Carey, S Cooper
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Eastern Canada

The Practical Application of Minimum Cost Planning to a Cordwood Operation in South Eastern Canada

by

S. C. Carey
School of Forestry and Conservation
University of Michigan

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Contents

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Data Sheet No. I

Block Number	Total Area Acres	Operable Area Acres	Total Volume Cords	Overall Volume Cords per Acre	Operable Area Cords per Acre	Normal Road Spacing in 100 foot units	Actual Road Spacing in 100 foot Units	Miles of Sulky Road	Av. Sulky Haul 100 foot units	Variable Twitching Cost per Cord in cents	Sulky Road (1) Cost per Cord in cents	Sulky Hauling Cost per Cord in cents	Fixed Cost, (2) per cord in dollars	Total Cost, per Cord in dollars
1	567	517	3019	5.32	5.84	4.9	5.5	7.75	25.3	9.8	7.7	51	2.54	3.23
2	741	539	2830	3.82	5.25	5.2	5.8	7.6	13.0	10.3	8.6	26	2.54	2.99
3	618	455	1911	3.09	4.20	5.8	6.7	5.6	10.3	11.9	8.8	21	2.54	2.96
4	431	352	2274	5.28	6.46	4.6	4.4	6.65	20.0	7.8	10.4	40	2.54	3.12
5	815	492	2052	2.52	4.17	5.8	6.25	6.5	9.5	11.1	9.5	19	2.54	2.94
6	1982	1783	9557	4.82	5.36	5.1	6.2	23.75	16.3	11.0	7.5	33	2.54	3.06
7	1346	977	5002	3.80	5.12	5.2	5.6	14.45	25.0	9.9	8.7	50	2.54	3.23
8	283	283	1316	4.65	4.65	5.5	6.7	3.5	14.3	11.9	8.0	29	2.54	3.03
9	1225	1045	4211	3.44	4.03	5.9	5.9	14.65	15.7	10.5	10.4	31	2.54	3.06
10	4171	2648	15690	3.76	5.93	4.85	5.5	39.4	28.4	9.8	7.4	57	2.54	3.28
11	322	322	1542	4.79	4.79	5.4	6.5	4.05	19.0	11.6	7.9	38	2.54	3.12
12	1465	1142	4385	2.99	3.84	6.0	6.4	14.65	21.0	11.3	10.0	42	2.54	3.17
13	2340	1538	8671	3.70	5.64	5.0	5.2	24.6	26.6	9.2	8.5	53	2.54	3.25
14	1412	777	3481	2.47	4.48	5.8	5.8	11.1	27.0	10.3	9.7	54	2.54	3.28
15	2057	1578	8490	4.12	5.38	5.1	5.0	26.2	23.0	8.9	9.3	46	2.54	3.18
16	930	666	3763	4.05	5.65	5.0	5.5	9.9	20.0	9.8	7.9	40	2.54	3.12
Total	20,705	15,114	78,194	Av. 3.78	5.17	5.2	5.56	Total 220.35	Av. 22	9.9	8.9	44	2.54	3.17

(1) Sulky Road Construction Costs = $30 per Mile

(2) See assembly of Fixed Costs on Data Sheet II

Data Sheet No. II.

Truck Hauling Costs: Class V and Class III Roads

Block Number Class V Roads	Total Cords	No. Loads 5 Cords each	Av. Hauling Distance-Miles	Round Trip Cost per Mile Dollars	Total Cost Dollars
1	3,019	604	——	.2017	——
2	2,830	566	1.91	.2017	218.05
3	1,911	382	1.91	.2017	147.16
4	2,274	455	0.44	.2017	40.38
5	2,052	410	1.90	.2017	157.12
6	9,557	1,911	1.91	.2017	736.21
7	5,002	1,000	2.45	.2017	494.17
8	1,316	263	2.85	.2017	151.18
9	4,211	842	6.95	.2017	1,180.33
10	15,690	3,138	10.05	.2017	6,360.99
11	1,542	308	8.02	.2017	498.23
12	4,385	877	9.86	.2017	1,744.14
13	8,671	1,734	13.27	.2017	4641.15
14	3,481	696	11.92	.2017	1,673.37
15	8,490	1,698	13.82	.2017	4,548.22
16	3,763	753	15.92	.2017	2,417.93
	78,194	15,637			\$25,008.63

Block Number Class III Roads	Total Cords	No. Loads 5 cords each	Av. Hauling Distance-Miles	Round Trip Cost per Mile Dollars	Total Cost Dollars
1	3,019	604	1.0	.5132	309.97
2	2,830	566	2.02	.5132	586.75
3	1,911	382	2.39	.5132	468.54
6	9,557	1911	1.67	.5132	1,637.81
	17,317	3,263			\$3003.07

Road Building Cost

Class of Roads	Miles	Cost per Mile	Total Cost	Sum of Total Cost	Cost per Cord-cents
III	6.65	\$400	\$2,660	24,260	31.0
V	18.0	1,200	21,600		

Total Average Cost per Cord: to point of delivery

Woods Cost (Data Sheet I)		\$3.17 per Cord
Main Road Building Costs		.31 " "
Trucking Cost-Class V Road	$\frac{\$25{,}008.63}{78{,}194 \text{ Cords}} =$	.32
Class III Road	$\frac{\$3{,}003.07}{78{,}194 \text{ Cords}} =$	.04
Total Average Cost		\$3.84

(2) Assembly of Fixed Woods Costs: - from Data Sheet I.

Fixed Costs:

Felling and Peeling	\$1.25 per cord
Arranging poles at Landings	.17
Cutting and piling	.50
Fixed twitching cost	.33
Fixed sulky hauling cost	.16
Truck Loading Cost	.13
	\$2.54 per cord.

All woods operators will readily agree that a logging job is most profitable when the total cost of operation is kept at a minimum level, but the method of reaching this minimum level has never been agreed upon. All operators realize that in planning their operation and road system, the cost of this system will eventually have to appear in their records as so much per M board feet. This cost first appears as a cost per unit of distance such as per mile, or per hundred foot station, and is then transferred to a cost per M board feet or per cord, which ever the unit of operation be, by spreading it over the volume moved over the road. This volume moved, then will depend upon the volume per acre on the area, and the area served by each road, which depends on, and varies with, the spacing of the roads.

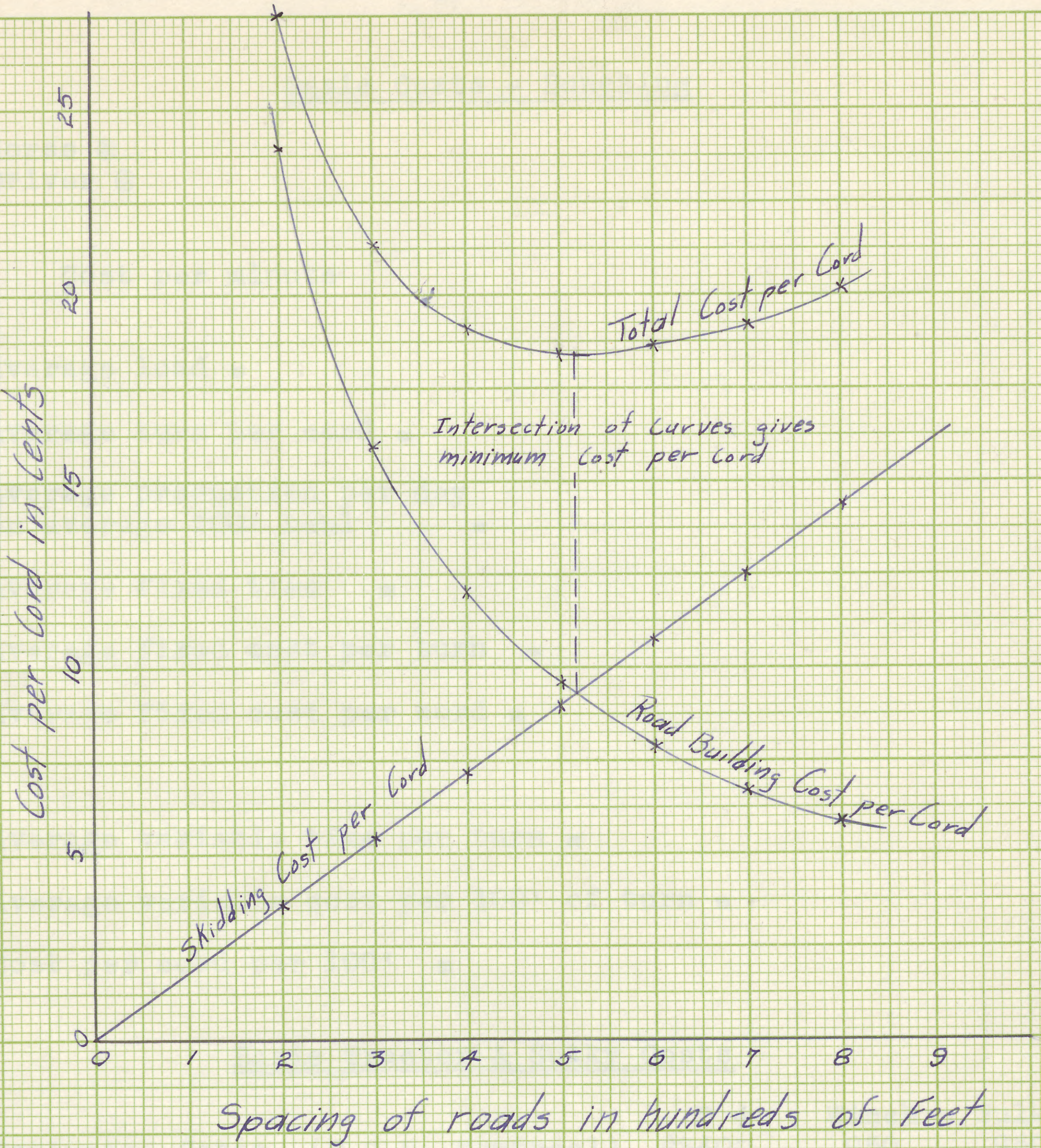
However, as the road spacing is increased, with a resulting decrease in the road building cost per acre, another cost enters the picture and this increases with a decrease of the road building cost. This cost is the pre-haul cost of moving the product to the road. It is not difficult to see, that as roads are moved further and further apart, the average pre-haul distance is going to increase. Then it must be recognized that to get minimum costs, these two costs must first be balanced so that an increase in one is met by an equal decrease in the other when expressed on a "per card" basis. This minimum cost then, depends on three variable cost factors: cost of road construction per unit of distance, cost of pre-haul of the product in units of distance, and volume per acre.

While this is recognized to some extent by all operators, very few have ever attempted to find a method of balancing these factors and thus arriving at their minimum cost. Instead, an average road spacing figure is taken from experience and applied to every tract, regardless of changes in volume or topography, which will send road construction and hauling costs far upward. Yet, in many cases, pre-haul operation in combination with the cost of the transport system commonly make up 50% or more of the total logging costs, exclusive of supervision. (D. M. Mathews - "Principles of Forest Industry Economy") This fact justifies careful attention to correct planning of the road system and constant adjustment of spacing to changes in condition.

Because in the past, operators have not been able to see the relationship between road building and pre-hauling costs, they have been wary of trying to log areas of low overall volume. They were unable to adjust their road systems to the areas, and so when they did try to operate on an area with low overall volume, they nearly always lost money and had to give up the job. This could be averted, as I will try to show in this report, by the correct spacing and planning of the road system so as to get minimum costs. Minimum costs up to loading on trucks or other methods of hauling on the main transportation system can be got when the skidding or twitching cost per cord is equal to the road building cost of the minor roads to which skidding is done. In this case, the minimum cost will be obtained when the twitching cost per cord is equal to the sulky road building cost per cord. This is so because the skidding cost is a variable cost which increases at an arithmetical rate with a changing value, and the road building cost is a fixed cost decreasing as the reiprocal of the same changing value. In a case such as this, the minimum cost is achieved when these two opposed cost components are equal. Graphical proof of this is shown on page (3A). Using the average volume (V = 5.17), skidding cost (S = 7.1), and sulky road cost (R = 3000¢) as developed later in this report. If we can achieve a reasonable balance between these two costs, then we will be well on our way to getting at the minimum cost per cord. Keeping this firmly in mind, we will now pass on to the development and explanation of the data as shown on Data Sheet I.

Development of Data Sheet I.

Before going into the work of drawing up the map and estimating the costs as shown on data sheet I, I think it is appropriate to develop first the basic costs of bunching and of tractor and sulky operation. These costs are based on the prevailing wage scale for Southeastern Canada, and with an effective 9 hour day. Tractor and sulky operation costs are developed from data supplied by the Caterpillar Tractor Company.



Data

Spacing of Road in Hundreds of Feet	Skidding Cost per Cord $7.1 \frac{S}{4}$ (1)	Road Building Cost per Cord $\frac{3000/12.1}{5.17\,S}$ (2)	Total Cost per Cord
2	3.5	24	27.5
3	5.3	16	21.3
4	7.1	12	19.1
5	8.9	9.6	18.5
6	10.7	8	18.7
7	12.4	6.8	19.2
8	14.2	6	20.2

(1) Explanation of Formulae $C \frac{S}{4}$ given on page .
(2) Explanation of Formulae $\frac{R/12.1}{\sqrt{S}}$ given on page .

Basic Costs - Bunching

Horse @
Driver @

Cost per minute

Average load =

Average turn per cord =

Average production per day on average 200' haul =

Average fixed time =

Average fixed cost per turn =

Average fixed cost per cord =

Average variable time per turn =

Average variable cost per 100' of turn =

Cost per cord per 100' =

Basic Tractor & Sulky Costs

	D 4	Winch	Sulky	Total
Estimated Costs (F.O.B. Montreal)	$3400	950	950	
Average Investment	2040	570	570	
Fixed Cost per hour				
Interest, taxes, & Insurance	.102	.028	.028	.158
Depreciation	.34	.095	.095	.53
Repairs	.34	.06	.045	.445
Total fixed cost	.782	.183	.168	1.133

Operating cost per hour	D 4	Winch	Sulky	Total
Operator	.40			.40
Fuel	.10			.10
Gasoline	.01			.01
Lubricating oil	.08			.08
Grease	.03			.03
Cable & rigging		.05		.05
Tires			.05	.05
	.62	.05	.05	.72
				1.85
				.30
Total plus choker setter				2.15

Cost per minute on 9 hr. effective day =

$$\frac{215\text{¢}}{540} = .4\text{¢}$$

Tractor & sulky Operation

Tractor & Sulky cost	4¢ per minute
Normal Load per turn	2 cords
Fixed Time per turn	8 minutes
Fixed Cost per turn	32 ¢
Fixed Cost per cord	16 ¢
Variable hauling cost per turn based on average of 1.00 minute per 100 ft. haul and return	4 ¢ per 100 ft.
Variable cost per cord per 100 ft. of hauling distance = $\frac{4\text{¢}}{2}$	2.0 ¢

From these calculations we have a fixed bunching cost of 33¢ per turn, a variable bunching cost of 7.1¢ per hundred feet, a fixed sulky hauling cost of 16¢ per turn, and a variable sulky hauling cost of 2¢ per hundred feet. These are the basic costs used throughout the calculations.

The next step was the laying out of the blocks on the map. The blocks were laid out regardless of area, but conforming as nearly as possible to what would be natural logging units, decided by the topography of the area. The map itself, and cruise data was supplied by the Oxford Paper Company, and the blue lines upon it are a tentative logging setup by their logging engineer.

After the boundaries of the 16 blocks had been set, the next step was to find the total area of the blocks, and the total cord wood area within the block. For Block 7, which will be used as an example to demonstrate the calculations followed in getting the data on data sheet I, the total area, scaled by using a plinometer, was found to be 1,346 acres, of which 977 acres were found to be in cordwood. The remainder being, scrub, bog, or hardwoods, as shown on the map.

Next the cordwood volume per acre for the operable area was calculated from the cruise data on the map. This was done by finding the sum of the figures such as P498, P629, P845, which represent cubic feet per acre as shown in the timber cruise, dividing the sum by the number of acre samples taken, and dividing this by 90 cubic feet which is the equivalent of one cord. In Block 7 this was = 5.12 cords per acre. Multiplying the average cords per acre by the total cordwood acreage of the block, the total volume was found. This in turn divided by the total area of the block gives the overall cordage per acre. In Block 7 this was

$$5.12 \times 977 = 5002 \text{ cords}$$

$$5002 \div 1346 = 3.80 \text{ overall cordage per acre}$$

The next step was the determination of the normal spacing of the sulky roads. The spacing formulae used is $S = \sqrt{\frac{.33\,R}{VC}}$, where:

S = spacing of roads in 100 foot units of distance

R = cost of road construction per mile, in cents

V = average volume per acre

C = skidding or twitching cost per 100 feet of distance.

For a further explanation and proof of this formula see "Principles of Forest Industry Economy", by D. M. Matthews, of the School of Forestry and Conservation, at the University of Michigan. In Block 7 the calculations were:

$$S = \sqrt{\frac{.33 \times 3000}{5.17 \times 7{,}1}} = 5.2$$

or the normal road spacing should be 520 feet in Block 7.

After finding this figure the next step was to sketch in the sulky roads on the map. Using a pair of dividers so as to keep the spacing as close as possible to normal, the sulky roads were drawn in. It must be kept in mind, that in locating the roads, contours, topography, and direction of slope have to be kept in mind. Also, that it is better to have a spacing slightly above the normal spacing, rather than below normal, because the costs rise faster on a narrower than normal spacing than on a wider than normal spacing. This can readily be seen on the cost graph on page (3A). After satisfactorily locating all the necessary roads, the total mileage of roads used was found with the aid of a map measure. This mileage divided into the cordwood area gives the number of acres served by one mile of sulky road. Then by finding the area in square feet served by each mile of road , and dividing this by the number of feet in a mile, the actual road spacing in feet is given: that is

$$\frac{977\ A}{14.45\ \text{miles}} = 67.6\ A \text{ per mile of sulky road}$$

$$\frac{67.6\ A \times 43{,}560}{5280} = 5.6 \text{ actual road spacing.}$$

This spacing of 560 feet is in contrast with the normal spacing of 520 feet and is as close as can be expected and is very satisfactory.

To find the average sulky haul, the sum of the maximum hauls was found with the aid of the map measure. This was divided by the number of maximum hauls to give the average maximum haul, and one-half of this was taken to be the average haul for the block. The maximum hauls are considered as the distance from every road end in the block to the point where that road joins the main truck road. In Block 7 there were 31 road ends or maximum hauls, with a total of 2.94 miles of maximum haul.

$$\frac{2.94 \times 5280}{.31 \times 2} = 2500 \text{ feet average sulky haul}$$

Next the variable twitching cost per cord was calculated. Letting S equal the spacing of the roads, then the distance served by each road is one half of this, or $\frac{S}{2}$, and the average twitching distance would be one-half of this, or $\frac{S}{4}$. Then letting C equal the twitching cost per hundred feet of distance, the average twitching cost per cord will be $C\frac{S}{4}$.

$C = 7.1$ as found in the basic cost calculation

or, $7.1\ \frac{5.6}{4} = 9.9$ cents per cord.

The sulky hauling cost per cord is next developed. Since we have already determined the average sulky haul to be 2500 feet, and the basic cost to be 2¢ per hundred feet then the sulky hauling cost is:

25 x 2¢ = 50¢ per cord.

The sulky road building cost per cord is then found by multiplying the total mileage of sulky roads to be built, by the building cost per mile and dividing this by the total cordage on the block.

$$\frac{14.45 \text{ miles} \times \$30 \text{ per mile}}{5002 \text{ cords}} = 8.7 \text{ per cord.}$$

While this cost of 8.7¢ for road building is not equal to the twitching cost of 9.9¢ per cord, they are close enough together so as to be considered in balance and their sum or 18.6 is the minimum cost per cord for twitching and sulky road construction.

The make up of the fixed cost per cord are developed on data sheet II, and need little explanation. The costs for felling and bucking, arranging poles at landings, and cutting and piling are from a report of the Oxford Paper Company from their cost records. The fixed twitching cost, and the fixed sulky hauling cost were basic costs developed earlier in this report, and the truck loading cost is from a report by Banghaf and Watson, Inc., of Wisconsin which was judged applicable to this area.

The total average cost per cord for Block 7 up to and including loading on trucks on the main road is then the sum of the average component costs, and for Block 7 are:

Variable twitching cost per cord	$0.099
Sulky road cost per cord	0.087
Sulky hauling cost per cord	0.50
Fixed costs per cord	2.54
Average cost per cord for Block 7	$ 3.21

Using this same method in the other blocks the average cost per cord was found for each block and from these, the average cost per cord, for the entire area, was found to be $3.17 per cord loaded on trucks on the main roads.

Development of Data Sheet II.

While it might be logical to take up at this point, the reasons for using the major road system indicated on the map, this will be left until later, and the cost calculations carried through to the end, so as to preserve a continuity of reasoning in the calculations.

There are two classes of main roads used, and a brief description of these might be helpful.

Class III Road - Fair haul roads - Hand or machine graded, more or less contour alignment, gradient changing frequently but more favorable, fairly smooth if properly maintained, considerable first and second gear.

Class V Road - Dirt and poor gravel - Fair alignment and gradient, about 20% second and first gear, surface smooth or rough depending upon maintenance.

The above classification was prepared by Bruce Spike of Banzhaf and Watson Inc., Milwaukee, Wisconsin, and these roads can be built over this area for a cost of $400 per mile for the Class III roads, and $1200 per mile for the Class V roads. Using the map measure the total mileage of Class III and Class V roads was found separately. This mileage multiplied by the cost per mile of the roads gives the total main road building cost. Then, since all main roads are to be pro-rated against the total volume on the area, rather than just figuring the cost of the roads against the area tributary to the road, this total cost is divided by the total volume and gives a cost of 31¢ per cord for all main road construction.

Truck hauling costs were necessarily figured out in two separate calculations. One for hauling on Class V roads and one set for hauling on Class III roads. The method used in each case is identical, the only change being in the round trip cost of operation per mile over the different roads.

From the report of Banzhaf and Watson Inc. truck hauling costs on Class V road were found to be $0.2017 per mile round trip hauling distance, and $0.5132 per mile for Class III roads. These costs are based on records kept by Banzhaf and Watson Inc., and are for tanden drive trucks which will carry five cords to a load. It was planned to use this type truck in planning the operation outlined here, and these costs are considered applicable to the area. From data sheet I the total cords per block were taken and by dividing this total by 5, the number of truck loads necessary per block was found. The next step was to find the average hauling distance separately for each block so as to estimate the average hauling cost per block, and then the grand average hauling cost per cord. To determine the average hauling distance, the weighted center of the timber block had to be found, and then the distance from this to the point of delivery scaled off. By the weighted center of the timber block, is meant the average hauling distance of the cordwood, which has been brought by the sulky haul to the main roads, to the end of the block nearest the point of delivery. Then the average hauling distance for the block is the distance from this point, to the point of delivery. For Block 7 this distance was found to be 2.45 miles and since there were 5,002 cords necessitating 1,000 truck,loads, the trucking costs for this block would be:

1000 x .2017 x 2.45 = \$ 494.17

Following the same procedure the hauling costs were found for Class III and Class V roads for all blocks. Then the total hauling cost was found by adding the costs per block, and this total divided by the total cordage on the area, to get an average cost per cord for the whole area. This average cost per cord was found to be 32¢ per cord for hauling on Class V roads and 4¢ per cord for hauling on Class III roads.

Then to get the total average cost per cord for the whole area, to the point of delivery these component costs were added, and gave an average cost of \$ 3.84 per cord:

Woods cost	$ 3.17 per cord
Main road building cost	.31 per cord
Trucking costs-Class V roads	.32 per cord
-Class III roads	.04 per cord
Average total cost per cord	$ 3.84

Development of the Main Road System

The determination of the class of road to be used in Block 5 to tap Blocks 2,3, and 6 was based on the normal break-even point formula which is $N = \frac{F^1 - F_1}{V - V^1}$. This was rewritten in our case to be cords $= \frac{R^1 - R_1}{H - H^1}$, where R^1 and R are costs of construction for Class V and class III roads, and H^1 and H are hauling costs per cord on the different roads. It was necessary to have a truck road to these three blocks, because all the cordwood in them has to come out the same route, and sulky hauling costs would be prohibitive for such a long haul. The break-even formula will give the number of cords at which the total road building and hauling costs of one class road is equal to the construction and hauling costs of the other class road. Then if the total cordage on the three blocks is higher than the number of cords given in the break-even formula, Class V roads should be built, and if lower, class III roads should be used. A complete discussion of this formula may be found in Matthews, "Principles of Forest Industry Economy".

The calculations used to justify the use of a Class V road are as follows:

C = number of cords at break-even point
R^1 = construction cost of Class V road
R = construction cost of Class III road
H^1 = Hauling cost per cord on Class V road
H = Hauling cost per cord on Class III road

It was necessary to build 1.125 miles of road, so

$$R^1 = 1.125 \times \$\,1200 = \$1350$$

$$R = 1.125 \times \$\,400 = \$450$$

$$H^1 = \frac{1.125 \times .2017}{5} = .04538 \text{ per cord}$$

$$H = \frac{1.125 \times .5132}{5} = .11547 \text{ per cord}$$

$$C = \frac{1350 - 450}{.11547 - .04538} = 12{,}840$$

So if there are over 12,840 cords in Blocks 2, 3, and 6 the Class V road should be used. From data sheet I, the cordage is:

Block 2	2830 cords
Block 3	1911 cords
Block 6	9557 cords
	14, 298 cords

Therefore, a saving will result if a Class V road is used.

The next step was to decide whether the road should be extended into Block 6, with a resulting cutting down of sulky hauling cost, or whether it would be too expensive to do this, and all wood should be got to this point by sulky haul. Since there was only a difference of about 1500 cords between the total cordage on the area and the break-even point, it can instantly be recognized that it would not pay to continue the Class V road into Block 6, and so the calculation is now between sulky roads with a relatively high hauling cost and Class III roads with a low hauling cost, but a high construction cost. The calculation is more difficult here, because as the road progresses into the block, the cordwood volume it serves, decreases. Again a break-even point formula is used, but not the simple one used in the last calculation. This formula is written

$$N = \frac{2R - S}{S}$$ (Matthews "Principles of Forest Industry Economy")

and the data necessary is:

V = volume of timber tributary to each distance unit of road as it extends into the area,

h = reduction in hauling cost per cord per unit distance of road resulting from road improvement,

$S = v \times h$

R = cost of improving road from one standard to the other, per unit of distance,

n = number of distance units at which the total costs of the two types of roads will be equal. If the area to be tapped is longer than n, a Class III road will be used, if not, sulky roads will be built.

To determine the value for V, the average length and width of the block must be determined. There is no simple way that this can be determined accurately, and so the best that can be done is a fairly accurate estimate made of the average length of the block and then by dividing the area of the block in square inches by the average length in inches, the average width is given. The average length of Block 6 was judged to be 10.7 inches. The area was 1,783 acres, and the scale of the map was 1 square inch equals 40 acres. Therefore, the average width is

$$\frac{1783 \text{ A}}{40 \times 10.7} = 4.17 \text{ inches} = 1.04 \text{ miles.}$$

Then, taking the unit of distance to be 100 feet, and with a volume of 5.36 cords per acre

$$V = \frac{100 \times 1.04 \times 5280 \times 5.36}{43560} = 67.5 \text{ cords}$$

and Sulky ~~Class III road~~ $= \frac{\$30}{52.8} = 57¢$ per 100 foot station

Hauling cost $=$ .02 per 100 feet

Class III road $= \frac{400}{52.8} = \$7.70$ per 100 foot station

Hauling cost $= \frac{.5132}{5 \times 52.8} = .002$ per 100 foot station

$$h = (.02 - .002) \times 67.5 = \$1.215$$

$$R = \$7.70 - .57 = \$7.13$$

$$n = \frac{(2 \times 713) - 121.5}{121.5} = 10.7$$

So, since the break-even point is 1,070 feet, and the average length of the block is 5,490 feet it will definitely pay to use a Class III road rather than sulky roads. The next question is how far should this road extend into the block. Using the spacing formula $S = \sqrt{\frac{.33R}{VC}}$

the normal spacing for Class III roads should be:

$$S = \sqrt{\frac{.33 \times 40000}{5.36 \times 2}} = 3500 \text{ feet.}$$

So Class III roads should normally be spaced 3500 feet apart, so as to serve a strip 1,750 feet on each side. Then the road should be continued to within 1,750 feet of the edge of Block 6. Using this as a guide, the road was drawn as shown on the map.

Using the same procedure, the roads were lain out in blocks 2 and 3.

In planning for a class V road to run through the entire property and north-east from Block 16 it must be remembered that this road had to be built to this standard and continued past the property boundary to serve as a supply road for camps to be established in an adjoining logging area. Otherwise a calculation similar to the one just completed would have to be used to determine the standard of road to be built into Block 16. But since this road had to be built, it was decided that the cost of building the road through the entire territory should be born by the cordwood on the area. The next question then was where to locate the road. There were two possibilities, to locate the road where it now stands, or to follow the blue line shown on the map. The deciding factor was the sulky hauling cost to the different locations. Calling the location of the road as shown on the map, Road I, and the other possible location as shown in blue, Road II, and letting the area west of Road I be known as Blocks 12B, 14B, and 15 B; the area east of Road II, Blocks 10, and 13; and the area between Roads I and II Blocks 12A, 14A, and 15A; the sulky hauling costs to each location were figured as follows.

The average sulky hauling distance for each of the blocks was estimated in chains, with 20 chains equaling one inch. Then the average cords per acre times the acres of cordwood area in each block times the average sulky hauling distance gives the total number of chains of sulky haul necessary per block. This figure divided by 80 gives the number of miles of sulky haul and this times the sulky haul cost per mile gives the total sulky hauling cost to Roads I and II. These calculations are:

Sulky haul cost to Road II

Block No.	Average Sulky Haul	Cords per A	Acreage	Total Sulky Haul
13	30 chs.	5.94	906	161,000
10	28	6.73	1,114	210,000
12 A	36	5.83	901	189,000
14 A	32	4.62	309	45,600
15 A	30	5.38	580	93,600
12 B	(46 + 72)	3.84	1,142	518,000
14 B	(59 + 64)	4.48	777	429,000
15 B	(43 + 60)	4.36	1,578	708,000
	Total sulky haul in chains			2,354,200

Sulky haul cost to Road I

Block No.	Average Sulky Haul	Cords per A.	Acreage	Total Sulky Haul
13	(30 + 62) chs.	5.94	906	495,000
10	(28 + 68)	6.73	1,114	720,000
12 A	36	5.83	901	189,000
14 A	32	4.62	309	45,600
15 A	30	5.38	580	93,600
12 B	46	3.84	1,142	202,000
14 B	59	4.48	777	205,000
15 B	43	4.36	1,578	295,000
	Total sulky haul in chains			2,245,200

2,354,200 - 2,245,200 = 109,000 chains

$\frac{109,000}{80}$ = 1,362.5 miles more of sulky haul to Road II than to Road I.

1,362.5 x 52.8 x.02 = $ 1,440

Or, there is a saving of $1,440 if Road I location is used rather than Road II location.

If it were not necessary to have a Class V road, the area could be better served by two Class III roads on a spacing of approximately 4,200 feet, as shown by using the spacing formula

$S = \sqrt{\frac{33R}{VC}}$ with V as the overall average cords per acre.

$S = \sqrt{\frac{33 \times 40000}{3.78 \times 2}} = 4200$ feet. This would result in a reduction in sulky hauling costs and road building costs, which would more than off set the increased truck hauling cost.

Another possibility would be putting a Class III road parallel to the Class V road along the route spoken of previously as Road II, thus having the area served by two roads rather than one, but by a calculation similar to the one deciding the location of the main road, it was found to be unprofitable, and so the idea was dropped.

Summary

Thus, by correct spacing of sulky roads, depending on cost of road construction, volume per acre, and twitching cost, and by a correct planning and locating of main road systems, again keeping in mind all changes in volume per acre and volume to be carried over each road, we have been able to draw up a logging plan with a total cost of only $3.84 per cord delivered to the point of delivery. This is for an area of 20,700 acres with an over-all volume of only 3.78 cords per a acre, and should be proof that, it is profitable to log areas with low over-all volume if enough attention is paid to correct planning so as to arrive at minimum costs per unit of volume. This correct planning can be done with the use of road spacing formulae, using the results given in the formulae as a guide to give the approximate road plan to be used in the woods, and then fitting this road plan to the area as topography and location of timber demand.