Breast High	6	8	10	12	14	16	18	20
(1) Surplus after Class "B" costs per cord.	$12.80	$12.80	$12.80	$12.80	$12.80	$12.80	$12.80	$12.80
(2) Class "A" costs per cord. (cutting, skidding and sawing) (From Table Va)	12.30	7.45	5.52	4.23	3.09	2.36	1.98	1.56
(3) Balance for Class "C" Costs and stumpage (line 1 minus line 2)	$ .50	5.35	7.28	8.57	9.71	10.44	10.82	11.24
(4) Volume per tree in cords. (Table IIa)	.0425	.0832	.139	.232	.352	.500	.666	.855
(5) Net value per tree in cents. (line 3 X line 4)	2.12	44.5	101.0	198.0	342.0	522.0	721.0	961.0
(6) Increase in value per tree in cents for each dollar increase in stumpage per cord. (line 4 X $1.00)	4.25	8.32	13.9	23.2	35.2	50.0	66.6	85.5
(7) Net value per tree in cents when balance for stumpage is $1.00 per cord at 6" d.b.h. (Sum lines 5 and 6)	6.37	52.82	114.9	221.2	377.2	572.0	788.6	1046.5

Table VI b

Machine Operation Tree Values

Balsam

	Diameter Breast High	6	8	10	12	14	16
(1)	Surplus after Class "B" costs per cord	$10.80	$10.80	$10.80	$10.80	$10.80	$10.80
(2)	Class "A" per cord (cutting, skidding and sawing) (From Table V b)	13.32	7.28	5.14	4.07	3.11	2.51
(3)	Balance for Class "C" costs and stumpage (line 1 minus line 2	-2.52	3.52	5.66	6.73	7.69	8.29
(4)	Volume per tree in cords (Table II b)	.0333	.075	.128	.189	.278	.378
(5)	Net value per tree in cents (line 3 X line 4)	-8.39	26.4	72.5	122.0	214.0	313.0
(6)	Increase in value per tree in cents for each dollar increase in stumpage per cord. (line 4 X $1.00)	3.33	7.5	12.8	18.9	27.8	37.8
(7)	Net value per tree in cents when balance for stumpage is $1.00 per cord at 6" D.B.H. (Sum lines 5 and 6)	-5.06	32.9	85.3	140.9	241.8	350.8


Operating Times
of
Pulp Machine
22
20
18
16
14
12
10
8
6
Diameter Breast High (inches)
1.00
2.00
2.00
4.00
3.00
4.00
Operating Time per tree (minutes)
where are the zero coordinates

Conclusion

By comparing the tree values, we see that at 12 inches D.B.H. the machine operation begins to pay more than the hand operation. This can be more readily seen in Table VII.

In inspecting the net recovery values from an acre on both operations, we find the machine operation paid more per acre than the hand operation. This is because the machine operation increases the value received from the larger diameter classes. Not only is the difference in value between the two operations much larger in the higher diameter classes, but the fact that over 60% of the stand is in the larger class, also affects this return per acre.

From the conclusions drawn, the best results would be obtained by setting up a combined operation, with the machine handling the timber from 12 inches up, and the hand operation from 6 to 12 inches. Though this would please the piecemakers as they would rather handle the smaller stuff, it would not be best for the operators as they would have to spend more for supervision and checking. It would probably not be advisable in this case, as the men would object strenuously to cutting the scattered timber that would result from restricting them to the lower classes. As the job is now set up, the piecemakers cut the pulpwood in the low-land areas where the average diameter is smaller and the machine handles the larger high-land timber.

It is apparent that if the machine is to be more universally practical, costs must be reduced. One specific cost that should be reduced is the skidding cost, which might be done by use of arches, or pan skidding. Most important, with improvements made on the machine, a more economical operation can be planned around it. There have been several changes made since this analysis, some of which have been mentioned already. Others are in the process of completion which should speed up the operation considerably. This speed-up of the operation should reduce the costs to a point where it would be economical to use the machine in almost any type of stand.

Table VI I

Comparison of Tree Values

Spruce

Line	Diam. Breast High	6	8	10	12	14	16	18	20
(1)	Net value per tree in cents, Machine Operation. (line 5 Table VI a)	2.12	44.5	101.0	198.0	342.0	522.0	721.0	961.0
(2)	Net value per tree in cents Standard Operation. line 5, Table IV a)	24.50	63.4	122.0	149.0	288.0	466.0	561.0	800.0
(3)	Difference in value per tree in favor of Machine Operation (cents) (line 1 - line 2)	-22.38	-18.9	-21.0	49.0	54.0	56.0	160.0	161.0

Balsam

Line		6	8	10	12	14	16
(4)	Diam. Breast High	6	8	10	12	14	16
(5)	Net value per tree in cents Machine Operation (line 5, Table VI b	-8.39	25.4	72.5	122.0	214.0	313.0
(6)	Net value per tree in cents Standard Operation (line 5, Table IV b)	7.56	39.3	84.0	74.1	149.0	250.0
(7)	Difference in value per tree in favor of machine operation. (cents) (line 5 - line 6)	-15.95	-13.95	-11.5	47.9	65.0	63.0

S O U R C E M A T E R I A L and A C K N O W L E D G M E N T S

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