SOME METHODS OF COLLECTING
LOGGING COSTS
by

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INTRODUCTION

To plan a logging operation in an efficient manner, it is necessary to have information regarding the area to be operated and the equipment which will be used on the operation. In a great many cases, information regarding the area and equipment is very sketchy and experience is relied on to take the place of the information that is lacking. In the days when a large margin existed between the sale value of the product and the cost of production, it was not necessary to carry out comprehensive estimates since there was always a large factor of safety as a cushion against unanticipated costs. The day is fast approaching, however, when stumpage prices will leave a profit margin which will not withstand any but minor underestimations of costs of production. In preparation for this day and as a means of increasing present profits through correct planning, the wise operator will commence assembling as much data, on costs and production times, as circumstances permit.

The important elements in the accomplishment of work in any industry are time and cost. Actually these are one and the same thing, since time through the medium of the machine rate leads directly to cost. In the logging industry, the element of time, although considered important in planning the operation as a whole, is often neglected in the specific instances in which it has the greatest effect on cost. Great care may be exercised, for example, to ensure that sufficient trucks are available to complete a trucking operation by a certain date, while the fact that each truck spends a half hour a trip covering a mile of ill prepared tap road, is ignored. That half hour per trip lost, due to an insufficient expenditure in fixed costs, may be raising the cost of trucking, per sale unit, by twenty percent. Whereas, the cost of extension of the trucking period, prorated over the entire volume moved, would cause an insignificant rise in the cost of trucking. The cost per day of running the operation is a well developed figure and increasing the period of operations is a recognized cost. On the other hand, the delays which really cost money are often neglected.

It is with the hope of developing some practical means of collecting time and cost of production figures, that this paper has been undertaken. The principles of "Cost Control in the Logging Industry" by D.M.Matthews are the bases for the examples of the use of cost data. The suggested forms have been devised with the aim of producing, with a minimum of effort, the data required to apply the techniques of the above mentioned text.

To be of use on other operations, costs from current operations must be expressed as "unit costs" or "unit times." Unit times in this case being distinguished from operation times by the fact that unit times refer to the components of the operation time. Skidding, for instance, is one of the major operations in logging, and the average time per sale unit for skidding, for the whole operation may be considered as an operation time. In skidding with a tractor, however, part of this average operation time will be spent in hooking on to the logs and part in moving with the logs through the woods. The hook on time and the travel time are the unit times referred to above. An operation time does not lend itself readily to use in planning future operations, where ground and stand conditions will almost surely be quite different from conditions on the area on which the operation time was observed. Unit times on the other hand can be collected more easily and can be readily used in planning future operations as well as in determining the efficiency of current operations.

Current accounting methods will usually give accurate information on costs of production but these figures are available only after the operation has been completed and it is then usually too late to make the alterations in planning that the recorded costs would indicate as desirable. By the use of unit times and machine rates, costs of current operations are always available and hence current planning may be done in the light of what is happening at the time. The estimate of cost using unit costs will not have the accuracy of the detailed accounts. This sacrifice of accuracy, however, is more than offset by the advantage of having the information available when operating plans are being formulated.

A Classification of Logging Costs.

There is a wide variety of costs involved in the production of logs. These costs, however, may be segregated into groups, all the costs of a group having the same general characteristics. A broad outline of these characteristics is as follows:

Class "A" Costs. Direct labor and machine costs which vary with the size of the tree. Included in this group are: felling and bucking, skidding, loading and hauling.

Class "B" Costs. Costs which are constant per sale unit. Such items as supervision, association dues, workman's compensation, etc., are included in this class. Piece rates for felling and bucking, although often considered to be in this class, should rightly be included in the Class A costs since analysis shows that the felling and bucking cost should vary inversely with the size of the timber.

Class "C" Costs. Fixed and Overhead Costs. In this category fall such costs as improvements, office saleries and cruising.

Following are two general statements concerning the above costs, which, if considered carefully by managers, would cause many of them to remodel their operations.

1. Class C costs should be incurred with only one aim, namely that of reducing Class A and B costs by an amount equal to, or greater than, the expenditure in the Class C category. The converse of this statement is probably the most significant in the practice of cost control, an insufficient expenditure in the class C category almost surely results in excessive Class A and B costs.

2. In calculating an economic diameter cutting limit it is the sum of the Class A and B costs which should be compared with the value of the logs. Every sale unit that is moved, is charged directly with the A and B costs and its value must cover these costs or it is being logged at a loss.

Relative Value of Direct and Indirect Time Studies.

(1) Direct Timing.

The usual procedure in making a time study consists of taking stop watch observations of all of the principal time elements of the logging operation and of measuring the amount of work performed in terms of volume produced and distance transported. This direct measurement has three major disadvantages:

a. The presence of a timer on a job tends to introduce abnormal working conditions which will almost surely affect the rate at which the work progresses.

b. The tendency in stop watch timing is to be content with too small a sample.

c. Direct measurement of this kind is costly and will usually be discontinued as soon as figures, deemed reasonably accurate,have been obtained.

(2) Indirect Timing.

This method involves observation of total time and total production from which average times per sale unit may be easily calculated. These average times are the "operation times" referred to on page 2 and in this form , are not readily applicable to other situations. However, from previously established trends of costs or unit costs these averages may be used to estimate future costs or check the accuracy of unit costs in current use. These averages are much more easily and cheaply acquired than by the detailed direct timing method, and once standardized, the studies can be set up to operate indefinitely without special supervision. This method, however, is limited in useful application and has the following disadvantages:

a. It must occasionally be supplemented by stop watch timing as it cannot be applied to the collection of data in all elements of the logging operation.

b. It is apt to be somewhat slower because, conclusive results can only be obtained on completion of the element of operation under consideration.

SECTION 1

Machine Rates.

Since frequent reference to machine rates will be made in the ensuing discussion, consideration will be given here to the nature of machine rates, and some methods of obtaining them.

The machine rate of a given piece of equipment may be described as the cost of owning and operating that equipment for a unit of time, usually expressed on a per hour or per minute basis. The ownership costs may be considered fixed costs independent of the amount of operating time. Operating cost as the name implies, includes the costs incurred as a result of operation.

The machine rate is one of the most important factors in the planning of almost any element of the logging operation as it is the basis of all cost control formulas. Accordingly care should be taken to obtain as accurate machine rates as possible. Fixed charges are the easiest to collect, since some record can usually be found of such expenditures as, initial cost, insurance charges, license cost, etc., for individual pieces of equipment. The operating charges, however, are almost never recorded separately for different pieces of equipment. Therefore, estimates by those men associated with the operation of the equipment, may have to be accepted, until accurate information can be assembled.

All of the costs involved in getting a piece of equipment into operation and keeping it in operation, should be included in the machine rate. For instance, in the discussion on road construction costs on pages 82 and 86, standard construction times using various pieces of equipment are set up. In estimating the total cost of road building using these standard times, machine rates must be set to cover every expense involved. The machine rate for labor must carry not only wages but also cost of food (if not covered by board charges), depreciation on small tools etc. Also,when when a temporary camp is used and frequent moves are made, the machine rate must include the cost of moving.

Examples of comprehensive machine rate development for a team and D-2 tractor are given on pages 8,9 and 10.

In order to provide some method of collection of operating costs Form 1 has been devised. As presented,the form lends itself more readily to use with a tractor than with any other type of equipment. By changing the headings, however, the same type of form could be used for horses or trucks. Each quarter, the totals for the three months in that quarter are posted from Form 1 to Form 2 and on this form the quarterly machine rates are calculated. (Forms 1 and 2 are presented on pages 11 and 12)

Explanation of Forms.1 and 2

Entries in Form 1 should be made by the camp clerk from information provided by the tractor operator. This information may be conveyed by means of supply slips on which the machine operator denotes the quantity of supplies taken and the machine for which they were used. The operating time is recorded for use in Form 2. The operating charges of the quarter are prorated over the hours worked by dividing by the total operating time for the quarter. By recording maintenance time, it is possible to attribute,to the equipment making most use

MACHINE RATE FOR TEAM.

		Per 8 hr. day
1.	Labor	
	A. Teamster @ 60 cents per hour plus 22% for Workman's Compensation, Social Security, etc.	$ 5.86
	B. Barn Boss, $75 per month plus Workman's Compensation and Social Security, prorated over 10 teams and on 230 work days per year.	0.48
	C. Blacksmith, $130 per month plus Workman's Compensation and Social Security. 230 work days per year, 30% charged to teams.	0.25
	Total Labor Charge	$ 6.59

2. Operating Cost

20 lbs. oats @ 3 cents	$ 0.60
50 lbs. hay @ 2 cents	1.00
	$ 1.60

Cost per day assuming 230 operating days per year. $\frac{\$1.60 \times 365}{230}$ $ 2.55

3. Depreciation, Maintenance etc.

A.	Initial cost, team and harness	$ 566
	Trade in value in 5 years	100
	Amount to be depreciated	$ 466

B. Average annual depreciation $\frac{\$ 466}{5 \text{ year life}} = \$93.20$

C. Interest on average investment, @ 6%

Average investment $\frac{I + R}{2} + \frac{\text{Ann. Dep.}}{2}$

$= \frac{\$566 + 100}{2} + \frac{\$93.20}{2}$

$= \$379.60 \times 0.06 =$ $22.70

D. Allowance for Taxes and Insurance or other provision for risk, 4% of $379.60 $15.18

E. Average annual repairs to harness & team $20.00

F. Average Annual Depreciation and Interest on Barns and Stables $ 9.40

Total annual depreciation etc. $160.48

G. Average daily charge for depreciation etc. $\frac{\$160.48}{230} = 0.70$

Average cost per day $9.84

Hourly Machine Rate $\frac{9.84}{8} = \$ 1.23$

MACHINE RATE FOR D-2 TRACTOR

1\. Labor — Per 8 hr. day

A.	Operator @ 75 cents per hour, plus 22% for Social Security etc.	$ 7.32
B.	Hooker @ 60 cents per hour, plus 22% for Social Security etc.	$ 5.85
C.	Mechanic and Blacksmith time prorated to one tractor.	$ 1.50
	Total	$14.67

2\. Supplies

A.	Diesel fuel, 8.7 gal. @ 10.5 cents	$ 0.92	
B.	Gasoline 0.7 gal. per day @ 16.9 cents	.12	
C.	Lubricating oil, 0.47 gal. @ 71 cents	.33	
D.	Grease, 3.22 lbs. @ 17 cents	.55	$ 1.92

3\. Depreciation and miscellaneous recurrent expenses

A. Annual depreciation,

Initial cost of tractor	$2,154.00
Hyster Winch	500.00
Cable, 100 ' of 5/8"	18.60
Tong rack	18.60
2 Skidding tongs and chains	20.00
Total initial investment	$2,711.20

Total Initial Investment	$2,711.20
Trade-in value after 3 years	800.00
Amount to be depreciated	$1,911.20

Average annual depreciation

$$\frac{\$1,911.20}{3\text{ yrs.}} = \$\ 637.07$$

B. Interest on average investment @ 6%

Average investment

$$\frac{\$2,711.20 + \$800}{2} + \frac{\$637.07}{2}$$

$$= \$2,074.14 \times 0.06 \qquad \$\ 124.45$$

C.	Average annual personal property tax 2% $2,074.14 x 0.02	$ 41.48
D.	Average annual insurance 2% $2,074.14 x 0.02	$ 41.48
E.	Average annual repair charges	$ 500.00
	Total Annual Fixed Charges	$1,344.48

Average fixed charges per day based on 230 work days per year.

$$\frac{\$1,344.48}{230} = \qquad \$\ 5.84$$

Total average cost per day.

Labor	$14.67
Supplies	1.92
Depreciation etc.	5.84
Average cost per day	$22.44

Hourly Machine Rate $\frac{\$22.44}{8 \text{ hrs.}} = \$2.80$

(11)

Machine Number........ Form-1

Daily Operating Cost Sheet

Month.............. 19.....

Machine Type.......................

Operators Hourly Wage.......

Location.......................

Helpers Hourly Wage.......

Date	Operating Time	Maintenance		Idle Time	Diesel Fuel		Gasoline		Lubricating Oil		Grease		Parts		Miscellaneous.	Remarks.
	Hours.	Time	Cost	Hours	Gal.	Cost	Gal.	Cost	Gal.	Cost	Lb.	Cost	Name or No.	Cost		
1	8				9	.95	3	.507	1	.71	3	.51				
2	8				10	1.05					4	.68				
3																
4	8				8	.84	3	.507	2	1.42	3	.51				
5	8				9	.95					3	.51				
6	8				10	1.05			1	.71	3	.51				
7	8				8	.84					3	.51				
8	8				8	.84	3	.507	1	.71	4	.68				
9	8				9	.95					3	.51				
10																
11	8				7	.73			1	.71	3	.51				
12	6				11	1.16	3	.507			3	.51				
13	8				9	.95			1	.71	3	.51				
14	8				8	.84					4	.68				
15	8				10	1.05			1	.71	3	.51				
16	8				10	1.05					3	.51				
17																
18	6				7	.73	3	.507	2	1.42	3	.51				
19	8				9	.95					4	.68				
20	6				7	.73			1	.71	3	.51				
21	8				8	.84					3	.51				
22	8				9	.95	3	.507	2	1.42	3	.51				
23	8				10	1.05					3	.51				
24																
25	6				7	.78			1	.71	3	.51				
26	8				8	.84					3	.51				
27	8				9	.95	3	.507	1	.71	3	.51				
28	8				12	1.26					3	.51				
29	8				11	1.15					3	.51				
30	8				15	1.58	3	.507	2	1.42	3	.51				
31																
Total	200				234	25.01	24	4.05	17	12.07	82	13.94				

Form-2

Equipment Operating Cost Summary

Estimated Useful Life . . 3 . . Years @ . . 2000 . . Hours per year. Machine Type . . . D-2 . . . .

Original Cost . . $3 000 . . . Machine Number . . . .

Date Acquired . . . .

	First Quarter						Second Quarter						Third Quarter						Last Quarter					
	1st Year		2nd Year		3rd Year		1st Year		2nd Year		3rd Year		1st Year		2nd Year		3rd Year		1st Year		2nd Year		3rd Year	
	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly
Fixed Charges:	$	¢																						
Depreciation	1000-	50.0																						
Interest on Average Investment.	180-	7.5																						
Insurance	40-	1.5																						
Taxes	80-	3.5																						
Total Fixed Charges	1300-																							
	Quarterly $		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly		Quarterly	
Operating Charge:																								
Operators Wage		75.0																						
Helpers Wage		50.0																						
Social Security		5.0																						
Diesel Fuel	75-	12.5																						
Gasoline	12-	2.0																						
Lubricating Oil	36-	6.0																						
Grease	42-	7.0																						
Maintenance																								
Overhaul (Yearly)																								
Quarterly Operating Charges	165-																							
Hourly Machine Rate		$2.20																						
Statistical Data																								
Days Operated	75																							
Hours Operated	600																							
Days of Breakdown	Nil																							

of it , the cost of maintaining a mechanic or garage staff. In the example of machine rate for D-2 tractor, the Mechanic and Blacksmith time were prorated, assuming that each tractor had the same charge against it. This practice fails to bring to light those pieces of equipment, which, through high maintenance cost are no longer economical to operate and should be replaced.

The fixed charges recorded in Form 2 are normally identical for each year, hence the fixed portion of the machine rate is constant and may be recorded as a total. The form may be expanded to include any number of years of useful life, and for the sake of easy comparison of machine rates at different ages, it is recommended that the entire life be recorded on one page.

If calculated by the method described, the machine rate will vary for each quarter and each year depending on the length of time worked and the expenses incurred. This does not mean that, for equipment of different ages and in different seasons of the year, different machine rates should be used in the planning of operations. The system is suggested as a means of collecting the data required to build up a reliable average machine rate for each type of equipment and at the same time provide a reliable check on the efficiency of the current operation of the equipment.

The use of this form in determining the advisability of retaining a machine for an additional year, as compared with replacing it now with a new machine, is illustrated as follows: Assuming that, from records of a certain tractor over two years of operation and from records of previous tractors over longer periods, the following data has been assembled.

Present age, 2 years

Initial cost $3,000.00

Present trade in value $1,000.00

Annual cost of insurance and taxes $ 120.00

Trade in value one year hence $500.00

Operating charges	1st year	$500.00
	2nd year	1,000.00
	3rd year	1,500.00

Interest on the investment to be calculated at 6%

In view of the rapidly mounting operating costs due to high maintenance charges the wisdom of retaining the tractor for the third year, is questioned. The following comparative annual cost calculations illustrate a method of deciding the question in the light of the costs involved.

If acquiring a new tractor would be more economical at this time it would also be more economical to replace the tractor every two years. Accordingly, for the new tractor the depreciation is calculated on the basis of a two year useful life.

Comparative annual cost of acquiring a new tractor.

Capital Recovery:

Depreciation $\dfrac{\$3{,}000 - \$1{,}000}{2 \text{ yrs.}}$ — $1,000.00

Interest on average investment,

$\left(\dfrac{\$3{,}000 + \$1{,}000}{2}\right) + \dfrac{\$1{,}000}{2} \times .06 =$ 150.00

Insurance and Taxes	120.00
Average annual operating costs	750.00
Total Annual Cost	$2,020.00

Comparative annual cost of retaining old tractor another year.

Capital Recovery:	
Depreciation, $1,000 - $500 =	$ 500.00
Interest on average investment, $1,000 x 0.06 =	60.00
Insurance and taxes	120.00
Operating costs	1,500.00
Total Annual Cost	$2,180.00

From the above calaulations it is evident that replacement at the end of two years of operation would be slightly more economical. Since the margin in this case is not great, the machine would probably be retained for the additional year. If the operating costs increased in the fourth year to the amount indicated by the trend, it would certainly be more economical to replace the tractor after three years of operation. Without records of operating costs including maintenance, the replacement of the tractor would rely on hunch and the possibility of saving money by replacement in the second or third years might well be overlooked.

Truck Machine Rates.

The example of a truck machine rate on page 16 illustrates the main differences between truck machine rates and tractor or team machine rates.

The distinction between fixed and operating costs in truck machine rates is of more significance than in tractors or teams. While under pay, tractors, teams and stationary equipment like loaders are presumed to be actually operating. For trucks, however, the situation is different in that during loading and unloading time, although drivers wages,

LAKE STATES REGION

MACHINE RATE FOR ONE and ONE-HALF TON TRUCK
(Based on 2000 Hour Year and 3 Year Life)

xed Cost per Hour

License and Insurance (Michigan data)

Registration	$55.00	
Public liability: $50,000/100,000 plus $25,000 Property Damage	52.20	
Collision ($50 Deductible)	40.00	
Fire and Theft	32.00	
	$179.20 ÷ 2000 hours =	$0.090

Depreciation

Original cost	$1,800.00	
Less tires	300.00	
	1,500.00	
Less wrecking value	200.00	
To be depreciated	$1,300.00 ÷ 6000 hours =	0.216

Labor (Michigan data)

Drivers' wages (plus 10% overtime)	0.880	
Helpers' wages " "	0.770	
Social security, workmen's compensation, etc., at 21%	0.347	
Total Fixed Cost per Hour		$2.303

erating Cost per Hour

Oil at $0.30 per qt. - 10 qts. every 50 hours	0.06	
Repairs - average of $400.00 per year	0.20	
Greasing and general maintenance	0.04	
Fuel (average)	0.40	
Tires - $300.00 ÷ 1,00 hours	0.30	
Total Operating Cost per Hour		1.00
Hauling Cost per Hour		$3.30

depreciation, etc., are going on, the truck engine is not running and no operating charges are being incurred. The charge against a truck while it is being loaded or unloaded, then, is the fixed charge only. While the truck is hauling and the engine is actually running the fixed cost and operating cost are summed up into the hauling cost.

The cost of tires, which require replacement at frequent intervals, should be deducted from the initial investment before depreciation is estimated. Depreciation on tires is more truly an operating charge than a straight fixed depreciation charge. Accordingly, the cost of tires when removed from the initial cost is placed in the operating charge category.

The roads over which the trucks operate will have a great effect on the length of life of the tires. In practice, it will rarely be possible to keep an accurate record of the mileage that a tire sustains on various road standards. If and when the opportunity presents itself, however, it would be a definite advantage to acquire such information, thereby increasing the accuracy of the machine rate.

SECTION 2

FELLING AND BUCKING

General.

Felling and bucking is the work involved in the conversion of standing trees into logs or pulpwood. This conversion process can be analyzed into a large number of distinct steps, and cost estimates made of each. Delay time in walking between trees, undercut time, felling time, limbing time and bucking time are components of the total time required to convert the standing timber into logs or pulpwood. Time studies have been made of each of these actions separately and such studies used in developing new methods and new equipment for the conversion process. The use of these times in estimating the cost of future operations has not been widely practiced, however, due to the variations in labor efficiency and stand conditions which make impossible the application of actual times.

The cost of felling and bucking does not have any effect on planning a logging operation. Naturally, it is important in calculating the total cost of the logs, but the selection of equipment, spacing of spur roads, standards of all roads, etc. will not be modified by the cost of felling and bucking.

Felling and Bucking Logs.

For use in estimating the cost of felling and bucking in proposed operations, a comprehensive study should be made of felling and bucking times by diameter classes. Times should be classified by species and locality, since considerable variation will exist between species, especially between the hard and soft woods. Labor efficiency and methods may vary in different localities, accordingly, classification by locality is necessary.

This comprehensive study should be conducted on a wide range of conditions and over a great many different operations. Efficient crews should be used as the basis for the studies. When completed the data will serve to establish, not actual times, but a trend of times, for use in future operations. The data required to establish trends are the actual time of felling, limbing and bucking, for all diameter classes that are likely to be encountered.

This comprehensive study may be quite expensive to make, since a fairly large quantity of sampling may have to be done to establish figures of desirable accuracy. However, once this work has been completed it can be used until a major change in felling and bucking methods makes the data obsolete. Time collection may be combined with the collection of data for volume tables, in which case a form similar to that represented on page 20 might be useful.

Use of Form 3.

The headings listed are required for the following reasons:

Species and D.B.H.- The bases of classification for both volume tables and time studies are species and d.b.h.

Total Length- This entry is added for use in volume table construction.

Log Diameters - The diameters of the logs produced from the tree will be necessary in calculating the board feet of lumber in the tree, for use in both the volume table and

Form-3

Felling and Bucking Time Record

Log Production.

Date ....   Recorder ....

Location ....

Species	D.B.H. (inches) o.b.	Total Length (ft.)	Log diam. at small end. Logs 16'3"				Felling Time	Limbing and Bucking Time	Topography	Terrain	Remarks
			1st/log	2nd/log	3rd/log	4th/log					

timing study.

Felling Time - All times in this study should be taken with a stop watch. The felling time would be a measure of the time actually spent in felling, no delay or idle time being included. The same principle applies to limbing and bucking time. Where there is any possibility that logging may be done in tree lengths, the limbing and bucking time should be recorded separately. The trend for felling and limbing may be slightly different than where bucking is included.

Topography and Terrain - Under topography and terrain should be recorded the slope, if any, upon which the tree is growing and the brush, windfalls or other interferences which might influence the production time.

The remarks column should cover exception to normal conditions such as condition of tools, which might affect the efficiency of the felling crew.

Presentation of the Data.

The following schedule illustrates the results of some reliable time studies taken in South Carolina on the felling and bucking of southern pine. The trend shown here may or may not be applicable to different species in different localities. At any rate, before these or similar data are applied to other stands, they should be carefully checked.

Felling and Bucking Time Per M bd. ft.

Southern Pine in South Carolina

D.B.H. inches.	Man Hours per M bd. ft.
10	5.12
12	4.45
14	3.65
16	3.15
18	2.70
20	2.37
22	2.17
24	2.10
26	2.18
28	2.36

Use of the Data in Determining Cost of Felling and Bucking in Other Stands.

The opportunity of management to exclude from the cut, those diameter classes which would be logged at a loss, represents the only justification for spending money on the collection of felling and bucking cost data of this kind. Having set up the basic times as indicated above, the next step in applying that data to the proposed cut, is to provide a reliable stand table of the area to be cut, with volume distribution by diameter classes. A small area of about 10 acres, which represents conditions on the entire cutting area, should be cut. From this sample cut, total volume and total cutting time only, need be recorded. These data can be obtained from scale and time sheets and collection in this case is exceptionally cheap and easy, a good example of indirect timing. From total time and total cut the average time per M bd.ft. is obtained, with this average time, the table of stand composition by d.b.h. classes, machine rate per hour of the cutters and the trend of times previously set up, the cost of felling and bucking by d.b.h. classes can be established. The following example illustrates the method.

Illustration of the Method of Adapting Basic Production Data to a Specific Production Situation.

1	2	3	4	5	6	7	8
			Basic Data				
DBH	Vol. per acre ft. b.m.	% Vol. in each d.b.h. class	Production time per M bd.ft hrs.	Time in % of time for 10" class	Relative time for prod. of timber in each class (Col.3 x Col.5)	% of time contributed by each class (entries col.6 ÷ sum col 6)	Time to produce 1 M bd. ft. of timber of each size class (6.24 hr. x col.5)
10	348	.0486	5.12	1.00	.0486	.076	6.24
12	831	.1162	4.45	.87	.1010	.158	5.43
14	1694	.2366	3.65	.713	.1690	.263	4.45
16	1800	.2514	3.15	.615	.1548	.241	3.84
18	1032	.1441	2.70	.528	.0761	.119	3.30
20	742	.1037	2.37	.463	.0480	.075	2.89
22	712	.0994	2.25	.440	.0438	.068	2.75
Total	7159	1.00			.6413	1.00	

From observations made on a small sample cut the average felling and bucking time for this stand has been determined as 4 hours per M bd.ft. when cutting all timber 10" d.b.h. and up.

To calculate time for 10" class alone:

64.13% of the time to produce 10" timber is 4 hrs

100%, or, the time to produce 10" timber is $\frac{4 \text{ hrs.} \times 1.00}{.6413}$

$= 6.24$ hrs.

Alternative calculation:

4.86% of the total volume or 48.6 bd.ft. of each M cut in the stand requires 7.6% of the average time of 4 hrs. therefore 1,000 bd.ft. in the 10" class would require $\frac{.076 \times 4\text{hrs.}}{.0486}$

$= 6.24$ hrs.

The felling and bucking times from Column 8 can be easily converted into cost per M by multiplying by the machine rate of labor. To the felling and bucking cost by d.b.h. classes should be added the cost of skidding, loading and hauling calculated by cost control methods. This makes the total of the Class "A" costs. The Class "B" costs must be added to this to give the total amount that the operator is obliged to pay on every M bd.ft. removed. By comparing this total to the selling price of the logs the gross profit or loss by d.b.h. classes is obtained. The diameter classes which are being logged at a loss are immediately apparent and plans should be made to eliminate these classes from the cut. The amount of the Class "C" costs has no effect on the d.b.h. limit and should be applied after the economic limit has been set by the above method.

The peculiar method of weighting used in the illustration on page 23, is necessary because felling and bucking times, although they vary inverseley with d.b.h. are not directly correlated with d.b.h. In other words the average time, with an average d.b.h. from one stand, may be quite different from the average time of another stand with the same average d.b.h. but of different stand composition.

Trends, in felling and bucking, are reliable because methods are fairly well standardized in this class of work. The same method of calculating skidding, loading and hauling costs can be used. Trends, however, in these categories are not so reliable, due to the wide range of methods and variations in roads (spacing and standard) and equipment. For this reason a calculation of skidding, loading and hauling costs patterned on the principles laid down in "Cost Control in the Logging Industry" is recommended.

SECTION 3

SKIDDING

It is in the skidding operation that some of the greatest savings can be made through proper planning. The allocation of equipment to skidding distances at which it is most efficient and the spacing of roads, where opportunity permits, at their most economic distance in the light of skidding cost, are the main points to be considered.

The "unit times" of a skidding operation are the hook-on time and the travel time. The hook-on or fixed time is constant per M bd. ft. for any given log size and is quite independent of the length of skid. The travel or variable time is constant per M bd. ft. per unit of distance and varies with the length of the skid. With these unit times known for any machine plus average load and machine rate, the economic spacing of roads and the skidding cost per M bd. ft. are easily calculated.

CASE PROBLEM

Probably the best way to demonstrate the advantages of breaking out fixed and variable time costs and to suggest methods of improving cost collection technique, is to consider an example where no attempt was made to distinguish between fixed and variable time costs.

In a paper presented at the annual meeting of the "Woodland Section of the Canadian Pulp and Paper Association," January 27-29, 1937, on the subject "Skidding Pulpwood with Tractor and Skidding Pan" the following costs and production data were presented:

Expences and Operating Data over a Period of Eleven Weeks.

Running time	629.5 hours
Number of trips to river	2586
Average number of trips per week	244
Maximum skidding distance	52 chains
Minimum skidding distance	8 chains
Average skidding distance	23 chains
Number of logs delivered to the river	37,520
Total f.b.m.	724,231
Labor costs including board	$850.23
Costs of fuel, lubricating oil, repairs	$154.34
Depreciation at $1.00 per hour	$629.50
Total cost	$1,634.07
Cost per M bd.ft. exclusive of depreciation	$1.39
Cost per M bd.ft. including depreciation	$2.25

Lost time

Bad weather	22 hours
Trouble starting tractor	3 hours
Tractor laid up for repairs	30.5 hours
Miscellaneous causes	8 hours

Skidding crew

Two men making up loads and fixing chokers

One tractor driver

One helper for tractor driver

Two men for unloading and rolling in at dump

Wages

Laborers $40.00 per month plus board

Tractor driver $75.00 per month plus board

Tractor helper $60.00 per month plus board.

Timber

Ninety-year-old Jack pine yielding approximately 4 M bd.ft. per acre with 3 M bd.ft. over 7 inches d.b.h. Logs are cut in 12 ft. and 16 ft. lengths, with about 80 % in the longer length class.

Equipment

RD-4 Diesel Caterpillar tractor and 8 ft. pans.

Operating conditions

The country is slightly rolling with shallow gullies parellel to the river bank. Grades are short but rather steep. The soil is sandy and dry with very little windfall or underbrush.

Conclusions regarding tractor skidding vs. horse skidding

Costs to date indicate that tractors can compete successfully with horses from distances of 10 to 20 chains and will prove cheaper than horse skidding and hauling for distances of from 20 to 50 chains.

This, in summary, is the data presented in the paper. No doubt the experiment was undertaken in the first place to gain some knowledge of the physical difficulties likely to be encountered in this type of work as well as its economic possibilities. However the statement of costs provides very little information which could be used in planning future operations. The fact that skidding Jack Pine logs of average d.b.h. of over seven inches, a distance of 23 chains using D-4 tractor and pan, will cost about $2.25 per M bd.ft. is the only information useful in future planning. There is no mention of the spacing of the tractor trails or of their cost of construction. Horses were used for bunching but no mention is made of average bunching distances. No attempt has been made to express skidding cost in its component factors of fixed and variable costs. The fixed time in this case is the time required to winch the load on to the pan, hook-on to it plus any time spent at the river bank in unhooking the loaded pan and hooking on to the empty pan for return to the woods. The variable time, for reasonable accuracy, would be the difference between the total round trip time and the fixed time divided by the skidding distance. In this type of experimental work, a comprehensive breakdown of total skidding time per turn, as outlined on page 44, could be undertaken to advantage, not only to obtain an accurate breakdown of total time, but also as a means of detecting inefficiencies in the set-up and thereby determining possibilities of reducing the time costs of the operation without a corresponding increase in expenditure.

The first item to be calculated in this case is a machine rate for the tractor. The nature of the operation indicates that on the minimum skidding distance the crew of two men making up loads and fixing chokers would not be capable of keeping ahead of the tractor, or, if such were possible on such short skidding distances as eight chains, then on the maximum skidding distance of fifty-two chains there would be a great deal of idle time for both the loading and unloading crews. The wages of the entire crew of six men should be considered as part of the machine rate of the tractor because, as shown above, the ground labor expense per unit is not constant but varies directly with the skidding distance.

The machine rate including ground labor, as indicated by the information contained in the paper is as follows:

Tractor Machine Rate.

Fixed Charges			Per Hour
Depreciation/[1]			$1.00
Operating Charges			
Labor costs	$\frac{\$850.00}{629.5 \text{ hrs.}}$	=	1.35
Supplies and repairs	$\frac{\$154.34}{629.5 \text{ hrs.}}$	=	.246
Cost of pan.			
Material	$60.00		
Labor	20.00		
Total Cost	$80.00 per pan		
Depreciation on 3 pans per hour			
	$\frac{3 \times 80}{629.5}$	=	.382
			$2.978

Machine rate per hour $2.98

Machine rate per minute $\frac{298}{60} = 4.96¢$

A more detailed machine rate could be drawn up if accurate records showing the various items of expense, were available. In organizing work of this nature care should be taken to keep explicit records of all items of expense connected with the operation of the equipment. It is probable that only a portion of the cost of the pans would be depreciated on this operation. If so, the machine rate would be slightly reduced.

The Machine Rate Excluding Ground Labor.

Calculation of the portion of the machine rate chargeable

1 The depreciation charge is rather high indicating that interest, insurance and taxes are probably included.

as ground labor.

Ground labor 4 men @ \$40.00		\$160.00
Machine labor:	Operator @ \$75.00 Helper @ \$60.00	135.00
Total labor charge per month		\$295.00

$$\frac{\text{Ground labor charge}}{\text{Total labor charge}} = \frac{\$160.00}{295.00}$$

Let "X" equal ground labor charge for the entire operation

$$\frac{X}{850.23} = \frac{\$160.00}{\$295.00}$$

$$X = \frac{160 \times 850.23}{295} = \$462.00$$

Ground labor cost per minute $\frac{\$462.00}{629.5 \text{ hrs.} \times 60} = 1.23¢$

Machine rate including ground labor	4.95¢	per	min.
Ground labor	1.23¢	"	"
Machine rate excluding ground labor	3.72¢	"	"

Calculation of Fixed and Variable Time Costs.

Since the data, as presented, allow no positive calculation of the fixed and variable time per M bd. ft., some assumptions are necessary. It should be pointed out that a simple timing of the tractor from the woods to the landing, over a few days of operation, would make possible fairly reliable calculations and obviate the necessity of making any assumptions.

Distances expressed in hundreds of feet rather than chains are more readily applicable to use in cost control formulas. The skidding distance will, therefore, be expressed in this form.

The average roading distance for this operation is 23 chains or expressed in stations of 100 ft. equals 15.2 stations.

The average total time per trip is

$$\frac{629.5 \text{ hrs.} \times 60}{2,586 \text{ trips}} = 14.6 \text{ min.}$$

Assuming that the tractor is roading at the rate of one round trip station of 100 feet in 0.75 min. the fixed trip time is calculated as follows:

Total round trip time for average trip	14.6 min.
Variable time on average trip 0.75 x 15.2 =	11.4 min.
Fixed time per trip	3.2 min.

If this assumed roading speed is correct, the low fixed time indicates great efficiency in winching the load on to the pan and in hooking and unhooking the pans. The fact that the logs are bunched by horses contributes greatly in reducing the fixed time. On this operation the logs were bunched on the tractor trails by horses, into bunches of thirty to fifty logs. The significance of pre-bunching being that, under these conditions horse skidding cost can be considered as a constant cost per M bd.ft. and should not be considered as part of the machine rate of the tractor. If, however, the bunching had been done as the skidding progressed, with the accompanying inefficient use of the horses on the long tractor roading distances, then the machine rate of the horse bunching would have to be included in the machine rate of the roading tractor. Under these conditions, the cost for bunching would be a function of the roading distance.

Calculation of fixed and variable cost per M bd.ft. including ground labor cost in the machine rate:

Load per trip $\frac{724.2 \text{ M}}{2586 \text{ Trips}} = 0.28$ M bd.ft.

Fixed time per trip 3.2 min.

Fixed time per M bd.ft. $\frac{3.2}{0.28} = 11.4$ min.

Fixed cost per M bd.ft. 11.4 min. @ 4.95 ¢ 57.0¢

Variable time per trip per 100 ft. 0.75 min.

Variable time per M bd.ft. per 100 ft. $\frac{0.75}{0.28}$ = 2.68 min

Variable cost per M bd.ft. per 100 ft. 2.68 x 4.95 = 13.25¢

Fixed and variable costs per M bd.ft. excluding ground labor from the machine rate of the tractor would be:

Fixed cost per M bd.ft. 11.4 min. @ 3.73¢ = 42.5 ¢

Variable cost per M bd.ft. per 100 ft. 2.68 min.@ 3.73¢= 10.0¢

Calculation of the Actual Total Skidding Cost per M bd.ft.

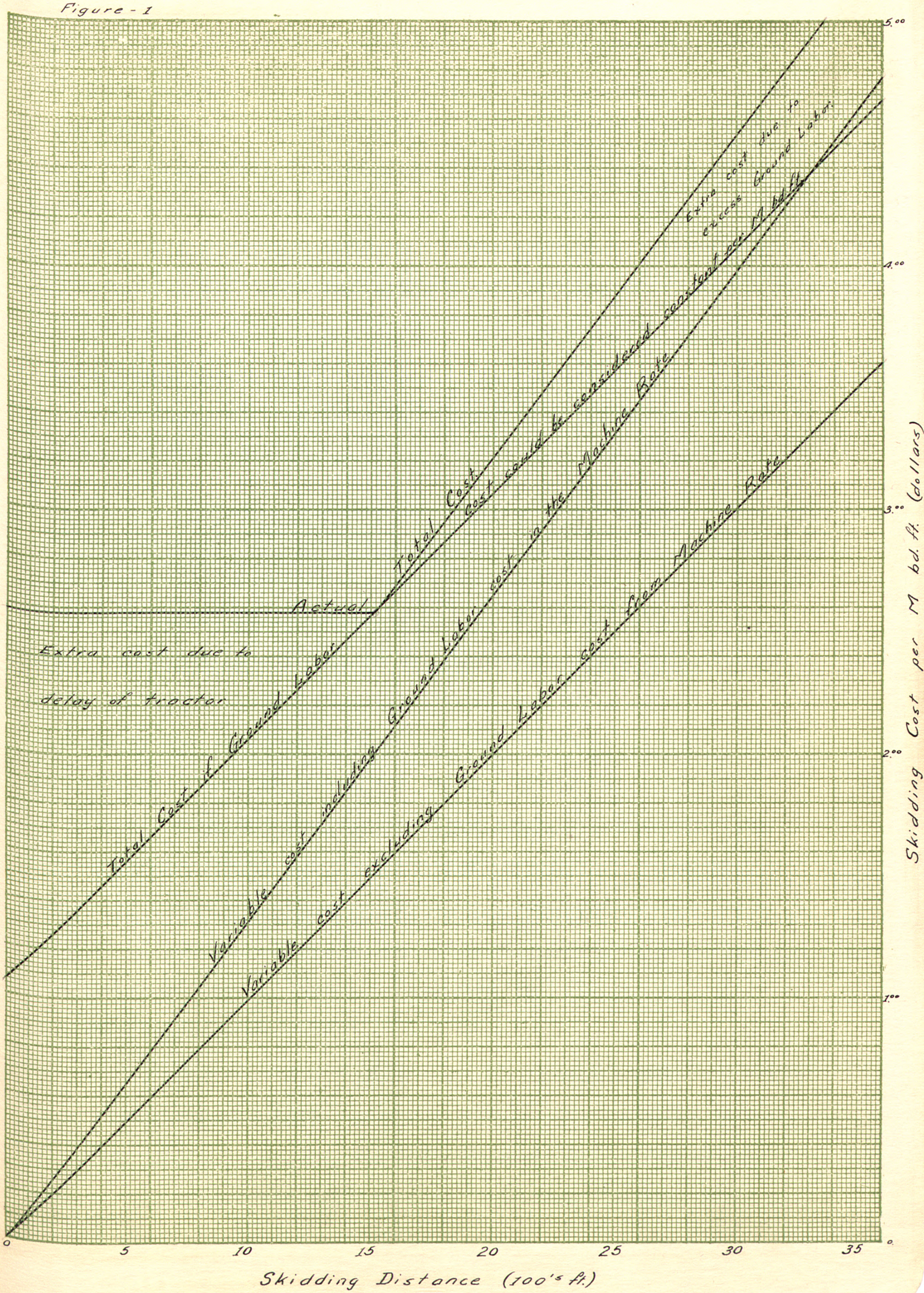
From the operating data presented it is noted that the average skidding distance is 23 chains or 15.2 stations of 100 ft. Since no record is available as to the length of time required, by the two man loading crew, to make up loads in the woods, the most reasonable assumption is that this crew was designed to give maximum skidding efficiency at the average skidding distance of 15.2 stations. The length of time required by this crew to load a M bd.ft. of logs then would be:

Fixed time per M bd.ft.	11.4 min.
Roading time on 15.2 sta. hauls $\frac{15.2 \times 0.75}{0.28}$ =	40.7 min.
Total time required to make up load of M bd.ft.	52.1 min.

If the foregoing assumption is correct, i.e. that skidding time and loading time are in balance at a skidding distance of 15.2 stations, then at any skidding distance up to 15.2 stations the loading time will be the limiting factor and regardless of the skidding distance the cost will be:

Ground Labor 52.1 min. @ 1.23 ¢ =	64.0¢
Tractor 52.1 min. @ 3.72¢ =	194.0
Total	$2.58

Figure - 1


Total Cost
Actual
Total Cost f. Ground Labor
Cost could be considered constant per M bd. ft.
Extra cost due to excess Ground Labor
Variable cost including Ground Labor cost in the Machine Rate
Variable cost excluding Ground Labor cost from Machine Rate
Extra cost due to delay of tractor
0
5
10
15
20
25
30
35
Skidding Distance (100's ft.)
1.00
2.00
3.00
4.00
5.00
Skidding Cost per M bd. ft. (dollars)

Reference to Fig. 1 page 33 shows the actual total skidding cost as a horizontal line at $2.58 up to 15.2 stations skidding distance. At distances greater than 15.2 stations, the tractor roading time is the limiting factor and ground labor becomes more and more in excess as the skidding distance increases. At a skidding distance of 30 stations, for instance, skidding time and time cost would be as follows:

	Time	Cost
Fixed time per M bd.ft.	11.4 min.	42.5¢
Roading time per M bd.ft. $\frac{30 \times 0.75}{0.28} =$	80.3 min.	299.5¢
Total Tractor Time per M bd.ft.	91.7 min.	342.0¢
Loading time	52.1 min.	64.0
Idle ground labor time per M bd.ft.	39.6 min.	48.6
Total Skidding cost		$4.55

From the above calculations it is obvious that ground labor cannot be considered as a constant cost per M bd.ft. unless it is so manipulated that no excess labor cost is charged to the skidding operation, such perfect balance could almost never be obtained. It is, therefore, advisable to consider ground labor cost of this kind as a function of the skidding machine and include the ground labor cost in the tractor machine rate. Considering ground labor cost as a part of the machine rate, total skidding cost for 30 station skidding distance is easily calculated as follows:

Fixed cost per M bd.ft.	57¢
Variable cost per M bd.ft. 30 x 13.25 =	398¢
Total skidding cost	$4.55

The calculations for the cost of skidding, given above, are for specific loads skidded that distance. Whereas, when the cost per M bd.ft. for skidding is to be calculated for the area logged, the cost must be given for the average distance that the total of all the material is to be skidded. In order to estimate the average tractor skidding distance for any trail or any depth of timber, the distance of direct horse skidding must be known.

Calculation of the Economic Direct Horse Skidding Distance.

For the case under discussion the first 8 chains or 5.3 stations were skidded by horse, directly to the river bank. The reason for selecting this as the maximum direct skidding distance, is not given nor is there given sufficient data to enable a comparison to be made of the cost of direct horse skidding with horse bunching and tractor skidding. To show the method by which this distance could be reliably estimated, some production and cost figures for horse skidding will have to be assumed.

Horse Skidding.

Fixed time per trip	5 min.
Variable time per trip per 100 ft.	1.5 min.
Load per trip	100 bd.ft.

Fixed time per M bd.ft. $\frac{5}{.100} = 50$ min.

Variable time per M bd.ft. per 100 ft. $\frac{1.5}{.100} = 15$ min.

Using an assumed machine rate for team of 1.5¢ per min. the fixed and variable costs per M bd.ft. would be:

Fixed time cost per M bd.ft. 50 x 1.5 = 75¢

Variable time cost per M bd.ft. 15 x 1.5 = 22.5¢

The limit of economic direct horse skidding will be the distance at which the cost of direct horse skidding equals the cost of the combination of horse bunching and tractor skidding.

Since the spacing of the tractor trails has not been given it will be assumed that they have been built about 4 stations apart.

C Cost of direct horse skidding for any distance "D":

Fixed cost per M bd.ft.	75¢
Variable cost per M bd.ft.	22.5 D
Total cost 75 + (22.5 x D)	

Cost of horse bunching and tractor skidding for the distance "D":

Fixed cost of horse bunching per M bd.ft.	75¢
Variable cost of horse bunching per M bd.ft.	
$22.5 \times \frac{S}{4}$ where S is the spacing of trails	
$22.5 \times \frac{4}{4} =$	22.5¢
Fixed cost of tractor skidding per M bd.ft.	42.5¢
Variable cost of tractor skidding per M bd.ft.	10 D
Total cost	140+(10 x D)

Solving for the economic direct skidding distance "D"

$$75+(22.5 \times D) = 140+(10 \times D)$$

$$22.5D - 10D = 140 - 75$$

$$12.5 D = 65$$

$$D = 5.2 \text{ Stations or about 8 chains}$$

This calculation would be correct if ground labor was being provided in sush a manner that the tractor was not delayed either at the landings or in the woods and that no waste labor expense was being charged to the operation. By reference to Fig.1 it will be found that actual tractor skidding cost at 5.2 stations, exclusive of the bunching charge, is $2.58. Under these conditions, the economic direct skidding distance would be calculated as follows:

$$22.5 D + 75 = 258$$

$$22.5D = 258 - 75$$

$$D = \frac{183}{22.5} = 8.1 \text{ stations or 12 chains}$$

It is evident then that direct skidding should be carried out up to distances of 8 stations, above this distance the combination of bunching and tractor skidding should be used.

Calculation of Skidding Costs for Tractor Trails of Various Lengths.

All trails 8 stations or less in length should be horse skidded directly to the river and the cost would be $F + C\frac{D}{2}$

where F = Fixed cost of horse skidding

C = Variable cost of horse skidding

and D = Depth of the skidding area from the river.

All trails over 8 stations in length should be skidded by direct horse skidding up to 8 stations and horse bunching with tractor skidding for distances of over 8 stations from the river. Skidding costs for various lengths of trail have been tabulated in Table 1 (page 38b). The tabulated figures have been arrived at as follows: Column 3 has been calculated by the use of the formula given above, up to a maximum of 8 stations. Column 4 is the average cost of the tractor skidding for the amount of timber tractor skidded. Column 5 is the weighted sum of Columns 3 and 4.

Illustration of Method of Calculating The Costs Presented in Table 1.

For a depth of timber of 30 stations along a stream the timber is to be skidded by teams and tractor with pan to the stream. What will be the average skidding cost?

Length of trail or Depth of timber 30 Sta.

Average skidding distance:

Horse skidding $\frac{8}{2} = 4$ Sta.

Tractor skidding $\frac{30 - 8}{2} + 8 = 19$ Sta.

Average. Weighted.

Cost of Horse skidding $F + C \frac{D}{2}$.

$75 + 22.5 \times \frac{8}{2}$ $1.65

Weighted for 8 sta. 8 x 165 = 1,320

Cost of Tractor skidding.

Skidding cost at 30 sta. $4.52 (See Fig. 1)

Skidding cost at 15 sta. 2.58 " " "

Average cost at 22.5 sta. $\frac{\$7.10}{2}$ = $3.55

Weighted for 15 sta. (from 15 to 30 sta.) 3.55 x 15 = 5,320

Skidding cost from 8 to 15 sta. (constant) $2.58

Weighted for 7 sta. (from 8 to 15 sta.)
7 x 2.58 = 1,805 7,125
7,125 8,445

Average cost of tractor skidding $\frac{7,125}{15 + 7}$ = $3.24.

Average cost of combination skidding $\frac{8,445}{30}$ = $2.81

The table given for average skidding costs per M bd. ft. will apply regardless of the spacing of trails that is used, because the bunching cost is considered separate from the skidding cost and does not enter the above calculations. It should be noted however, that bunching cost will apply to that portion of the timber only, which lies beyond 8 stations from the river bank (the horse skidded timber will not be bunched). In the case above, if trails are spaced at 4 station intervals, the bunching cost would be $F + C \frac{S}{4} = 75 + 22.5 \times \frac{4}{4} = 97.5¢$ per M bd. ft. applied to $\frac{30-8}{30}$ = 73.5% of the total volume skidded.

It is desirable, in the final analysis, to express skidding and bunching cost as so much per M bd. ft. for every M bd. ft. logged. Accordingly, the bunching cost of 97.5¢ applied to 73.5% of the volume is not a convenient way of expressing the bunching cost. A more desirable method is to prorate the bunching cost, applicable to 73.5% of the volume, over the entire volume. In this case the bunching cost applicable to the entire volume would be 0.735 x 97.5¢ = 71.6¢ per M bd. ft. As the "length of trail" is decreased the bunching charge of 97.5¢ will apply to a smaller proportion of the total volume and accordingly, a smaller charge per M bd. ft., applied to the total, will be required. The bunching cost per M bd. ft. which can be applied to the total volume is represented in Fig. 2 page 39 for various spacing of tractor trails and various lengths of trail.

In any particular operation where one arrangement of skidding is adhered to and where machine rates have been

BLE 1

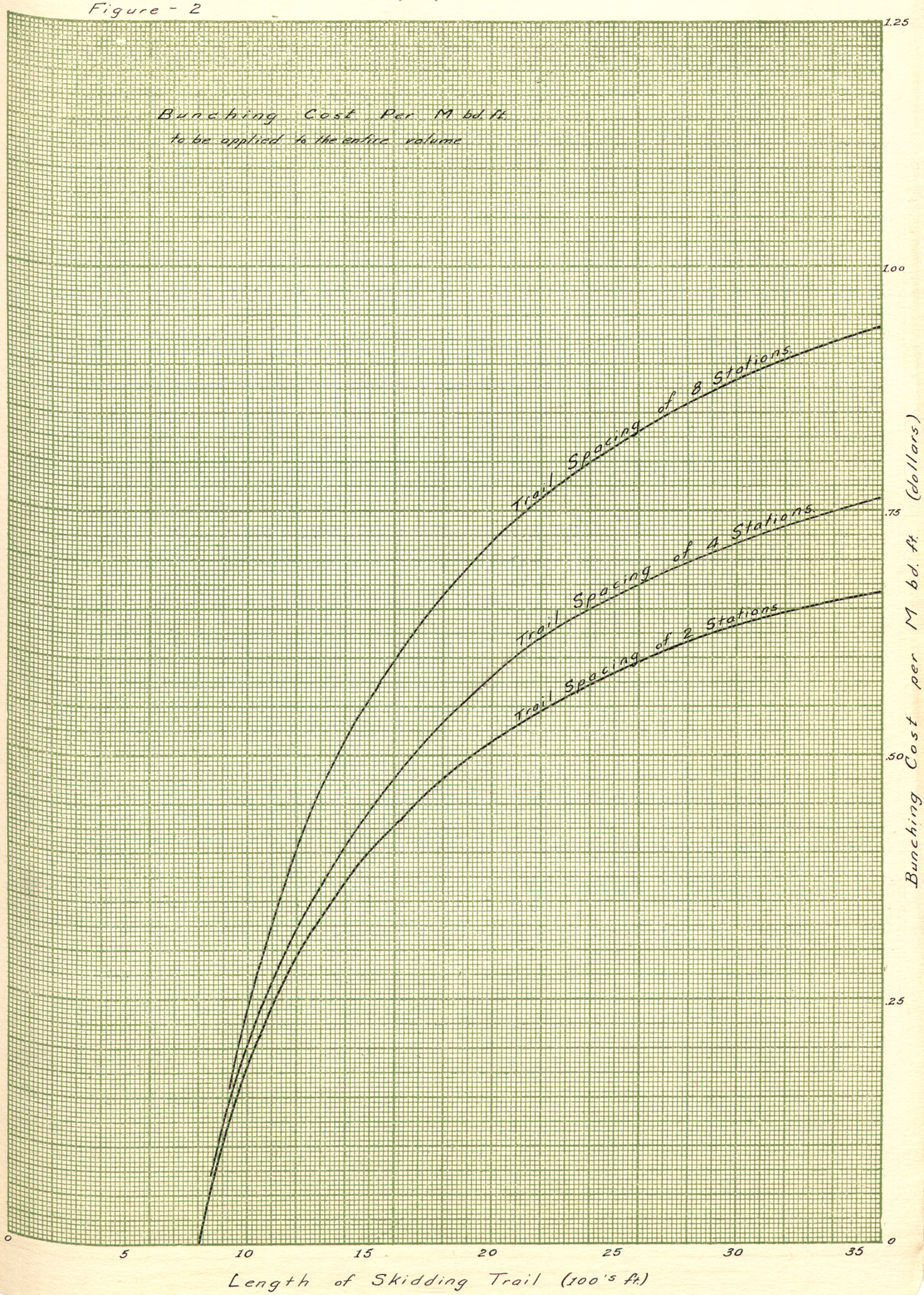
Skidding Cost for Various Depths of Timber

(1) Depth of Timber Sta.	(2) Average Skidding Distance Horse.	Tractor.	(3) Cost of Horse Skidding	(4) Cost of Tractor Skidding	(5) Total Average Skidding Cost
2	1	-	97.5¢	-	97.5 ¢
4	2	-	120	-	120
6	3	-	142	-	142
8	4	-	165	-	165
10	4	9	165	258 ¢	183
12	4	10	165	258	196
14	4	11	165	258	205
16	4	12	165	259	212
18	4	13	165	265	220
20	4	14	165	271	228
22	4	15	165	280	237
24	4	16	165	290	248
26	4	17	165	301	259
28	4	18	165	312	270
30	4	19	165	324	281
32	4	20	165	335	292
34	4	21	165	347	305
36	4	22	165	359	317
38	4	23	165	372	328
40	4	24	165	385	340

NOTE: The average skidding cost, for the average skidding distance of 15.2 stations as given in the original data on page , is \$2.25 while that read from the table above is \$2.82. This rather marked discrepancy may be attributed to the necessity of assuming, (1) roading speed of the tractor (2) all production figures for horse skidding, and (3) loading time required by the loading crew.

With accurate and complete data collection no estimates or assumptions would be necessary and the calculated cost would agree more closely with the actual cost obtained by dividing total cost at the end of the operation by total production.

Figure - 2



Bunching Cost Per M bd. ft.
to be applied to the entire volume
Trail Spacing of 8 Stations
Trail Spacing of 4 Stations
Trail Spacing of 2 Stations
1.25
1.00
.75
.50
.25
0
0
5
10
15
20
25
30
35
Bunching Cost per M bd. ft. (dollars)
Length of Skidding Trail (100's ft.)

established with reasonable accuracy, the operating manager may find it convenient to draw up schedules similar to Table 1 which will enable rapid and accurate calculation of total skidding costs.

Location of the Tractor Trails.

Experience may be relied on to a great extent in the location of tractor trails but even men very experienced in such work, and surely those who have had but little experience, will welcome a method of calculating the spacing of roads or trails which is quite independent of training. The following formula allows such a calculation, provided certain information regarding costs and volumes are available.

$$S = \sqrt{\frac{0.33\ R}{V \times C}}$$

Where S = Spacing of roads in stations of 100 ft.

R = Cost of road construction per mile, cents.

V = Volume per acre in M bd.ft. or other unit.

C = Cost per M bd.ft. or other unit, of skidding a distance of 100 ft., cents.

This formula, originally designed for skidding to a truck or haul road, is applicable to a case of this kind if "R" represents the cost of trail construction and "C" the cost, per M bd.ft., of horse skidding a distance of 100 ft. Since data concerning cost of trail construction are not presented they must be assumed. In sandy rolling country of the type chosen for this experiment, tractor trails can be built for as little as $50.00 per mile, and this rate will be assumed for this example. The following values for the unknowns in the above formula have been assumed or measured --

R = \$50.00 per mile

V = 4 M bd.ft. per acre

C = 22.5¢ per M bd.ft. per 100 ft.

The spacing of trails as calculated by the formula would be:

$$S = \sqrt{\frac{.33 \times 5000}{4 \times 22.5}} = \sqrt{\frac{1650}{90}} = \sqrt{18.35} = 4.2 \text{ sta.}$$

The indicated spacing of 420 ft. will serve as a guide in locating tractor trails, naturally it is not intended that this spacing shall be rigorously observed. Careful scrutiny of the spacing formula will reveal some pertinent facts which are too often overlooked.

(1) Increase in trail construction costs will increase the economic spacing of trails.

(2) Decrease in the volume of timber removed per acre will increase the economic spacing of trails.

(3) Increasing efficiency of the bunching machine with a corresponding decrease in the variable skidding cost will increase the economic spacing of trails.

Simple Application of the Spacing Formula and Cost Table.

On a driveable stream in the area under consideration the average depth of timber, to be logged by horse bunching and tractor skidding, is 35 sta. The stand per acre averages 7 M bd.ft. and trail construction will cost \$70.00 per mile. Machine rates as determined above.

$$\text{Spacing of trails} = \sqrt{\frac{.33 \times 70000}{7 \times 22.5}} = 14.65 = 3.8 \text{ sta.}$$

Skidding cost per M bd.ft. (Table 1)	\$3.110
Bunching cost per M bd.ft. (Fig.1)	.705
Total skidding cost per M bd.ft.	\$3.815

Collection of Skidding Times and Costs.

The application of the formula and the use of the cost graph and table are very simple, as illustrated above, the accuracy of the results, however, is only as good as the accuracy and completeness of the data used. In the calculations given above many assumptions were made which would have been unnecessary, if complete records had been prepared.

Preliminary to a study of collection techniques it is advisable to list the facts that will be required in the final analysis.

(1) Required. Comprehensive breakdown of total skidding time per turn for all types of equipment used.

Uses. (a) To pick out inefficiencies in the operation.

(b) To obtain accurate data on fixed and variable time.

(2) Required. Simple method of determining fixed and variable time.

Uses. (a) To ckeck computations under (1).

(b) To keep time costs up to date.

(3) Required. Comprehensive study of ground labor requirements.

Uses. (a) To prevent waste of tractor or ground labor time.

(4) Required. Machine rates on all equipment used.

Uses. (a) For accurate computation of time costs.

(b) For a comparison of the relative efficiency of machines of the same type.

(c) To determine the most efficient distribution of different types of machines.

(5) Required. Determination of the cost of construction of tractor trails of various standards.

Uses. (a) To determine the most economic spacing of tractor

(b) To increase tractor roading efficiency.

(6) Required. Accurate determination of the volume of timber per acre, to be removed.

Uses. (a) To determine the spacing of tractor trails.

(b) To determine the economic standard of the tractor trails.

Many of these requirements may be collected at the same time and forms should be constructed with this in mind.

Items 1 and 3 above will ordinarily be carried out where new equipment is being introduced or where standard equipment is being used in a new or different capacity. The case problem here described may be considered to lie in the latter classification, since the use of tractor and pan skidding, on operations of this type, was not common in Quebec at the time of these observations.

Item 2 is essentially the same as Item 1 except that it should be designed to operate without direct observation or timing by other than the men normally on the job. The information obtained by this method will not be as accurate or as comprehensive as by Item 1 but the volume of measurmens obtained will outweigh these disadvantages.

Machine rates can be accurately obtained only by recording separately, for each piece of equipment, all of the costs that are involved in the owning and operating of that equipment.

Road and trail construction costs are simple time costs of the men and equipment used in their construction plus a proportion of the overhead costs chargeable to the operation.

The use of cruise data in the determination of the volume to be removed (for use in the spacing formula) is satisfactory provided there is no wide variation of volume per acre within a small area. If types and volumes change frequently it will be necessary to make a preliminary estimation of volume on the area prior to the layout of roads.

Techniques of Data Collection.

The following quotation[1] will serve to introduce the type of classification necessary in the collection of "unit times."

Breakdown of Skidding Time Per Turn

Classification	Description of Time and Summarization of Controlling Factors
Fixed Time--Woods	Total from time tractor arrives at loading point until it is fully loaded and started toward road or landing.
a. Turn-around time	Time taken to maneuver into position to pick up load of logs that has been yarded or bunched by another machine. Controlled by topography, ground conditions, brush, and efficiency of ground crew.
b. Yarding or bunching time	Time taken by tractor to assemble its own load. Controlled principally by volume per acre and size of logs -- decreasing as stand per acre and average log size increases. Also affected by topography, ground conditions, and efficiency of ground crew, as above.
c. Hook time	Time taken actually hooking load onto drawbar or assembling load on pan or under arch and hooking tractor thereto.

1 D.M.Matthews, "Cost Control in the Logging Industry." p.89

Controlled principally by, and roughly proportional to, number of logs making up load.

d. Delay time — Time lost by machine between arrival at loading point and departure therefrom that cannot be attributed to mechanical failure. Principally due to difficult ground conditions and/or inadequate ground crew. This condition may be unavoidable when the skidding distance is short and when ground conditions are particularly difficult. It should then be included with fixed time and reasons given. If avoidable, it should be so reported and excluded from fixed time and reported as idle time.

Fixed Time--Landing or Road — Total from time tractor arrives at point where it drops its load until it is started on the return trip to the woods.

a. Unhook time — Time taken placing load at unloading point, unhooking load, and moving off landing or away from point where load is dropped. No delay time should be chargeable, since landings should be large enough to permit prompt dispatch of tractor on return trip.

Variable time — Total of elapsed time between woods and landing, exclusive of fixed time at landing or unhooking point.

a. Delay time — Time lost by machine while towing load or returning to woods because of hang-ups, slipped chokers etc. Such delays should be included with variable time to the extent that they are normal recurrent delays on the chance.

Idle Time

Time lost by the machine that cannot be attributed to it or to the crew. For example, waiting to be unhooked at landing; waiting to pass another machine that is stalled and blocks the way; waiting for load to be assembled by yarding team or tractor, etc. Delays such as these should be avoidable under proper planning and should not be included with either fixed or variable time.

Lost Time

Time lost by the machine that can be directly attributed to mechanical breakdown. Such lost time may or may not be avoidable, but it should not be included in performance data on which plans of operation are based. The character of such breakdowns should be recorded in order that appropriate action may be taken to prevent their recurrence.

The principles of the above quotation, initiated primarily for the recording of tractor skidding time, are applicable, within limits, to recording the breakdown of skidding time for any skidding machine.

Under the conditions of the case problem, since the logs are bunched with horses, a collection of the horse bunching or horse skidding time is the first consideration. Form 3 which follows closely the outline presented by Matthews[1] for tractor time record, ispresented as a possible means of collecting the required information.

In horse skidding small sized material (10 to 12 inch) horses are frequently used singly and in almost all cases the horse will go right to the log, obviating the necessity of yarding. The main time consuming element of the fixed time, therefore, will be dogging or choke setting in the woods and unhooking at the landing or tractor trail. If long skidding distances are resorted to in horse skidding or where slight adverse grades occur, there is apt to be considerable resting time for the horse which is actually a function of distance. Such delays should be included in variable time.

Since time studies of this kind will have to be carried out by personnel not ordinarily included in the skidding crew there should be ample opportunity to make all of the measurements indicated in the form. A continuous record of observed clock time tends to more accurate results and is generally easier to record. A stop watch may be used, however, in which case computed times would be recorded directly.

The example on Form 4 is purely hypothetical. It has been made to agree with the assumed data on page 35. By recording diameters of logs and average D.B.H. of the stand it would be possible to investigate the effect of diameter on the fixed and variable skidding costs. The relationship of diameter to cost of production is becoming more important as the margin between selling price and cost of production is decreased.

1 D.M.Matthews, "Cost Control in the Logging Industry." p.92

Horse Skidding Time Record

Location .... Date .... Recorder .... Ave. d.b.h. of stand.........

Arrived at Woods	Load: Log diam. small end.	Load: Length	Load: Scale (f.b.m)	Hook Time: Start	Hook Time: Finish	Computed Time (min): Turn Around	Computed Time (min): Hook	Computed Time (min): Swamp	Computed Time (min): Delay	Left Woods	Total Time: Productive	Total Time: Delay	Total Time: Idle	Total Time: Lost	Total Time: Total	Arrived Landing	Left Landing	Distance (100's ft.)
7:30	12"	14'	85	7:30 —	:34	1.0	2.0	1.0	-	7:34	40	-	-	-	4	7:37	7:38	3 Sta.
7:39.5	13"	16'	115	7:39.5 —	:42	0.5	2.0	-	-	7:42	2.5	-	-	-	2.5	7:46	7:48.5	4 Sta.
7:50.6																		

Example of the Use of Form 4

From the records taken on Form 4 page 48, fixed time per trip is the total under "Total Time" plus time spent at the landing. Variable time can be found by subtracting from the difference between the "Left Woods" time and the next "Arrived at Woods" time, the time spent at the landing.

For the example given on Form 4:

First Trip -

Fixed time - Total in woods time 4 min.

Time at landing 1 min.

Second Trip -

Fixed time - Total in woods time 2.5 min.

Time at landing <u>2.5</u> min.

Total time for 2 trips 10.0 min.

Average time per trip 10.0/2 = 5 min.

First Trip -

Variable time(0739.5 - 0734.0)-1 = 4.5 min.

Second trip -

Variable time(0750.5 - 0742.0)-2.5 = <u>6.0</u> min.

Total variable time for 2 trips 10.5 min.

Total one way distance for the 2 trips 4 3 = 7 sta.

Average round trip time per station 10.5/7 = 1.5 min.

Load per trip: First trip 85 bd.ft.

Second trip <u>115</u> bd.ft.

Volume skidded in 2 trips 200 bd.ft.

Average load per trip 200/2 = 100 bd.ft.

Fixed time per M bd.ft. 5/.100 = 50 min.

Variable time per M bd.ft. per 100 ft. 1.5/.100 = 15 min.

Tractor Time Records

The tractor time record shown in Form 4a page 51 has been copied almost unchanged from Matthews "Cost Control in the Logging Industry" page 92 and illustrates a practical method of obtaining a comprehensive breakdown of tractor time on a direct skidding operation. Detailed explanation of the use of this form can be found in the text from which it was taken.

In the case under discussion the tractor picked up loads that had already been made up on established tractor trails and Form 4a would not be applicable. From the foregoing discussion of ground labor it is apparent that a careful consideration of ground labor is necessary in operation planning. Accordingly, Form 5 page 52, Ground Labor and Tractor Time Record, has been devised as a possible means of obtaining the required data on tractor and ground labor time in their most useful form.

Description of the Headings of Form 5

Following is a description of the headings which are not self explanatory:

Tractor Number:- For the purpose of time studies and machine rate records each tractor should be alloted a number for easy reference.

Load M bd.ft.:- Where opportunity permits, the load should be recorded in greater detail - number of logs, average diameter and length being included.

Time:- The observed clock time is recorded under "Clock" for entries such as "Arrived Woods" or "Left Woods". The computed time is the breakdown, in minutes, of the elapsed time between sucessive entries in the "Clock Time" column.

Form- 4a

Tractor Time Record

Location .... Date .... Recorder .... Ave. d.b.h. of stand ....

Tractor No.	Arrived Woods	Yarding									Turn Around and Hook					Left Woods	Total Time					Arrived Landing	Left Landing
		Start	Log	Dist. 100 ft	Diam. small end	Length	Scale ft. b.m.	Computed Time (min.)			Start	Finish	Computed Time (min)				Productive	Delay	Idle	Lost	Total		
								Yard	Delay	Total			Turn Around	Hook	Delay								

Form - 5

Ground Labor and Tractor Time Record

Average d.b.h. of stand (in.) . . . . . .   Location . . . .

Recorder . . . .   Date . . . .

Trip Number	1		2		3		4		5			
Tractor Number	4								4			
Ground Labor Crew (Number of Men.)	2								2		Total Load	Average Load.
Load (M's bd. ft.)	0.28								0.28		0.56	0.28
Time	Clock	Computed	Clock	Computed	Clock	Computed	Clock	Computed	Clock	Computed	Total	Average
Ground Labor Time — Computed Time (min.) — Swamping												
Bunching		11.4								11.4	22.8	11.4
Hook		2.0								2.0	4.0	2.0
Trail Improvement												
Idle										52.2	52.2	26.1
Total		13.4								65.6	79.0	39.5
Tractor Fixed Woods Time — Arrived Woods	7:30								2:59.7			
Left Woods	7:32						7:56.1		3:01.7			
Computed Time (min.) — Turn Around		1.0								1.0	2.0	1.0
Hook		1.0								1.0	2.0	1.0
Delay												
Idle												
Total		2.0								2.0	4.0	2.0
Distance (100's ft.)	15.2	—		—		-	30	—	30	-	45.2	22.6
Roading Time — Arrived Landing	7:38.5								3:14.4			
Arrived Woods	7:44.6								3:25.3			
Computed Time (min.) — Roading Out		6.5								12.7	19.2	9.6
Roading In		4.9								9.7	14.6	7.3
Delay Out												
Delay In												
Idle Out												
Idle In												
Total Variable Time Out	11.4	6.5							22.4	12.7	33.8	16.9
Total Variable Time In		4.9								9.7		
Tractor Fixed Landing Time — Left Landing	7:39.7								3:15.6			
Comited Time (min.) — Unhook		0.5								0.5	1.0	0.5
Delay		0.7								0.7	1.4	0.7
Idle												
Total		1.2								1.2	2.4	1.2
Total Fixed Time.		3.2								3.2	6.4	3.2

Remarks — Trip Number	
1	
2	
3	
4	
5	

Ground Labor Time:- Where one tractor only is skidding, the "Total" under "Ground Labor Time" is the difference between successive "Left Woods" entries of the tractor. In the example on Form 5, the total ground labor time of 65.6 minutes is the difference between "Left Woods" time on Trip 4 and "Left Woods" time on Trip 5. The breakdown of the 65.6 minutes is self explanatory since it merely records the occupation of the ground crew during the absence of the tractor. Where more than one tractor is skidding from the same ground crew the total ground labor time will be the difference between the "Left Woods" time of successive tractors.

Delay time is omitted from the headings of ground labor computed time because, all ground labor time which is not productive, is idle. It is a problem of planning and supervising to reduce this idle time to a minimum. If idle time can be completely eliminated from the ground labor time, and tractor delay time, due to loading, eliminated from tractor [illegible] time, then ground labor may be considered as a fixed cost per M bd.ft. Such efficiency may be approached by keeping a large loading crew on short skids and using a small loading crew in conjunction with the pre-bunching and tractor trail construction crews on the long skids. In that case only the load and hook time of the ground labor time would be charged to the tractor operation and it would be almost constant.

Tractor Fixed Woods Time:- The difference between "Arrived Woods" time and "Left Woods" time is the total under "Tractor Fixed Woods Time", the breakdown of that time into it's various components is self explanatory.

Roading Time:- Space is left for double entries under "Roading Time" to cover the trips into and out of the woods. The total

"Out" time under this heading, is the difference between the "Left Woods" time and the "Arrived Landing" time. The total "In" time is the difference between the "Left Landing" time and the "Arrived Woods" time. The total variable time is the sum of the total "In" and "Out" times.

Tractor Fixed Landing Time:- The difference between "Arrived Landing" time and "Left Landing" time is the total fixed landing time.

Total Fixed Time:- The total of "Tractor Fixed Woods Time" and "Tractor Fixed Landing Time" is the "Total Fixed Time".

Distance Measure

Care should be taken in measuring distance to assure that the direct distance from the load to the landing, is recorded. If the tractor trail is crooked so that the distance travelled is more than the direct distance, then, by recording the distance travelled, an error would be introduced. The total variable time would be considered as a measure of the time required to move the load a direct distance equal to the length of the trail, whereas, in map distance it would be moved only a fraction of this total. The effect of this type of misinformation would be to give an underestimation of the variable time per trip, with the resulting underestimation of skidding cost in future planning.
Example: If distance, in the example of Form 5 had been trail distance at 30 stations(average) instead of actual distance at 22.6 stations(average) then the variable time per 100 feet per trip would have been 16.9/30 =0.56 min. instead of 16.9/22.6 = 0.75 min, which is the correct value.

Summary of Comprehensive Time Collection

The hypothetical examples shown in Form 5 will serve to emphasize the large amouns (t) of idle ground labor time on long skidding distances where the loading crew is not adjusted. On very short runs a large amount of tractor delay time will be evident if the same crew is maintained. Reference to Fig.1 page 33, will illustrate the effect of these delays on the total skidding cost, and emphasizes the necessity for accurate information on production time in planning an efficient operation.

Although an important use of data collected in this form is as a means of determining inefficiencies in the operation, the main purpose is a comprehensive breakdown of total time into fixed and variable time.

From the average figures presented in the example, fixed and variable times per M bd.ft. can be easily determined as follows:

$$\text{Fixed time per M bd.ft.} = \frac{\text{Total fixed time per trip}}{\text{Load per trip}}$$

$$= \frac{3.2}{0.28\ \text{M}} = 11.4 \text{ min.}$$

Variable time per M bd.ft. per 100 ft.

$$= \frac{\text{Total variable time per trip}}{\text{Load x Ave. Skidding dist.}}$$

$$= \frac{16.916.9}{0.28 \times 22.6} = 2.68 \text{ min.}$$

These fixed and variable times per M bd.ft. will lead directly to an accurate computation of fixed and variable cost as soon as the machine rate for the tractor and average skidd- ind distance have been established.

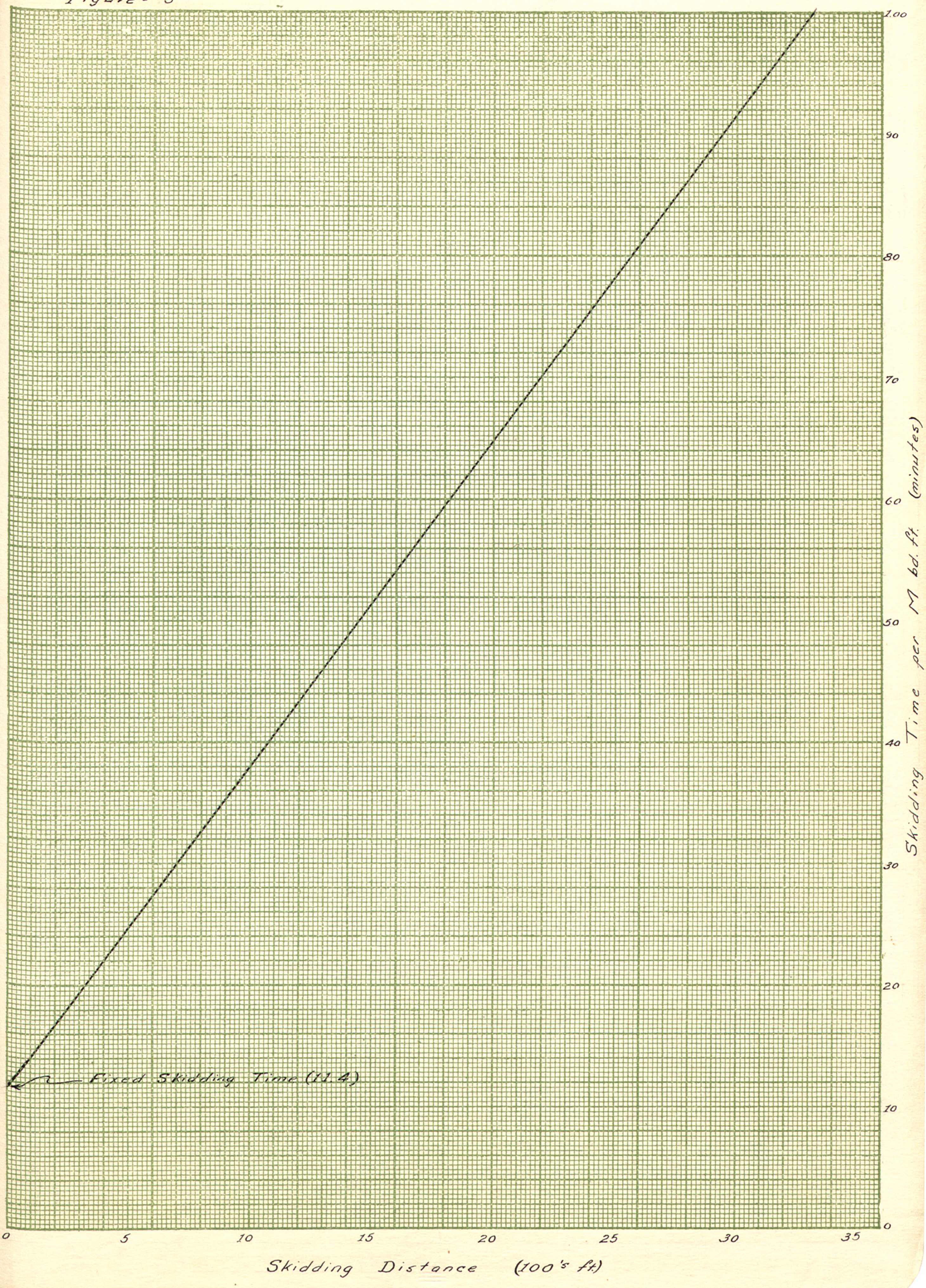
Simple Fixed and Variable Time Collection

The rather complicated time collection methods, which have been described above, do not lend themselves readily to any but the more intensive types of production studies. When fixed and variable times have been established within fairly narrow limits by the above mentioned methods, a less complicated system may be adopted which will serve as a check on the figures in use but will not involve an increased number of personnel on the job.

With reference to Form 5 page 52, the sum of fixed and variable time is seen to be 3.2 + 11.4 = 14.6 min. per trip or 14.6/0.28 = 52.2 min. per M bd.ft. for a skidding distance of 15.2 stations. For a distance of 30 stations the sum would be 3.2 + 22.4 = 25.6 min. per trip or 25.6/0.28 = 91.4 min. per M bd.ft. By plotting these total times per M bd.ft. on a total time over skidding distance graph, as shown in Fig. 3 page 57 and by joining the points and projecting the line the fixed time can be read where the line intersects the total time axis at 11.4 min. Since these were hypothetical cases, the fixed time read from the graph agrees exactly with the actual fixed time. In practice, a great many observations would be necessary to establish the fixed time by this method, with any degree of accuracy. However, the fact that total time per trip, average skidding distance and load are the only figures required, makes it possible to use this method without putting special observers on the job.

In a situation where the trail is logged, over its entire length, by the same arrangement of equipment and where no delay time due to insufficient loading crew or similar loss of tractor time, exists, the problem is comparatively simple.

Figure- 3


Fixed Skidding Time (11.4)
0
5
10
15
20
25
30
35
Skidding Distance (100's ft)
0
10
20
30
40
50
60
70
80
90
100
Skidding Time per M bd. ft. (minutes)

A measure of the total quantity of timber skidded, average skidding distance, number of trips and total time, will give a fairly accurate result. For example, timber distributed evenly over a 30 station trail is skidded entirely by tractor and pan. The following information being collected:

Volume skidded	28 M bd.ft.
Total time 3 days @ 8 hrs.	24 hrs.
Number of trips	100

From the above data:

Time per trip $\frac{24 \times 60}{100}$ =	14.4 min.
Volume per trip $\frac{28}{100}$ =	0.28 M bd.ft.
Average skidding distance 30/2 =	15 sta.
Total time per M bd.ft. 14.4/0.28 =	51.5 min.

These figures are the average of a comparatively large number of trips although they were not recorded individually, therefore the point determined by total time of 51.5 min. and average skidding distance of 15 stations would be quite reliable. From tractor trails of various lengths corresponding times could be obtained which would make possible the construction of a reliable graph.

In the case under discussion, two difficulties arise when a collection system of this kind is adopted (1) the first eight stations of each trail are horse skidded and (2) the delay time due to loading increases all times for distances below 15 stations to the same level.

The first difficulty may be eliminated by calculation of the average skidding distance by the formula -

$$\text{Average skidding distance} = \frac{D - d}{2} + d$$

where D = Total length of tractor trail

d = Portion of the trail skidded by horse

The error due to delay time in loading may be greatly reduced by a direct measurment of the maximum delay time (delay on the shortest run) and the total number of trips in which any delay was experienced due to loading. The product of one half the maximum delay time and the number of trips in which delay occured will give an approximation of the total delay time due to loading for that trail.

Form 6, page 60, "Tractor Skidding Record" is suggested as a possible means of obtaining the information from which to calculate total skidding per M bd.ft. for various lengths of trail.

Method of Recording Information on Form 6.

"Total length of trail" is not the length for any one day but should be entered when the skidding on that trail is completed and its total length is known. Where the entire operation is planned in detail before the work commences, this figure would be known in advance and may be filled in by the camp foreman. The length of trail to be horse skidded should be well established at its economic limit.

The maximum loading delay must be actually timed by the skidding foreman, tractor driver or other available person. As the trips are made they may be recorded directly on Form 6 or the tractor driver may use a separate pad and the final only transferred to Form 6. If correction is to be made for loading time it is necessary to keep a separate record of the trips in which delay due to loading occured.

The record of skidding times is for the purpose of obtaining total time from which total time per trip may be obtained.

Form - 6

Tractor Skidding Record

Location.................... Date.............

Tractor Number ...4.... Equipment ..Tractor and Pan.. Recorder...........

Total Length of Trail	30 Sta.
Length of Trail Skidded by Horse	8 Sta.
Maximum Loading Delay (Delay on shortest run)	5.4 minutes.
Trips where Delay Due to Loading Occured (Number)	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ || 32 trips } Total 100 Trips.
Other Trips (Number)	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ||| 68 trips

Date	Commenced Skidding		Finished Skidding		Volume of Timber Skidded from Trail
	A.M.	P.M.	A.M.	P.M.	
June 3 - 1945	7:30	1:00	12:00	5:30	12 M bd. ft.
" 4 "	7:30	1:00	12:00	5:30	9 M " "
" 5 "	7:30	1:00	12:00	5:30	5 M " "
" 6 "	7:30	~~1:0~~	11.00		2 M " "
	Total Time 31 hrs. 30 min.		Total Volume 28 M bd. ft.		

Any exceptional delays:— None.

Remarks:- Logs averaged about 10" diam and 16' in length. The Trail was in a generally good condition with a few short steep grades, Tractor run in 3rd gear loaded and 4th gear light. Logs were 90% Jack Pine

J.B.A.

Volume of timber skidded may be recorded by the method most convenient to the scaler, a daily record of volume is not necessary, only total volume is actually required. Where more than one trail is being skidded to the same landing at the same time it will be very difficult to keep the volume from different trails separate unless the loads are scaled as they arrive. Under these circumstances if the same type of equipment is being used by all of the skidding machines it may be assumed that each machine on the average carries the same load. The volume at the landing, therefore, would be proportioned to the different machines on the basis of the number of trips made by each.

Where exceptional delays due to breakdown or accident occur the cause and duration of the delay should be noted. The remarks space may be filled in by the camp foreman or skidding foreman and should include the approximate average diameter and length of the logs as well as the general conditions of weather, topography and trail.

From the data on Form 6 the following values may be established for use in constructing a graph of total time over average skidding distance:

Average skidding distance $\frac{D - d}{2} + d$

$$= \frac{30 - 8}{2} + 8$$

$$= 11 + 8$$

$$= 19 \text{ sta.}$$

Total time per trip

Total time 31.5 hrs. x 60 =	1831 min.
Total delay time(5.4/2)x 32 trips =	86 min.
Total productive time	1745 min.

Total time per trip 1745/100 = 17.4 min.

Load per trip.

Total volume skidded 28 M bd.ft.

Load per trip 28/100 = 0.28 M bd.ft.

Total time per M bd.ft. 17.4/0.28 = 62.3 min.

With reference to Figure 3, page 57, it can be seen that this figure agrees exactly with the actual total time per M bd.ft.

Use of Data Collected On Form 6

In the event that sufficient direct timing has been done to establish a graph, of the type shown in Figure 3, with accuracy, then the use of the data collected on Form 6 would be to check the direct timing calculations and establish the operating efficiency of the tractor.

If the fixed and variable times of the tractor had not been previously established the point on the "Average Skidding Distance"--"Total Skidding Time" graph determined by 19 stations and 62.5 minutes could be used with a few similar observations for different average skidding distances, to construct a graph as shown in Figure 3 and thereby establish the fixed and variable times.

The fixed and variable times may be determined from the graph as follows: the fixed time is the time on the total skidding time line where average skidding distance is zero. The variable time is best calculated by subtracting from the total time, at some fairly high average skidding distance, the fixed time calculated above and dividing the difference by that average skidding distance. For example, the total time at an average skidding distance of 30 stations is 91.4 min. Subtracting the fixed time of 11.4 min. and dividing by 30 we have $\frac{91.4 - 11.4}{30}$ = 2.66 min. per round trip station per M bd.ft. and average roading time per round trip station equals 2.66 x 0.28 = 0.75 min.

SECTION 4

LOADING AND HAULING

The case problem, just discussed, illustrates some methods of obtaining skidding cost data and the use that can be made of that data in improving skidding operations at present under way or planning future operations. In many cases the logs are skidded to landings at the road side in preparation for hauling by the use of sleighs, trucks or rail roads. Of these, the most common and the one in which planning has the greatest opportunity of affecting savings, is truck hauling.

Summer trucking in the north, and year around trucking where there is not sufficient snow for snow or iced roads, is well established and increasing in importance. Accordingly, some consideration will be given at this point to a means of collection of the costs involved.

R.R.Reynolds prepared an article, "Pulpwood and Log Production Costs As Affected By Type of Road", published in the December, 1940 issue of the Journal of Forestry, which presents trucking costs in considerable detail. A duplication of some of the tables and machine rates presented in the article, follows.

Table 3 Time Required Per Load

Product	Load	Unload	Delay	Total	Basis
	minutes				No.Loads
Pulpwood	44.87	26.61	4.14	75.62	84
Logs	41.30	13.70	9.20	64.20	184

Table 4

Time Required Per Load Per Mile Round Trip

Product	Type of Road: Woods	Graded Dirt	Gravel or Hard Surface
Pulpwood	22.7	7.9	4.7
Logs	21.1	8.6	4.5

The times for various types of roads, as listed in Table 4 above, are converted into costs per M bd.ft. for various loads of logs by the application of the machine rate. The results are tabulated in Table 8.

Table 8

Hauling Cost Per M bd.ft. Per Round Trip Mile

Average Log Bd.ft.Doyle	Average Load Scribner	Type of Road: Woods	Graded Dirt	Gravel or Hard Surface
		Dollars		
60	1060	.423	.205	.168
70	1110	.404	.196	.160
80	1160	.386	.188	.153
90	1215	.369	.179	.146
100	1265	.354	.172	.141
110	1320	.339	.165	.135
120	1370	.327	.159	.130
130	1420	.315	.153	.125
140	1470	.305	.148	.121
150	1520	.295	.143	.117

Derivation of Table 8.

Machine rate on woods roads:
Fixed cost per hour — $0.585
Operating expenses per mile/1 — 0.121

/1 Classification of operating costs on various road standards, due to variations in fuel consumption and tire depreciation, gives a more accurate machine rate. However, the additional work involved is not justified, normally, in view of the small errors that would be incurred by considering operating cost on a per hour basis.

Time per round trip mile on woods roads 21.1 min.(Table 4)

Fixed cost per mile of woods road $\frac{21.1 \times .585}{60.}$ = \$0.206

Operating cost per round trip mile 2 x 0.121 = 0.242

Total cost per mile per load \$0.448

Total cost per M for a load of 1,265 bd.ft.

$$\frac{\$0.448}{1.265} = \$0.354$$

Expansion of Table 3

Table 3, Time required per Load, is a fixed loading time schedule made for loads averaging 1,450 bd.ft. From Table 8, a load of this size would be made up of logs averaging about 135 bd.ft. each. Accordingly there would be $\frac{1,480}{135}$ = 11 logs per load. Since loading was done by teams and in all probability only one log was loaded at a time, the loading time per log would be $\frac{41.30 \text{(Table 3)}}{11}$ = 3.75 min. Unloading time might be expected to increase somewhat with a larger number of logs but should not increase in direct proportion to the number of logs. For ease of calculation it will be assumed that unloading time varies inversely with the volume of the load. Delay time may or may not increase with the number of logs per load but for simplicity will be assumed constant. From these assumptions the following table of loading times has been derived.

Table a.

Variation in Load and Loading Time With Log Size

Average Log	Average Load	Number of Logs	Time per load (minutes) Loading	Unloading	Delay	Total
60	1060	17.7	66.4	18.4	9.2	94.0
70	1110	15.9	59.6	17.5	9.2	86.3
80	1160	14.5	54.4	16.7	9.2	80.3
90	1215	13.5	50.6	16.0	9.2	75.8
100	1265	12.6	47.2	15.3	9.2	71.7
110	1320	12.0	45.0	14.7	9.2	68.9
120	1370	11.4	42.7	14.2	9.2	66.1
130	1420	10.9	40.9	13.7	9.2	63.8
140	1470	10.5	39.4	13.2	9.2	61.6
150	1520	10.1	37.9	12.8	9.2	59.9

Assuming that the basic data with regard loading time and hauling time are correct, these figures may be applied to other conditions in the following manner:

Example: An area of 2 sections is to be logged over. Skidding and loading will be done with teams and hauling with 1½ ton trucks. One team will be assigned to each truck, skidding being done when the team is not loading. The average log contains about 120 bd.ft. The average haul will consist of one mile of woods road, 4 miles of graded dirt road and 10 miles of gravel road. Machine rate for the team is $0.90 per hour and for the truck, fixed cost $1.20 per hour and operating cost $0.30 per hour. Hauling cost will, therefore, be $1.20 + $0.30 = $1.50 per hour.

Solution: Reference to table"a" indicates a loading time of 42.7 min. One half of the delay time of 9.2 min. should be charged to the loading operation making a total loading time of 42.7 4.6 = 47.3 min.

Hauling times indicated by Table 4 are:

1 mile woods road @ 21.1 min. round trip	21.1 min.
4 miles graded road @ 8.6 min. round trip	34.4 min.
10 miles gravel road @ 4.5 min. round trip	45.0 min.
Total round trip hauling time	100.5 min.

Skidding time per trip will be round trip hauling time plus unloading time = 100.5 + (14.2 + 4.6) = 119.3 min., assuming that one truck load can be skidded while the truck is away.

Skidding cost	
119.3 min. @ 1.5¢	$1.79
Loading cost	
Standby charge on truck	
Loading 47.3 min. @ 2¢	0.95
Unloading 18.8 min. @ 2¢	0.38
Loading cost of team 47.3 min. @ 1.5¢	0.71
Hauling cost	
100.5 min. @ 2.5¢	2.51
Total cost per trip	$6.34

Total cost per M bd.ft. $\frac{\$6.34}{1.370M} = \$4.62$

It should be noted that the costs of Table 8 could not be used in the example since the machine rate used in calculating Table 8 did not agree with the machine rate of the example. Only when machine rates remain fairly constant will the work of setting up cost schedules by log size be justified. The method used in the example is not too cumbersome and is recommended for use under ordinary circumstances.

The average log - average load relationship, since it is likely to remain constant would be useful in calculating hauling costs. Information for construction of a table of this kind may be obtained from Form 7 if types of trucks for different loads, were designated.

LOADING

Table 3 represents accurate measurements of the time required in loading and unloading under the particular conditions that exist on the areas in which the study was made. To make these figures applicable to another operation, the equipment used and the size of the crew should be described in considerable detail because a slightly different arrangement or a machine of different efficiency will change the loading times considerably. Therefore, time studies should be undertaken for all variation in crew and equipment that are likely to be encountered. Each set of time studies should be accompanied by a careful description of the conditions under which such times were observed.

In most of the northern timberland some sort of truck road is required for trucks loading in the woods. The poorest grade of woods road can be constructed very cheaply but it does require some expenditure. This fact leads to better organization of equipment and calls for a detailed plan of location for these and higher standard roads. The cost of the road construction, the cost of skidding and the volume of timber per acre decide the economic location of roads. As soon as the spacing of the roads has been determined the cost of skidding will be fixed, as shown in case problem I. When roads are constructed the timber is usually skidded to landings. This concentration of material makes it economical to introduce some type of loading equipment which has considerably greater efficiency than the cross haul method using teams. Under these conditions the skidding and loading operations are not closely linked as in the case where no interior roads are necessary and the teams do the skidding and loading concurrently.

Information Required in Estimating Loading Costs

As shown in the example on page 69, the standby charge on the truck being loaded is one of the major cost items of the loading operation. When large trucks with a high machine rate are being loaded it will be necessary to introduce very efficient loading devices to maintain the economy of the operation.

In almost all cases there will exist a possibility of introducing loading equipment of increased or decreased efficiency with a corresponding increase or decrease in the machine rate. In order to choose the most economical equipment, it is necessary to have the following information:

1. Rate of loading for the types of equipment under consideration.
2. The machine rates of the loading equipment.
3. The machine rate of the equipment being loaded.
4. The quantity of timber output expected at the loading point.

These quantities are brought together in the following formula, to give loading cost per M bd.ft. for each type of equipment to be considered.

$$\text{Cost per M bd.ft.} = (F \times T) + \frac{L}{\text{M bd.ft.}}$$

where F = Fixed or standby truck charge per minute.

T = Loading time per M bd.ft. in minutes.

L = Hourly cost of loading equipment.

M bd.ft. refers to the average hourly output.

In comparing the cross haul method, used in the preparation of Table 3, with a "speeder" loader the total costs per M bd.ft. by each method are equated. The volume of output per hour which would justify the introduction of a speeder loader can be easily found.

Cross haul method: $F = 2¢$ per min. $T = \frac{47.3}{1.370} = 34.6$ min.

$\frac{L}{M\ bd.ft.}$ in the cross haul method, where teams are used for skidding when not loading, would be the loading cost of the team per M bd.ft. and from the example on page 69 would be $\frac{0.71}{1.370\ M} = \$0.518$

Speeder loader: (Assumed data) $F = 2¢$ per min.

$T' = 20$ min. per M bd.ft.

$L' = \$1.10$ per hour

By equating cost per M bd.ft. by each method, with output per hour unknown, we have:

$$(F \times T) + \frac{L}{M\ bd.ft.} = (F \times T') + \frac{L'}{M\ bd.ft.}$$

$$(2 \times 34.6) + 51.8 = (2 \times 20) + \frac{\$1.10}{M\ bd.ft.}$$

$$69.2 + 51.8 = 40 + \frac{\$1.10}{M\ bd.ft.}$$

$$M\ bd.ft. = 1.36\ M$$

This means that the speeder loader could be introduced to advantage if only one load were handled every hour. The load would have to be loaded in 20 minutes, of course. If the operation had been planned so that an average of two trucks would be loaded every hour, the saving by acquiring the speeder loader would be considerable.

Cost of loading two trucks per hour using cross haul

Standby loading charge on trucks 2 x 47.3 x 2¢ =	$1.90
Cost of two teams 2 x 47.3 x 1.5¢ =	1.42
Total cost of loading two trucks	$3.32
Loading cost per M bd.ft. $\frac{3.32}{2 \times 1.37}$ =	$1.21

Cost of loading two trucks per hour using speeder loader

Standby charge on trucks 2 x 20 x 1.370 @ 2¢ =	$1.09
Cost of loader for one hour	1.10
Total cost of loading two trucks	$2.19

Loading cost per M bd.ft. $\frac{2.19}{2 \times 1.37} = \$0.80$

Saving by installing the speeder loader $1.21 - $0.80 = $0.41 per M bd.ft.

Collection of Loading Costs

The machine rates of any equipment which has been previously operated by a company should be available, if records, similar to those outlined in Form 2, have been preserved, otherwise such information as is available may be used to establish approximately correct rates. For new equipment the manufacturers should be able to provide a fairly reliable machine rate which should be checked as the machine is operating.

The operating time of loading equipment of all kinds should be accurately established for use in planning future operations. Reference to Table "a" page 68, will illustrate the decrease in loading time with increased log size in loading by the cross haul method. This reduction in time with increased log size will be observed with any type of loading equipment but with more efficient types the difference will not be as marked as is indicated by Table "a". In order to build up a table comparable to Table "a" for all types of loading equipment operated, data as to loading time, volume and number of logs for each load, should be collected. Form 7 page 74, is suggested as a possible arrangement of headings for time and production studies of loading equipment.

Explanation of Form 7.

"Commenced Operating" is the time at which the loading crew commenced drawing pay for that day.

Form-7

Loading Equipment Time Record

Location . . . . Sheet No. . .1. .

Type of Equipment . . . . Recorder . . . .

Date	A.M.	P.M.	Machine Rate (including wages) . . . .
Commenced Operating	7:30	1:30	Crew
Closed Down	12:00	1.58	

		Load Numbers	1	2	3	4	5	6	7	8	9	10	Total	Average
Computed Operating Time (minutes)	Truck Time	Truck Arrived	7:30	8:02	8:35	9:00	9:32	10:00	10:30	11.01	11.35	1:30		
		Truck Left	8:00	8:30	8:59	9:31	9:58	10:29	11:00	11.30	12:00	1:52		
	Computed Loading Time	Loading	25	24	19	27	22	24	25	26	20	20	232	23.2
		Delay	3	4	4	4	2	2	4	3	3	2	31	3.1
		Idle	2	-	1	-	2	3	1	-	2	-	11	1.1
		Total	30	28	24	31	26	29	30	29	25	22	274	27.4
		Idle Operating Time	2	5	1	1	2	1	1	5	-	6	24	2.4
		Moving Time												
		Total Operating Time	32	33	25	32	28	30	31	34	25	28	298	29.8
Load Data		Volume ft. b.m.	1510	1390	1180	1550	1310	1450	1510	1440	1260	1090	13,690	1,370
		Number Logs	13	12	9	14	10	12	12	13	10	9	114	11.4
		Volume of Average Log ft. b.m.	115	115	130	110	130	120	125	110	125	120	1200	120

Remarks:

"Closed Down" is the time at which the crew ceased drawing pay for that day.

"Load Number" is chiefly for use in refering to a specific load when making entries in the remarks column.

"Computed Operating Time" is the breakdown of the difference between "Closed Down" time and "Commenced Operating" time.

"Truck Arrived" and "Truck Left" times are, of course, not reserved for the same truck but are taken for all trucks as they arrive and leave.

"Computed Loading Time" is the breakdown of the time that the trucks were at the landing. As in all timing, the distinction between "Delay" and "Idle" time rests with the observer. If, in his opinion, the loss of time is unavoidable, such as waiting for logs to be skidded into the landing, then it should be considered as delay. Otherwise any lost time, while the truck is at the landing, is idle loading time.

The "Total" under "Computed Loading Time" is the length of time that the truck was at the landing.

"Idle Operating Time" is the lost time between the time one truck leaves and the next arrives.

"Moving Time" is the time required to move the loading equipment from one loading point to another.

"Total Operating Time" for each trip is the time between sucessive arrivals of a truck. The sum of "Total Operating Time" for all trips should equal the total length of time that the loading equipment was under pay for that day.

The load data may be arrived at in several different ways. If scaling is done on the truck the total volume and number of logs can be copied from the scale sheet. In this case "Volume of the Average Log" can be obtained by dividing "Total Volume" by "Total Number of Logs". If the yards have been scaled before loading commences the scaler should be able to provide a reasonably accurate figure for the volume of the average log. In this case, the number of logs per load is the only load data required when making the time study.

In "Remarks" should be included the causes of any exceptionally long delay or idle periods or any exceptional feature of any load.

The example used on Form 7 is purely hypothetical and represents better efficiency than would normally be expected.

Summary.

As far as the loading equipment is concerned, the object of running time studies of this nature, is to establish the rate of loading for various sizes of timber. In the example of Form 7 the average actual loading time per load is 27.4 minutes for an average load of 1,370 bd.ft. The loading time per M bd.ft. in timber averaging 120 bd.ft. per log would be $\frac{27.4}{1.370} = 20$ minutes.

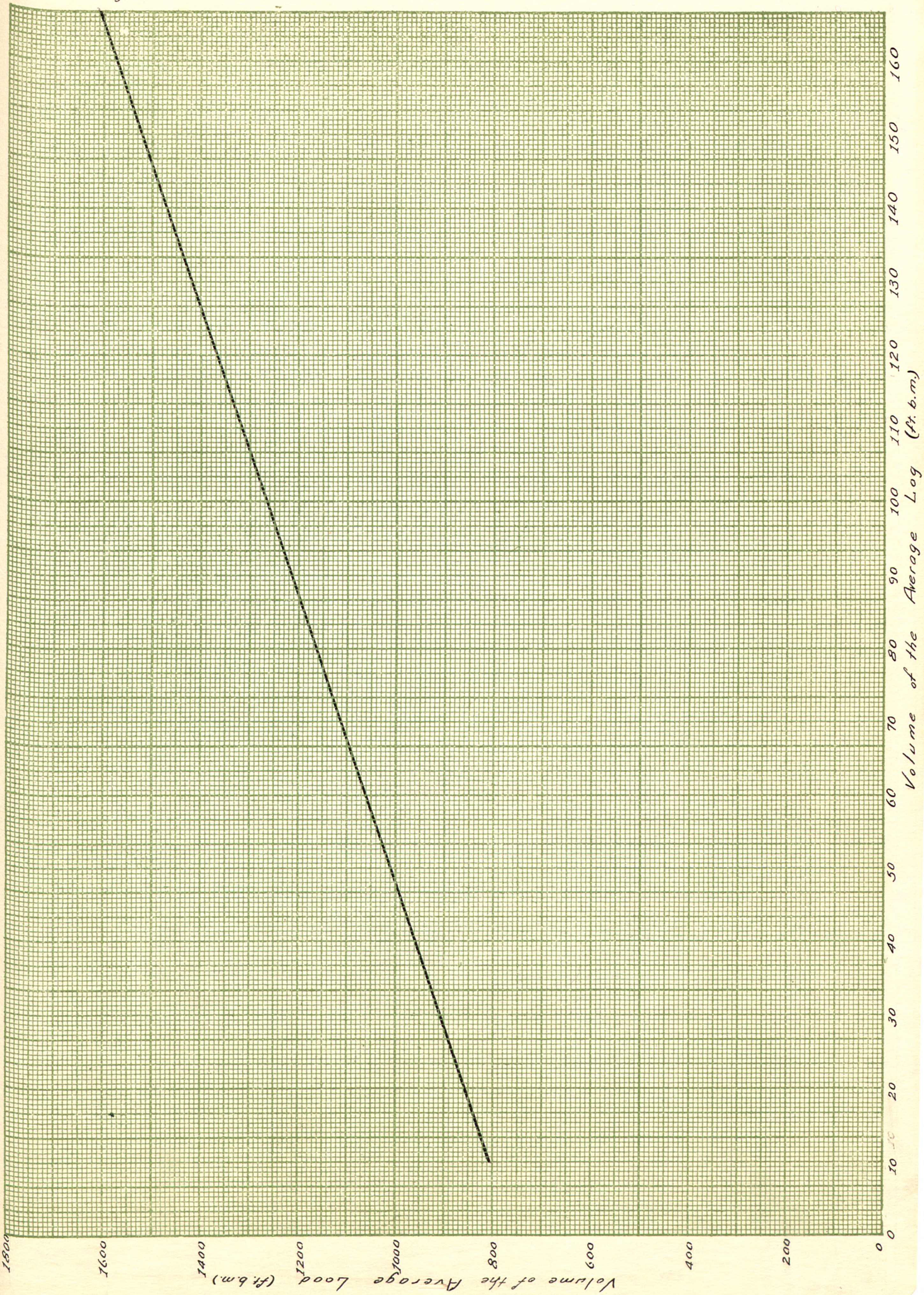
As more data are collected for different average volumes per log, a graph can be built up from which loading times per M bd.ft. for different average log volumes can be read.

Delay and idle time were included in the loading time above as it is assumed that a certain amount of delay and idle time are almost sure to be present in any operation. If delay and idle time represent a relatively large proportion of the total loading time, it indicates poor planning or poor supervision and in such cases should not be included unless equally poor planning is anticipated on future operations.

The object of recording total operating time is to establish the volume of output from the landing. This figure for output has no value in future planning since it is merely a measure of the efficiency of the trucking operation. It does however, serve to prove or disprove the economy of using this type of equipment as compared to some other. From the data recorded on Form 7 one load of 1,370 bd.ft. is sent out on the average every 29.8 minutes. The output per hour, then, would be $\frac{60}{29.8} \times 1.370 = 2.75$ M bd.ft. The calculation on page 72 shows that the speeder loader could be used to advantage if an output of 1.36 M bd.ft. per hour were maintained. This indicates that the choice of the speeder as against the cross haul method was well within the bounds of economy.

Where only one type of truck is used for hauling or if loads are kept separate by truck types, the data from Form 7 will serve in setting up tables of average load for different volumes of the average log. The relationship of load plotted over volume of the average log should be very nearly a straight line as indicated by the data published by Reynolds, reprinted in Table 8 and plotted in Figure 4 page 78.

Figure - 4


Volume of the Average Log (ft. b.m.)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Volume of the Average Load (ft. b.m.)
0
200
400
600
800
1000
1200
1400
1600
1800

TRUCK HAULING

The major consideration in truck hauling should be to establish a minimum for the sum of the costs of road construction and the costs of hauling over those roads. It is in this field that the surplus which should be profit, is often cut in half or even completely exhausted through lack of planning.

Reference to Table 8, page 66, will serve to emphasize the difference in hauling costs on roads of various standards. Unfortunately, the costs of construction for the various standards were not included in the data presented by Reynolds. However, the nature of the hauling costs indicates clearly that it would be very uneconomic to construct a road to "woods" standard if a large volume of timber were to be transported over that road.

The technique of estimating just what expenditure in road construction will be most economical depends to a large extent on the determination of road construction costs and speeds of travel over those roads. It is of course, impractical to set up a schedule of construction costs and respective speeds for roads of various standards and expect that relationship to hold universally. Where $500 might build a mile of graded road in flat gravelly soil the same expenditure in rocky or swampy terrain might not build a quarter of a mile of graded road. It is obvious, therefore, that if a schedule of construction costs with respective speeds is to have any value it must be classified according to terrain. The possibility exists that a company's holdings may be so nearly uniform in terrain that discrepancies from the average could be neglected, in which case one schedule would be sufficient.

Wages also represent a variable which is very significant in the fluctuation of costs in any line of work and road building is no exception to the general rule. Accordingly, the cost of road construction should be expressed in time, as well as cost, and variations in wage rate or machine operation cost could be applied directly to times to get current construction costs. A change in the construction machinery would introduce another variable since all types of road building equipment will not construct roads at the same rate. The modern road building equipment which is quite standard for all except the very poor standards, is the bulldozer equipped tractor. Frequently the bulldozer does all construction work from clearing to grading, the road crew being required for the building of culverts and bridges only. Trucks will enter the picture where filling or gravelling is required and some type of power shovel for loading would then be required.

By recording the quantity of work done by the different pieces of equipment and the conditions under which these times would apply, it would be possible to calculate the cost of roads in future operations, provided machine rates were known.

Along with the cost of construction, the average speed of travel must be known for the various expenditures in construction. This requires actual timing of trucks on the various road standards. Such data must be classified according to the type of truck since variations in truck type may be accompanied by variations in average speed.

Road Classification

As a first step in collecting road construction costs and speeds of travel it is recommended that a classification of roads be established.

Bruce Spike, of George Banzhaf and Co., Milwaukee, Wisconsin has made a study of trucking costs in northern Michigan and commences his work with a road classification as follows:

I. Strip Roads. :- Brushed out, stumps cut low, little or no grading, rough, no alignment, creeper gear. Made by piece cutter or trucker.

II. Poor Haul Roads. :- Brushed out, stumps cut low, hand-graded with shovel or grubhoe, rough or not smooth, more or less contour alignment, creeper and first gear.

III. Fair Haul Roads. :- Hand- or machine-graded, more or less contour alignment, grading changing but more favorable, fairly smooth if properly maintained, considerable first and second gear.

IV. Good Haul Roads. :- Machine graded, drainage provided for, usually dirt surface, fair alignment and gradients, fairly smoothe

Public Roads

V. Dirt and Poor Gravel. :- Fair alignment and gradient, about 20 per cent second and first gear, surface smooth or rough, depending on maintenance.

VI. Good gravel and Old Macadam. :- Good alignment and gradients, surface more or less uneven, nearly equal to hard-surface roads.

VII. Pavement and Good Macadam. :- First class alignment and long-sustained gradients. Maximum performance and safety.

Any classification, if not identical should be very similar to the above.

Collection of Road Construction Time and Cost

Having established the specifications of the various road standards, costs of construction of the various standards should be collected as soon as operations make it possible to do so.

On current construction work a real effort should be made to record accurately the times and costs incurred, as well as the standard and length of road constructed. To facilitate time and cost recording, monthly, semi-monthly or weekly reports of times and costs should be made up. Time sheets of individual workers in which the distribution of hours worked was recorded, would increase the accuracy of the periodic report. Form 8, page 83, is an example of such a time sheet which lends itself readily to use in making up payrolls as well as for time collection. A similar record of machine time is required and data of this nature may be collected on Form 9, page 84. If the time sheet is on a weekly basis the summary should be weekly and may be along the lines indicated in Form 10, page 85. The summary should contain the times of those items which contributed directly to the construction of the road. Total costs, however, will be true total costs since the machine rates should be adjusted to include all other expenses attributable to the operation. For instance, the machine rate of labor per hour should include the man's wages (plus social

Form- 8

Individual Weekly Time Record
(Road Construction)

Week Ending ....

Name ....

Location ....

Day of Week	Distribution of Hours Worked								Describe "Other Work" Here.	Summary		
	Construction on Road Standard					Road main-tenance	Moving Camp	Other Work		Total Hours	Regular Time	Over-time
	I	II	III	IV	V							
Mon.												
Tues.												
Wed.												
Thurs.												
Fri.												
Sat												
Sun.												
Total Hours												

Rate of pay ..... per ....

Earnings			Deductions				Net Cash
Regul-ar	over-time	Total	Soc. Sec.	W.H Tax			

Approved by ....
Signature of Camp Foreman

Received Payment in full ....
Signature of Employee.

Form-9

Weekly Machine Time Record
(Road Construction)

Week Ending ....
Location ....

Machine Type ....
Machine Number ....

Day of Week	Distribution of Hours Worked: Construction of Road Standard I	II	III	IV	V	Road Maintenance	Moving Camp		Other Work	Describe "Other Work" Here	Total Hours
Mon.											
Tues.											
Wed.											
Thurs.											
Fri.											
Sat											
Sun.											
Total											

Total cost of ...... hours at current machine rate of ..... per hour equals ......

Remarks:—

Form-10

Road Construction Time and Cost Record
Weekly Summary

Location .... Construction Foreman ....

Weather Conditions .... Date ....

Ground Conditions ....

Topographic Conditions ....

Equipment Item	Number of Items	Days worked since last report	Hours Worked	Machine Rate (per hr.)	Total Cost	Road Construction		Remarks
						Standard	Length (miles)	
Labor (Men)	2	5	80	$0.80	$64.00	III	1.0	Men actually engaged in Construction Work.
Tractor D-4	1	4	32	1.75	56.00			Laid up for one day with broken track.
" D-4	1	5	40	1.75	70.00			
" D-6	1	5	40	2.00	80.00			
Total	Cost				$270.00			Cost per Mile $270.00
Labor (Men)	4	5	160	$0.80	$128.00	II	2.0	
Tractor D-4	1	4	30	$1.75	52.50			
Total	Cost				$180.50			Cost per Mile $\frac{180.50}{2.0}$ = $90.25

security and withholding tax) cost of supervision and cost of camp moving, if a temporary camp is used, prorated over total man hours. The machine rate for the tractor should include the operators wages, depreciation, etc., as indicated in the form on page 9. Care should be taken to describe accurately the conditions of terrain under which the construction work was carried on for the period covered by the summary. The schedule of road standards may now be defined as to length of time to construct, under different ground conditions.

Average Speeds for Various Road Standards

The speeds which can be safely maintained by various types of trucks over the various road standards should now be determined. This involves a simple time and distance record, which may be kept by the truck driver or preferably by a special observer riding the trucks. It is most important in collecting these data that the timer have a clear understanding of the specifications of the various road standards. Collection of data with regard to speed of travel may be combined with a comprehensive timing of the truck operation to determine points of inefficiency or it may be conducted separately as would be the case if Form 11 were used. The example shown on Form 11, page 87, illustrates the use of the form and should be self explanatory. The average round trip speed for the standards on which data were collected may be calculated by the use of the formula:

$$\text{Average speed} = \frac{2HL}{H+L}$$

where H = speed when the truck is light

and L = speed when the truck is loaded

Form - 11

Truck Travel Speeds for Various Road Standards.

Location ....   Date ....

Weather ....   Truck Type ....   Recorder ....

Time: Clock Time	Time: Computed Time (min)	Road Standard	Speedometer Reading	Distance (miles)	State of Truck (Loaded or Light)	Condition of Road 1 Below Standard 2. Standard 3. Above Standard	Remarks.
7:30	30	I	677	1	Loaded	2	Left Woods
8:00	36	III	678	3	"	2	Entered Class III
8:36	24	VI	681	10	"	2	" " VI
9:00	-	-	691	-	-	-	Arrived Mill Yard
9:10	20	VI	691	10	Light	2	Left Mill Yard
9:30	16	III	701	3	"	2	Entered Class III
9:46	27	I	704	1	"	2	" " I
10:13	-	-	705	-	-	-	Arrived Woods

To obtain the average round trip speed for the Class III road standard in the example on Form 11 the following calculation would be necessary:

$L = 3/36 \times 60 = 5$ m.p.h.

$H = 3/16 \times 60 = 11.2$ m.p.h.

$$\text{Average m.p.h.} = \frac{2 \times 11.2 \times 5}{11.2 + 5} = \frac{112}{16.2} = 6.9 \text{ m.p.h.}$$

This average represents only one measurement over 3 miles of Class III road and could not be assumed to apply to all roads of this class until more measurements had verified the validity of the above data. In determining the mean of a number of average m.p.h.'s (as calculated above) it is suggested that averages be weighted by length of road. If 6.9 had been the average determined on a three mile run and 7.5 the average on a ten mile run, then the weighted average would be calculated as follows:

$$6.9 \times 3 = 20.7$$

$$7.5 \times 10 = \underline{75.0}$$

$$95.7$$

$$\text{Average m.p.h.} = \frac{95.7}{13} = 7.35$$

Assuming that sufficient data has been collected on construction time and speeds for various road standards, a schedule for different conditions of terrain may be set up as shown in Form 12, page 89.

Use of the Construction Time and Speed Schedule

If the average speed and construction time for the various road standards have been established with reasonable accuracy, current costs of construction can be estimated by applyiny the current machine rates of the equipment used.

The average round trip speeds may be converted into costs

Form-12

Average Speeds and Construction Times for Various Road Standards*

Topography :- Gently rolling, good drainage, few culverts required.

Ground Conditions- Lightly wooded, sandy to gravelly soil, few rocks or boulders.

Data collected or revised to ....19......

Road Standard	Man Hours per Mile exclusive of Machine Operators	Machines	Machine Hours per mile	Average Round Trip Speeds (m.p.h) Standard 1½ Ton Truck	Tandem-axle 1½ Ton Truck
I	100	-	-	2.1	2.1
II	80	Tractor D-4	15	3.9	4.1
III	80	Tractor D-6	40	6.9	6.9
		Tractor D-4	72		
IV	150	Tractor D-6	50	9.0	8.7
		Tractor D-4	100		
		Truck 1½ Ton.	50		
		Speeder Shovel	20		
V	250	Tractor D-6	100	19.0	19.4
		Tractor D-4	200		
		Truck 1½ Ton	150		
		Speeder Shovel	100		
VI	Specialized equipment and techniques —			27.0	25.3
VII	strictly an engineering problem.			30.6	28.4

* Note: The data regarding construction times presented in this table are purely hypothetical.

per round trip mile per sale unit by use of the following formula:

$$\text{Hauling cost per sale unit per round trip mile} = \frac{2HC}{m.p.h. \times L}$$

where HC = Hourly cost of operating the truck

m.p.h. = Average round trip speed

L = Load carried by the truck

The problem of determining to what standard the road should be improved can be solved quite easily if accurate information on road construction costs, average speeds on different standards, average loads carried and machine rates of the trucks doing the hauling.

Example: It has been determined from cruise data that 5000 cords of pulpwood will be hauled 5 miles over a tapline road. Standard 1½ ton trucks will be used. The machine rate of the trucks is \$1.50 per hour and the average load carried is 3 cords. What standard of road should be built to haul this wood?

Current Costs of Road Construction From Form 12

Road Standard	Man Hours	Rate \$	Cost \$	Machine	Machine Hours	Rate \$	Cost \$	Current Total Cost Per Mile
I	100	0.80	80	- -	- -	--	--	\$ 80.00
II	80	0.80	64	Tractor D-4	15	2.00	30	94.00
III	80	0.80	64	Tractor D-6	40	2.25	90	
				Tractor D-4	72	2.00	144	298.00
IV	150	0.80	120	Tractor D-6	50	2.25	112	
				Tractor D-4	100	2.00	200	
				Truck 1½ Ton	50	1.50	75	
				Speeder Shovel	20	1.25	25	532.00
V	250	0.80	200	Tractor D-6	100	2.25	225	
				Tractor D-4	200	2.00	400	
				Truck 1½ Ton	150	1.50	225	
				Speeder Shovel	100	1.25	125	1175.00

The aim of planning is to reduce the sum of hauling cost and road construction cost per cord to a minimum. It is necessary, therefore, to calculate hauling cost per mile per cord by the formula $\frac{2HC}{m.p.h. \times L}$ and construction cost per cord by dividing cost per mile by 5000 cords, the amount of wood carried over the road. The results of these calculations are presented in the following schedule:

Road Standard	Hauling	Road Construction	Total
	Cost per mile per cord		
I	$0.447	$0.016	$0.493
II	0.256	0.022	0.278
III	0.145	0.060	0.205
IV	0.111	0.106	0.217

It is apparent from the above table that the reduction in hauling cost is greater than the increased cost of construction as the standard of the road is increased up to Class III. Improvement beyond Class III would involve an improvement expense which would not be equalled by savings in hauling resulting from the improvement.

CONCLUSION

The forms and procedures in data collection, suggested in this paper, are for the most part entirely untried. It is appreciated that many impractical features will be apparent if the suggestions are rigorously followed in the field. These forms and methods of time and cost collection should be considered more as a starting point from which the user may digress along those lines which indicate more accurate or more easily obtained results.

It is hoped that this paper may impress the reader with the fact that logging costs are not the elusive intangibles that they are so frequently considered. Some ingenuity is frequently required to break out the significant costs involved in a logging operation. Every situation will present its own peculiar problems which will require a modification of the more or less general methods described here. However, considerable expenditure in collection of data is justified when it is realized that planning, in the light of the information collected, may result in savings several times larger than the original expense of collecting the information.