

# **THE WEAK LINK LOGGING SYSTEMS ANALYZER**

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## INTRODUCTION

The Weak Link Logging Systems Analyzer is a relatively unique approach to logging systems analyses. It is implemented through nomograms that enable a logger to readily analyze a wide variety of machine combinations and operating conditions.

Applying Weak Link to his current operation, a logger can locate production bottlenecks, and estimate his production costs. Weak Link can also predict logging systems performance, enabling loggers to estimate production levels, logging costs, and systems inefficiencies resulting from a change in logging conditions. Similar predictions could be made regarding the impact of proposed management action such as the addition of men and machines, or changes in production factors such as skidding distance.

The application of this version of Weak Link is limited to logging operations similar to those from which the time study data was collected; specifically, conventional chain saw-skidder-loader-tandem-axle truck operations in eastern mountain areas. However, the methods employed by Weak Link could have very broad applications.

By preparing a set of nomograms that relate machine cycle time and payload to operating conditions, any variety of terrain-condition machine-type combinations could be evaluated.

The Weak Link Logging Systems Analyzer is a management tool designed to provide loggers with a means of systematically locating, defining, and analyzing their log production problems. It provides the logger with a much needed framework for interrelating cost and production factors for each machine in the system, making a systems analysis possible. By defining which cost and production items are required for a systems analysis, Weak Link can also help a logger set up a cost and production accounting system that provides the needed input to his decisionmaking.

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## HOW WEAK LINK WORKS

This logging systems analysis consists of three parts. The first part develops an operating cost rate for each type of machine in the system and a fixed cost rate for the entire system. Operating costs are those cost items such as fuel, oil, and tires that are actually consumed during machine operation. The operating cost rate represents the cost of goods consumed during 1 hour of machine operation, \$/MOH (dollars per machine operating hour).

Fixed costs are required to make the system available for production and are incurred whether the machines are working or idle; they include items such as depreciation, taxes, interest, supervision, and labor. Fixed costs are handled on a systems basis, adding up all annual fixed costs, dividing by the number of shifts worked per year, and adding to this the labor cost per shift; systems fixed cost expressed in \$/shift.

The second part of Weak Link analyzes the potential productivity of felling, skidding, and trucking. This analysis is based upon logging machine cycle times. Nomograms used in the analysis to estimate logging machine cycle times were derived from regression equations developed from the data gathered through several logging machine time studies.

We define cycle time as the time required for a machine to complete one full production cycle; the time a cutter requires to walk to a tree, fell it and limb it; the time a skidder requires to travel from the landing, hook up logs, return to landing, and unhook logs; or, the time taken by a logging truck to load, travel to the mill, unload, and return to the landing.

Operating conditions are used to predict machine operating time per cycle, log volumes per cycle, and all other cycle time elements. Operator-caused delay times represent the averages sampled during our time studies. However, loggers can substitute their own estimates based upon their personal observations.

The production analysis then predicts potential production rates. We define potential production as the volume of logs each part of the system could produce under specified operating conditions, if no bottlenecks or similar interactions are encountered.

A potential production rate is estimated for each of three phases of the logging operation: felling and limbing, skidding, and trucking. The potential production of log bucking and log loading is not evaluated because we feel that these two functions will seldom limit systems production. Generally, logs are bucked immediately upon their arrival at the landing and backlogs seldom occur between skidding and bucking. Likewise, loading is regulated by either the availability of skidded timber or trucks; the loader itself will seldom be the bottleneck.

The following general equation, incorporated in chart form, is used to estimate potential production rates:

$$\frac{\text{Length of shift (hours)}}{\text{Average cycle time}} \times \text{Average volume/cycle} = \text{MBF shift}$$

Machine availability is another factor used to estimate skidding and trucking production rates. Machine availability represents the percent of scheduled machine operating time that the machine is mechanically fit to do productive work.

To estimate the system production rate, the potential production rates for the three groups of logging activities are compared to one another. Of these three, the one group with the lowest potential production rate is designated the Weak Link. It is assumed that the average systems output cannot exceed the productivity of the Weak Link. Therefore, the production rate for the system is set equal to the Weak Link level of production; for example, if the estimated potential production rates were as follows: felling and limbing - 25,000 MBF/shift, skidding - 18,000 MBF/shift, and trucking - 30,000 MBF/shift. Skidding with a potential of only 18,000 MBF/shift would be the Weak Link and the system could be expected to produce only 18,000 MBF/shift.

Part 3 estimates logging costs measured in dollars per MBF, \$/MBF. This cost is developed by integrating the cost rate analysis with the production rate analysis. There is one set of nomograms each for felling, bucking, skidding, loading, and trucking. These nomograms combine machine operating times per cycle, volumes produced per cycle, and the machine operating cost rates to derive an operating cost per MBF for each logging activity.

Machine operating hours/MBF X Operating cost rate =

\$ Operating cost/MBF, or MOH/MBF X \$/MOH = \$/MBF

Fixed costs per MBF are derived by a nomogram incorporating the following equation:

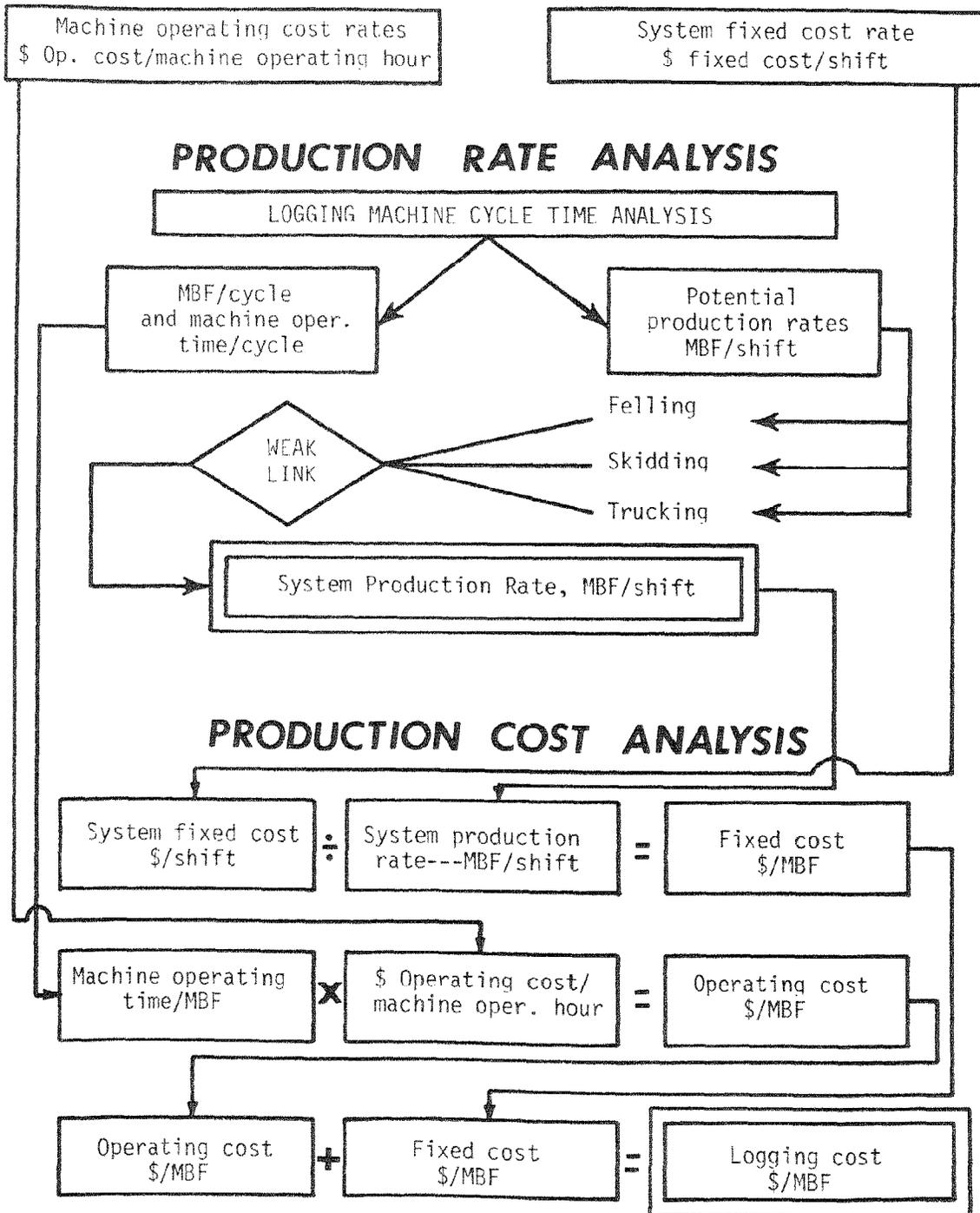
$$\text{Fixed costs/MBF} = \frac{\text{Systems fixed cost} - \$/\text{shift}}{\text{Systems production} - \text{MBF/shift}}$$

By restricting the productivity of the entire system, the Weak Link regulates the relative amount of fixed costs charged to each unit of production. Using this approach, any event which influences the cost input to the system or flow of production from the system is put into proper cost perspective.

The sum of operating cost/MBF plus fixed costs/MBF equals the total logging costs.

# WEAK LINK FLOW DIAGRAM

## COST RATE ANALYSIS



## THE WEAK LINK LOGGING SYSTEMS ANALYZER

### THE LOGGING SYSTEM AND OPERATING CONDITIONS

All of the information must be recorded on the operating conditions worksheet. Descriptions of logging conditions could be taken from measurements on the logging site and sampled as accurately as possible.

### SYSTEMS FIXED COSTS

Open the fixed cost worksheet on pages 14 and 15; this lists all of the items needed to calculate fixed costs. The first item, FC-1, is supervision. Record here the total annual salaries and payroll related costs for supervisors, foremen, and other overhead personnel. If a person in this category divides his time among two or more operations, include that portion of his costs proportional to the time he spends on the operation being analyzed.

Item FC-2 is vehicle license costs. This includes the annual cost of truck licenses as well as licenses for support vehicles such as pickup trucks.

Insurance costs represent fixed cost item FC-3. Do not include payroll or labor related insurance costs. Do include all liability insurance on trucks and other equipment.

All taxes except payroll taxes are recorded as FC-4.

OPERATING CONDITIONS WORKSHEET

Felling	Skidding	Hauling
No. of cutters in the system _____	No. of skidders in the system _____	No. of trucks in the system _____
Average slope: _____ percent	Ave. No. of trees skidded/turn _____	Ave. truck capacity: _____ bd. ft.
Method of payment: \$ per _____	Ave. skidding distance _____ ft.	Round-trip hauling distance _____ by road type:
Length of working day _____ hours	Aspect of skidding inturn: 1. Uphill 2. Level 3. Downhill	2-lane paved _____ M 1-lane paved _____ M 1-lane gravel _____ M Woods road _____ M
	Are trees bunched? _____	Length of working day: _____ hours
	Machine type: 1. Rubber-tired 2. Tracked	
	Operator's <sup>1/</sup> agressiveness: 1. High 2. Average 3. Low	
	Length of working day: _____ hours	

General:

Ave. dbh \_\_\_\_\_ inches  
 Ave. merch. height \_\_\_\_\_ 16' logs  
 Ave. tree volume \_\_\_\_\_ bd. ft.  
 Ave. log diameter \_\_\_\_\_ inches  
 Ave. log length \_\_\_\_\_ feet  
 Ave. log volume \_\_\_\_\_ bd. ft.  
 Other crew members & equipment \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

<sup>1/</sup> See page 36.

To calculate the total annual depreciation charge for the entire logging system, first record the purchase price, salvage value, and years of estimated machine life for each type of production machine in the system. Record the information in the spaces provided, columns A, B, and C. Then for each machine, subtract salvage value from purchase price and record the difference in column D. Using purchase price minus salvage value (column D), and machine life (column C), enter the depreciation nomogram in Figure 1 and estimate the annual depreciation charge for each machine. Record this in column E. When the depreciation charge for each machine has been estimated in this manner, total up all of them and enter the sum as FC-5, systems depreciation.

Interest on the average annual investment, FC-6, is calculated by first estimating the average annual investment for each machine. This estimate is made using purchase price minus salvage value (column D), salvage value (column B), machine life (column C), and the nomogram in Figure 2. After calculating the average annual investment for each machine, total them all up and record the sum as the system average annual investment, FC-5.5.

Next, select an interest rate. If you normally finance your equipment, use an interest rate equal to that which you pay on equipment loans. If you invest your own capital in logging machinery, use an interest rate that reflects what you could earn had you invested your capital elsewhere. Apply whichever interest rate you select to the systems average annual investment (FC-5.5) using the nomogram in Figure 3, page 12. Record interest on average annual investment as cost item FC-6.

The next fixed cost item, FC-7, is maintenance repairs. This includes the estimated total annual cost for tools, maintenance equipment, and repair parts. It also includes maintenance personnel wages. It does not include servicing items such as oil, filters, and lubrication.

The estimated annual cost of owning and operating support vehicles such as pickup trucks is recorded as FC-8.

FC-9 is the estimated total annual overhead cost and is the sum of cost items FC-1 through FC-8.

Total overhead cost per shift, FC-10, is determined by applying the total annual overhead cost, FC-9, and the estimated number of shifts worked per year to the nomogram in Figure 4, page 13.

FC-11 is total labor cost per shift. This cost should include wages for all hourly rate personnel as well as the employers' contribution to Social Security taxes, unemployment compensation costs, and workmen's compensation costs. Also include the costs of processing payrolls and overtime costs when applicable.

Adding systems overhead cost per shift, FC-10, to systems labor cost per shift, FC-11, you come up with total systems fixed cost per shift, FC-12.

Figure 1.--Nomogram for equipment depreciation

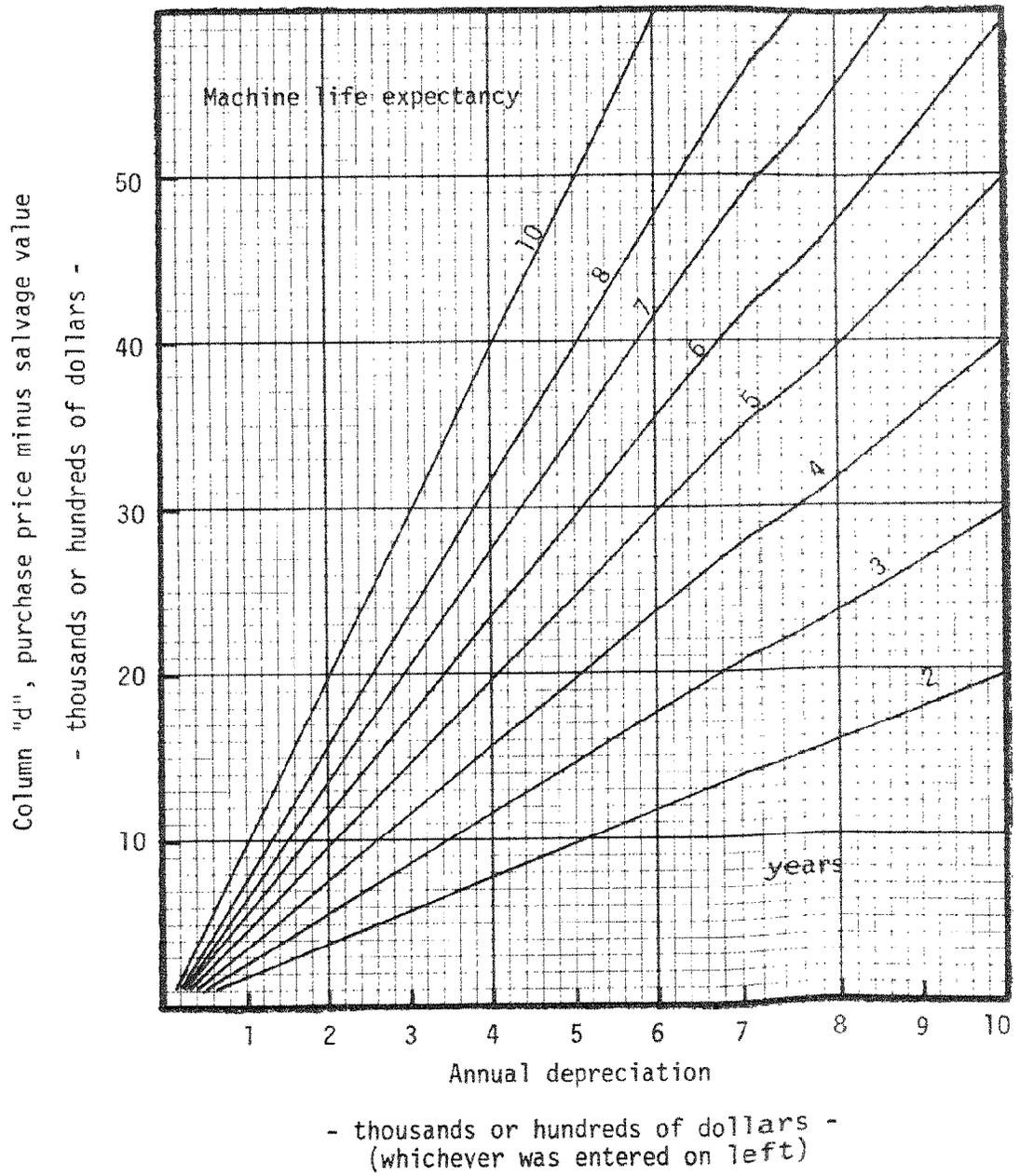


Figure 2.--Nomogram for average annual investment

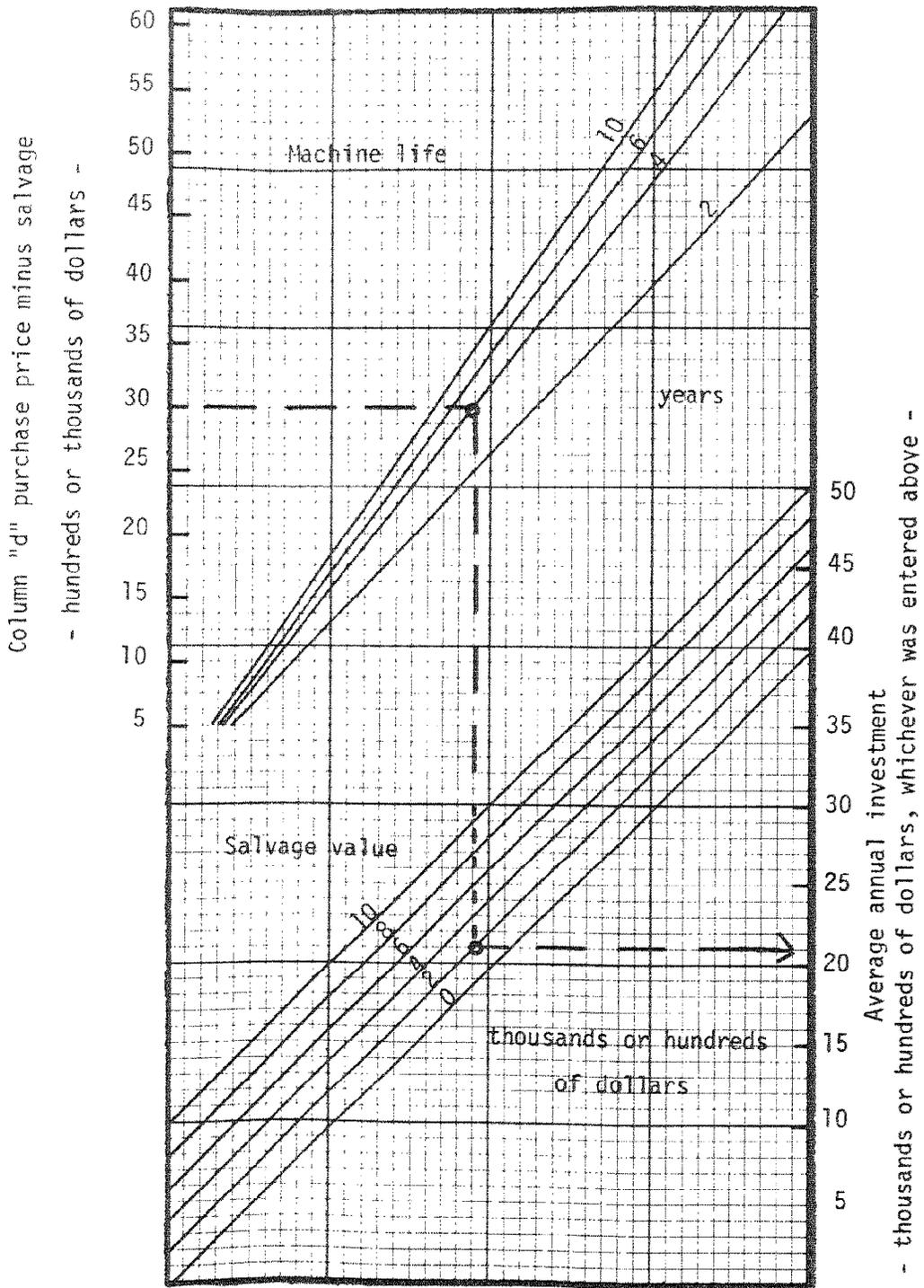


Figure 3.--Nomogram for interest on average annual investment

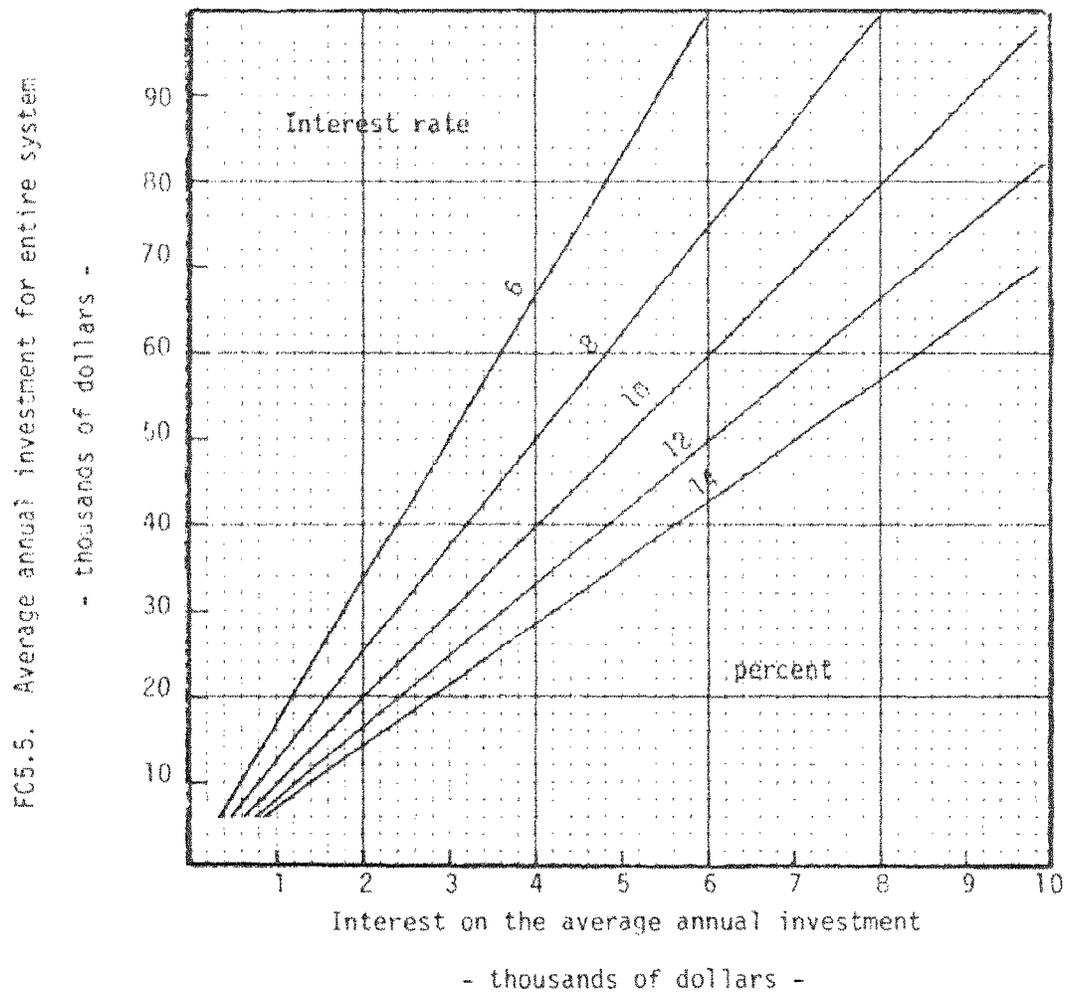
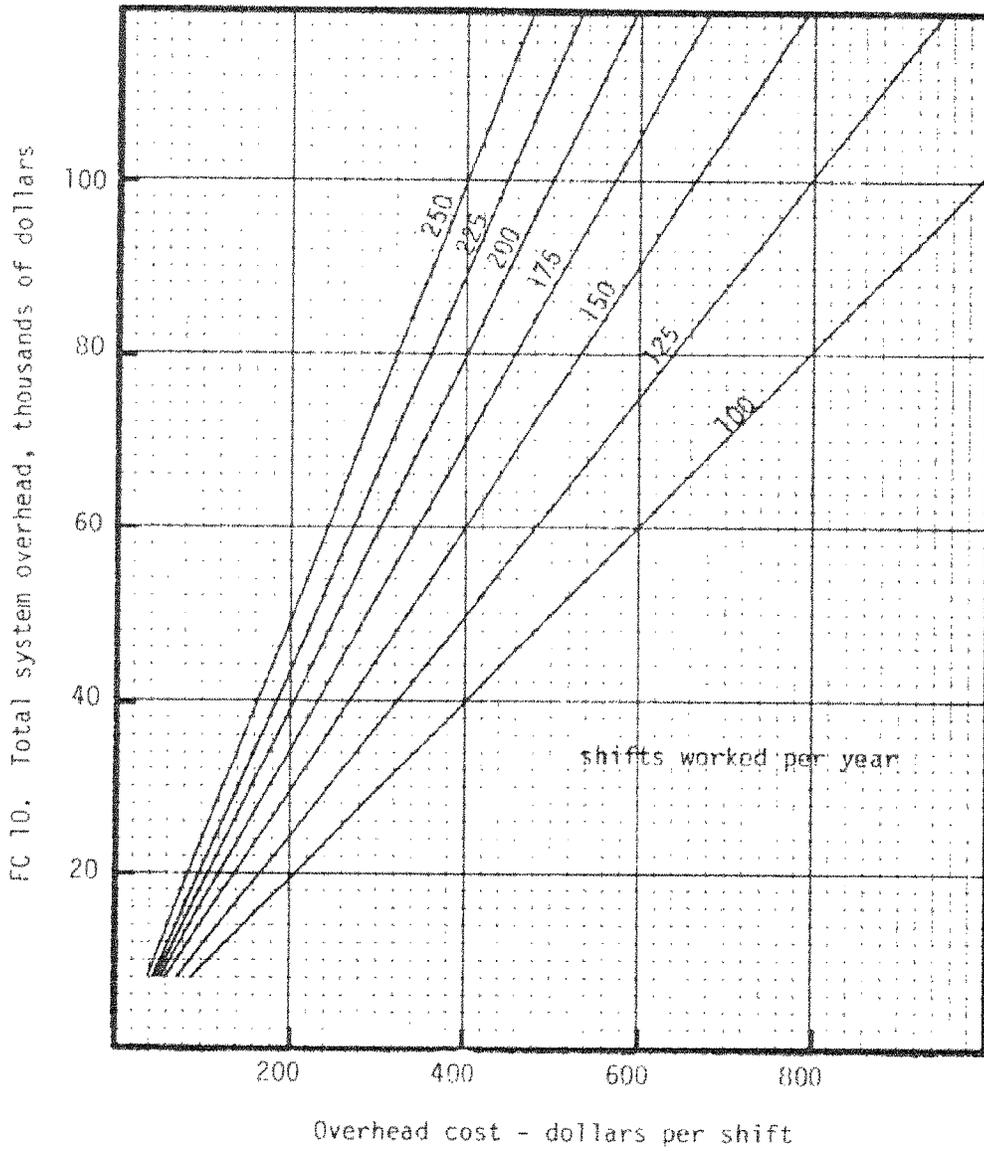


Figure 4.--Nomogram for overhead cost per shift



FIXED COST WORKSHEET

FC-1	Supervision	\$ _____/year
FC-2	Licenses	\$ _____/year
FC-3	Insurance	\$ _____/year
FC-4	Taxes	\$ _____/year
FC-5	Depreciation	\$ _____/year
FC-6	Interest	\$ _____/year
FC-7	Maintenance	\$ _____/year
FC-8	Support vehicles & equipment	\$ _____/year
FC-9	Total annual overhead	\$ _____/year
FC-10	Overhead per shift	\$ _____/shift
FC-11	Labor per shift	\$ _____/shift
FC-12	System fixed cost	\$ _____/shift

Machine number	A Purchase price	B Salvage value	C Expected machine life	D Col. A minus Col. B	E Annual depreciation charge	F Average annual investment
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						

FC-5 Total Annual Depreciation \_\_\_\_\_

FC-5.5 Average Annual Investment \_\_\_\_\_

Interest rate \_\_\_\_\_%

FC-6 Interest on Average Annual Investment \$ \_\_\_\_\_/yr.

Labor Cost Calculation

Total wages \$ \_\_\_\_\_/shift

Social Security \$ \_\_\_\_\_/shift

Unemployment \$ \_\_\_\_\_/shift

Workmen's Compensation \$ \_\_\_\_\_/shift

Administration \$ \_\_\_\_\_/shift

Overtime \$ \_\_\_\_\_/shift

Total Labor Cost (FC-11) \$ \_\_\_\_\_/shift

## OPERATING COSTS

Open the operating cost worksheet on pages 21 and 22. On the left side of the worksheet, record all of the operating cost items listed for each machine. Initially, loggers who haven't kept cost records may have to estimate these costs. However, keeping records for each machine will provide more reliable information for subsequent analysis.

Fuel costs are measured in dollars per gallon. Fuel consumption is measured and recorded in gallons per machine operating hour.

The cost of oil changes is recorded for each machine requiring regular oil changes. If oil filters are also changed, this cost should be included. The interval between successive oil changes is also recorded, measured in machine operating hours between changes.

The cost of lubrication should include only the cost of the grease and fittings when the lube job is performed by your own maintenance man. His labor cost has been accounted for in overhead costs. However, if a service station handles your lube jobs, include the entire cost of lube and labor. Measure the interval between the lube jobs in machine operating hours.

## TIRES

Record the total cost of all tires on each vehicle or machine. Also record the estimated average tire life, measured in machine operating hours.

## SUPPLIES AND EQUIPMENT

Items such as filters, wire rope, and saw chains wear out and must be replaced at regular intervals. These items should be listed, their cost recorded, and an estimate given on the life of the equipment. Do not include maintenance and repair items such as engine overhauls or breakdowns. These items are accounted for in the maintenance and repair portion of systems overhead costs.

Once all operating cost items and their use rates are listed for every type of machine on Operating Cost Worksheet, operating cost rates are established and recorded. On the right side of this worksheet, a separate column is provided for each type of machine. In these columns are recorded the fuel costs, oil costs, lube costs, and equipment costs for each hour of machine operating time. The total of these costs is the hourly operating cost for each machine type in the system.

Operating costs are expressed in dollars per machine operating hour, \$/MOH. These hourly cost rates are derived using the cost data listed on Operating Cost Worksheet and the nomograms in Figures 5 through 7. Using fuel consumption rates, fuel costs, and the nomogram in Figure 5, determine fuel costs per hour of machine operating time. The nomogram in Figure 6 can be used for oil changes, lube jobs, or minor equipment costs by applying the cost of equipment or servicing and the interval between lube jobs, oil changes, or the life of the equipment.

A third nomogram, Figure 7, converts the cost and expected life of tires and other major equipment expenses into an hourly operating cost.

When all of the worksheets are complete, you are ready to use Weak Link.

Figure 5.--Nomogram for hourly fuel cost

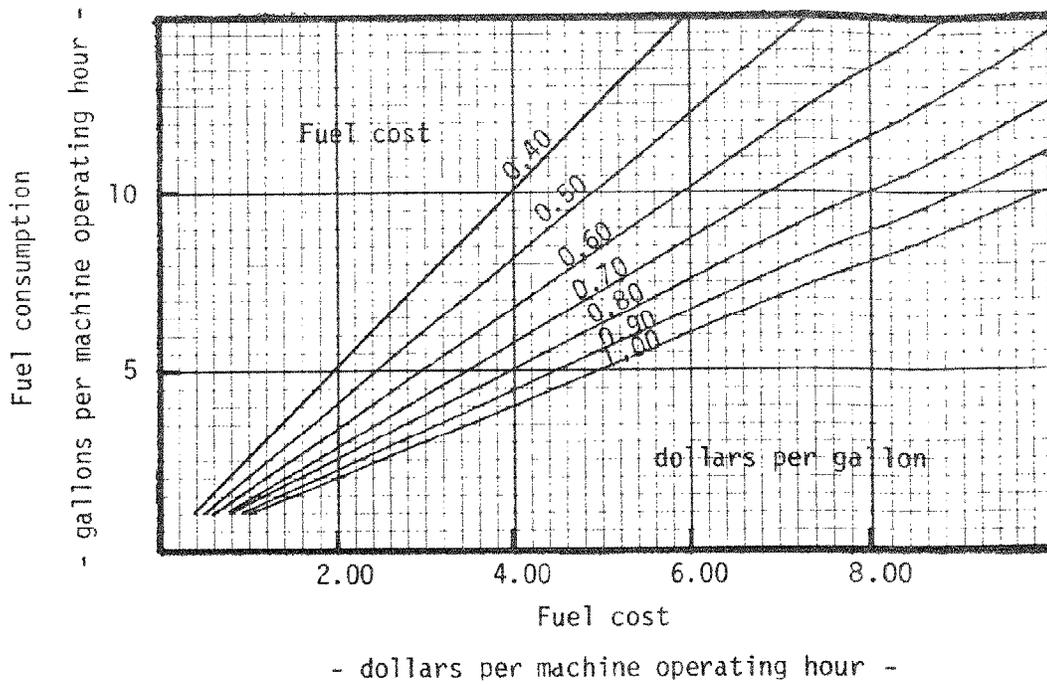


Figure 6.--Nomogram for hourly cost of minor service and supply items

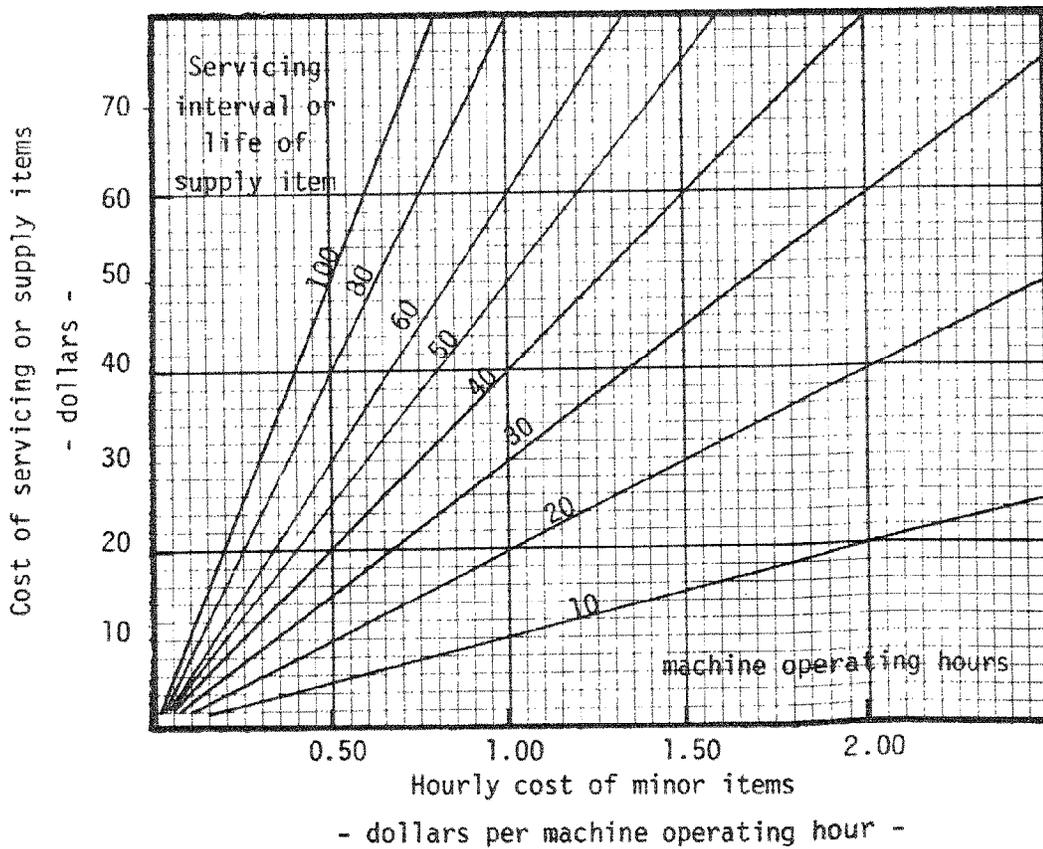
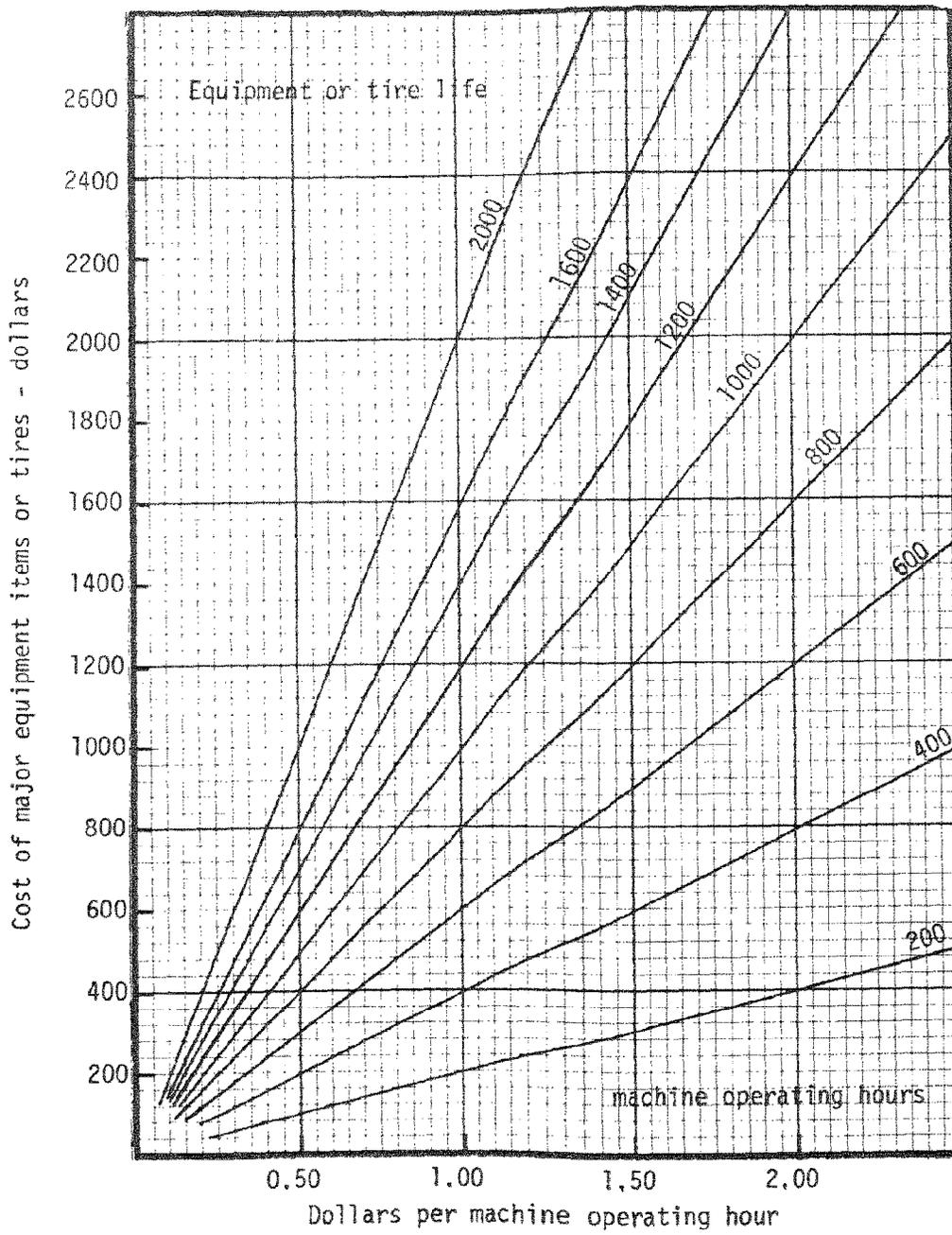


Figure 7.--Nomogram for hourly cost of major items



/CHAINSAWS/

COST

CONSUMPTION

Fuel \$ \_\_\_\_\_/gal. \_\_\_\_\_ gals./hr.  
 Oil \$ \_\_\_\_\_/qt. \_\_\_\_\_ qts./hr.  
 Sawchain \$ \_\_\_\_\_/ft. \_\_\_\_\_ ft. \_\_\_\_\_ hrs.

/SKIDDERS/

COST

CONSUMPTION OR INTERVAL

Fuel \$ \_\_\_\_\_/gal. \_\_\_\_\_ gal./hr.  
 Oil \$ \_\_\_\_\_/change \_\_\_\_\_ hrs./change  
 Lube \$ \_\_\_\_\_/lube \_\_\_\_\_ hrs./lube  
 Filters \$ \_\_\_\_\_/filter \_\_\_\_\_ hrs./filter  
 Tires \$ \_\_\_\_\_ hrs./tire change  
 Wire rope \$ \_\_\_\_\_/ft. \_\_\_\_\_ ft./\_\_\_\_\_ hrs.

/LOADER/

COST

CONSUMPTION OR INTERVAL

Fuel \$ \_\_\_\_\_/gal. \_\_\_\_\_ gals./hr.  
 Oil \$ \_\_\_\_\_/change \_\_\_\_\_ hrs./change  
 Lube \$ \_\_\_\_\_/lube \_\_\_\_\_ hrs./lube

Other Items:

\_\_\_\_\_ \$ \_\_\_\_\_  
 \_\_\_\_\_ \$ \_\_\_\_\_  
 \_\_\_\_\_ \$ \_\_\_\_\_

/TRUCKS/

COST

CONSUMPTION OR INTERVAL

Fuel \$ \_\_\_\_\_ gal./hr.  
 Oil \$ \_\_\_\_\_ hrs./change  
 Lube \$ \_\_\_\_\_ hrs./lube  
 Filters \$ \_\_\_\_\_ hrs./filter  
 Tires \$ \_\_\_\_\_ hrs./tire change

Other Items:

\_\_\_\_\_ \$ \_\_\_\_\_  
 \_\_\_\_\_ \$ \_\_\_\_\_  
 \_\_\_\_\_ \$ \_\_\_\_\_

OPERATING COST WORKSHEET

Machine No.	1	2	3	4
Description				
Cost Item				
Fuel				
Oil				
Lube				
Tires				
Total				

Machine No.	5	6	7	8
Description				
Cost Item				
Fuel				
Oil				
Lube				
Tires				
Total				

### ESTIMATING POTENTIAL PRODUCTION RATES

Three series of nomograms are used to predict potential production rates for felling and limbing, skidding, and trucking. These predictions are based upon the information listed on the operating conditions worksheet.

Once the potential production rates are estimated for each of the three categories (felling and limbing, skidding, and trucking), they are listed on page 50; and the estimated system production rate is determined.

### POTENTIAL FELLING AND LIMBING PRODUCTION

Felling and limbing cycle time estimates are based upon the diameter and height of the trees, the slope of the terrain, and the method of paying the felling crews. The average felling and limbing cycle times and the length of the workday are then used to predict the number of trees felled per man-day. Finally, trees felled per man-day together with average tree volume and number of fellers are used to estimate the potential felling and limbing production rate.

Estimate felling time by using method of payment (\$/hour or \$/MBF) and the average diameter at breast height of the trees to be felled. Felling time is measured in minutes per tree and recorded as F1.

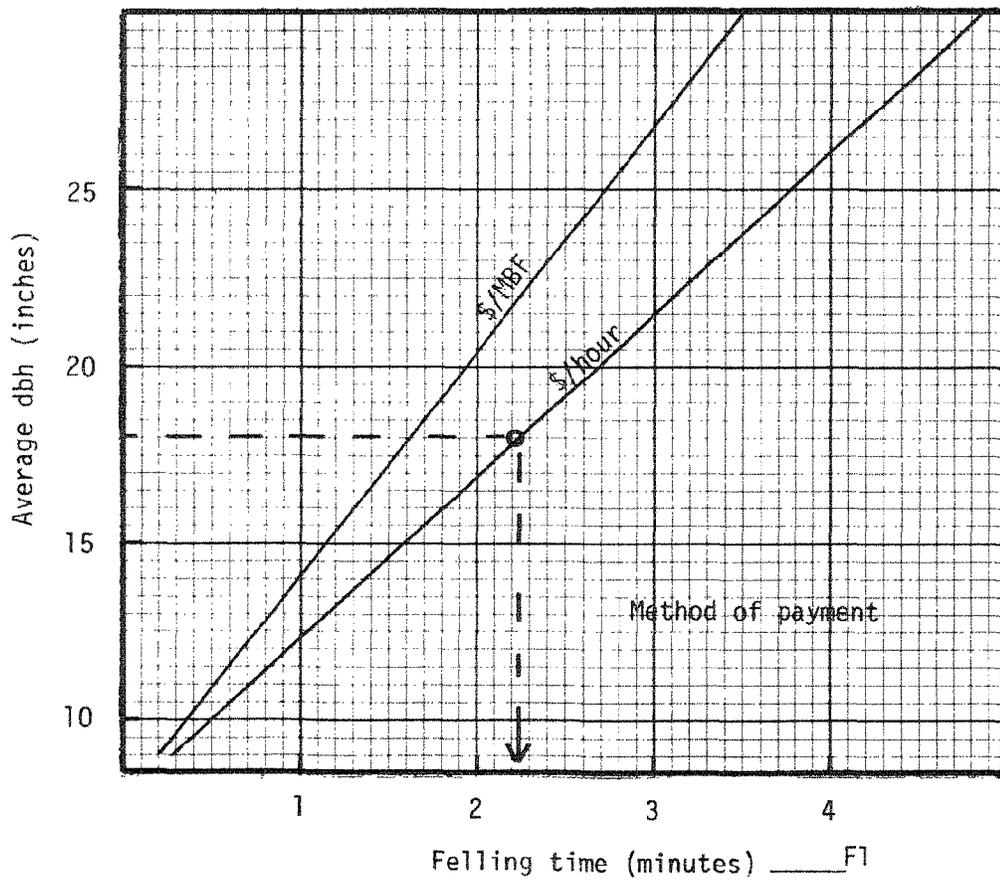
Example:

Average dbh = 18 inches

Method of payment = \$/hour

F1, felling time = 2.3 minutes per tree

Figure 8.--Nomogram for felling time



## LIMBING AND TOPPING TIME

Estimate limbing and topping time using the average dbh of trees felled and the average merchantable tree height, in number of 16-foot logs. Limbing and topping time is measured in minutes per tree and recorded as F2.

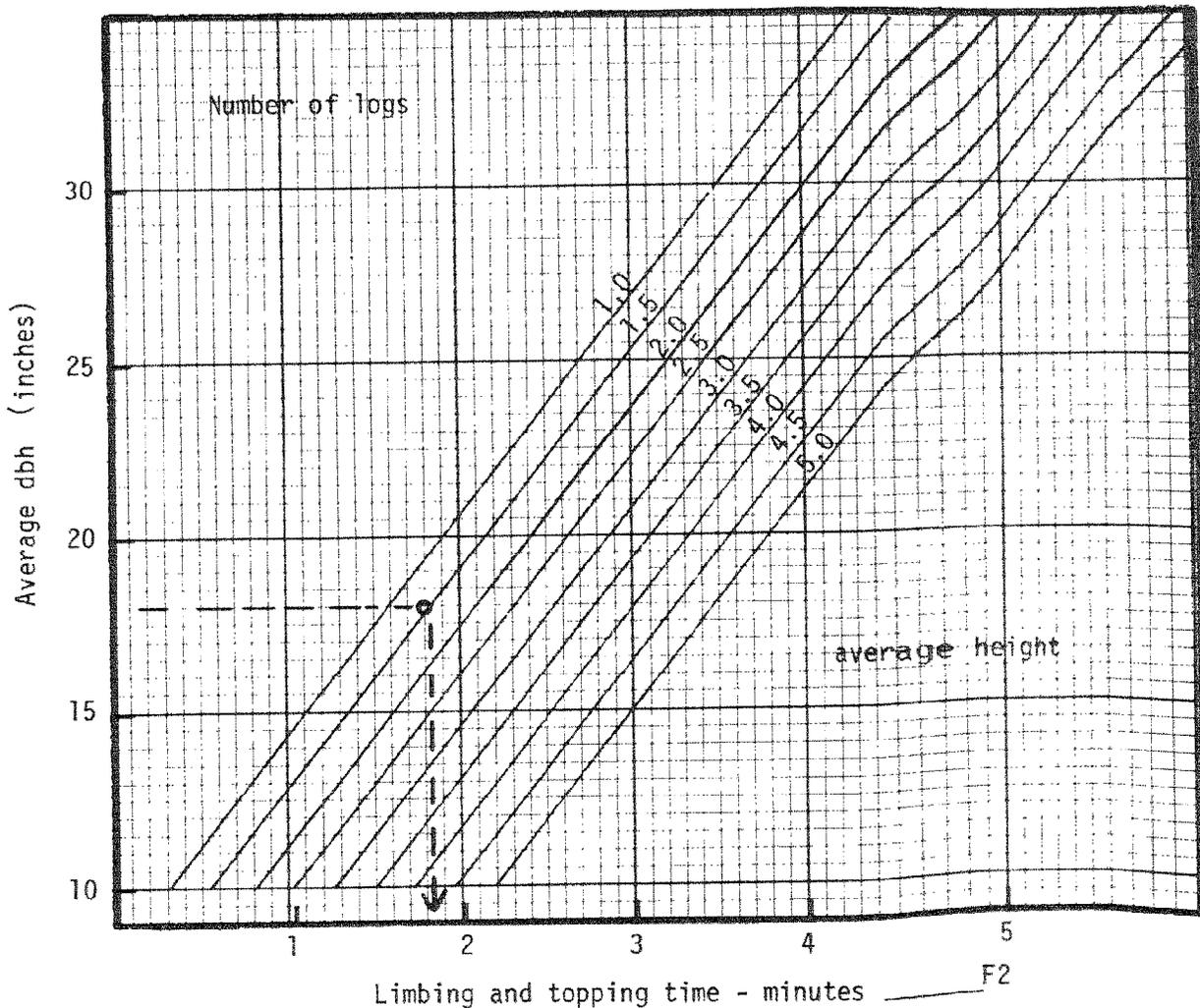
Example:

Average dbh = 18"

Average merchantable tree height = 1.5 logs

F2, limbing and topping time = 1.8 minutes per tree

Figure 9.--Nomogram for limbing and topping time



TIME TO WALK BETWEEN TREES

The time required to walk from one tree to the next is estimated using the slope of the terrain. Walking time, F3, is recorded in minutes per tree.

Example:

Slope = 16 - 30 percent

F3, Walking time = 1.0 minute per tree

Slope of terrain (Percent)	Walking time (Minutes per tree)
0 - 15	0.6
16 - 30	1.0
+30	1.4

Time to walk between trees \_\_\_\_\_ F3  
(minutes per tree)

SELF-CAUSED DELAY TIME

Self-caused delay time is determined by the method of payment. It is measured in minutes per tree and recorded as F4.

Example:

Method of payment = \$/hour

F4, Average self-caused delay time = 3.5 minutes per tree

Method of payment - \$/MBF	<u>2.5 min.</u>
Method of payment - \$/hour	<u>3.5 min.</u>

Average delay time \_\_\_\_\_ F4  
(minutes per tree)

AVERAGE FELLING CYCLE TIME

Record felling and limbing cycle time elements F1, F2, F3, and F-4 below. Adding felling time (F1) to limbing and topping time (F2) determines average saw operating time per tree. Average cycle time per tree is the sum of all four time elements, F1 + F2 + F3 + F4. Both operating time and cycle time are measured in minutes per tree.

Example:

F1, Felling time	2.3 minutes
F2, Limbing and topping time	1.8 minutes
F2.5, Saw operating time	4.1 minutes per tree
F3, Walking time	1.0 minute
F4, Self-caused delay	3.5 minutes
F5, Total cycle time	8.6 minutes per tree

AVERAGE CYCLE TIME - FELLING

F1, \_\_\_\_\_

F2, \_\_\_\_\_

F2.5 Machine operating time \_\_\_\_\_ minutes per tree

F3, \_\_\_\_\_

F4, \_\_\_\_\_

F5 Average total cycle time \_\_\_\_\_ minutes per tree

NUMBER OF TREES FELLED PER DAY PER CUTTER

Use average cycle time (F5) and the number of hours per shift to estimate the number of trees felled per shift per cutter, F6.

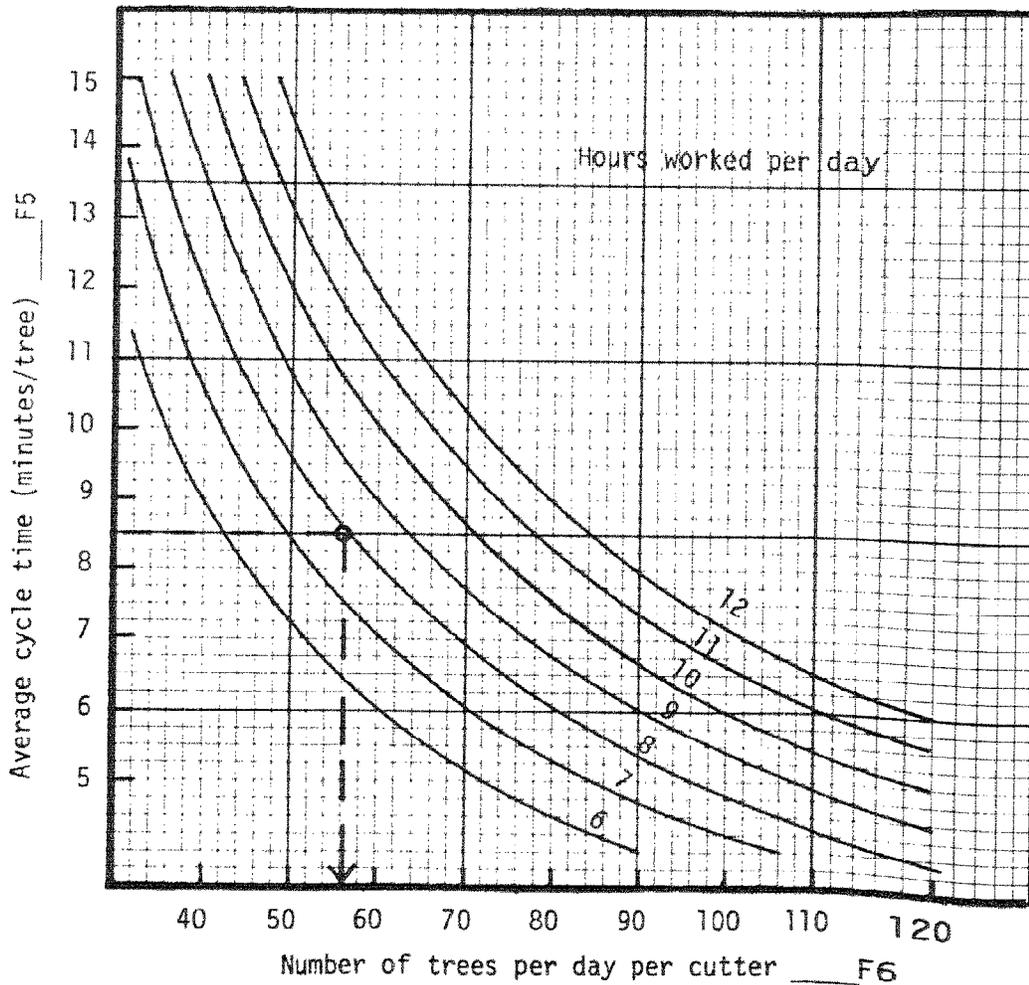
Example:

Average cycle time = 8.6 minutes per tree

8 hours per shift

F6, number of trees per day, per cutter = 56 trees

Figure 10.--Nomogram for trees cut per day



#### ESTIMATED FELLING PRODUCTION RATE

The potential felling and limbing production is estimated using trees felled per shift per cutter,  $F_6$ , the average board foot volume per tree, and the number of felling crews. Potential felling and limbing production is measured in MBF per shift and recorded as  $F_7$ .

Example:

Trees felled per shift per cutter = 56

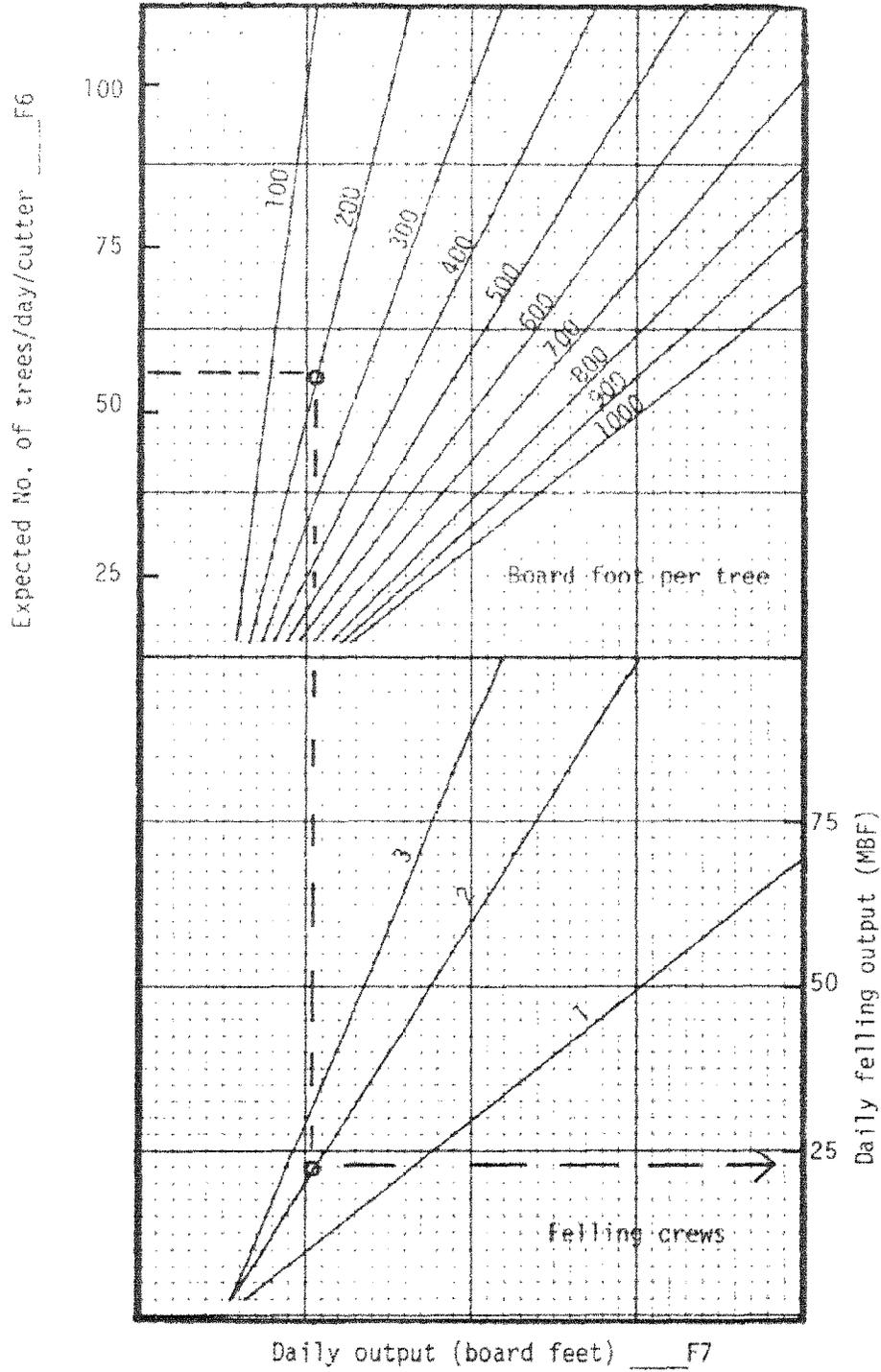
Average volume per tree = 200 board feet

Number of cutters = 2

$F_7$ , potential felling and limbing production =

22 MBF per shift

Figure 11.--Nomogram for felling production rate



## POTENTIAL SKIDDING PRODUCTION

Skidding production is estimated by first determining the average cycle time per turn of logs. This includes travel time empty, hooking and unhooking time, delay time, and travel time loaded. Average cycle time and hours per shift are then used to predict the number of turns per shift per skidder. This value in turn is coupled with the number of skidders in the system, number of logs per turn, and average log volume to predict potential skidding production on a shift basis.

## OUTTURN TIME

S1 - Outturn time or travel time empty is estimated using two factors, skidding distance, and whether the outturn was on level ground, uphill, or downhill. Record outturn time, S1, in minutes per cycle.

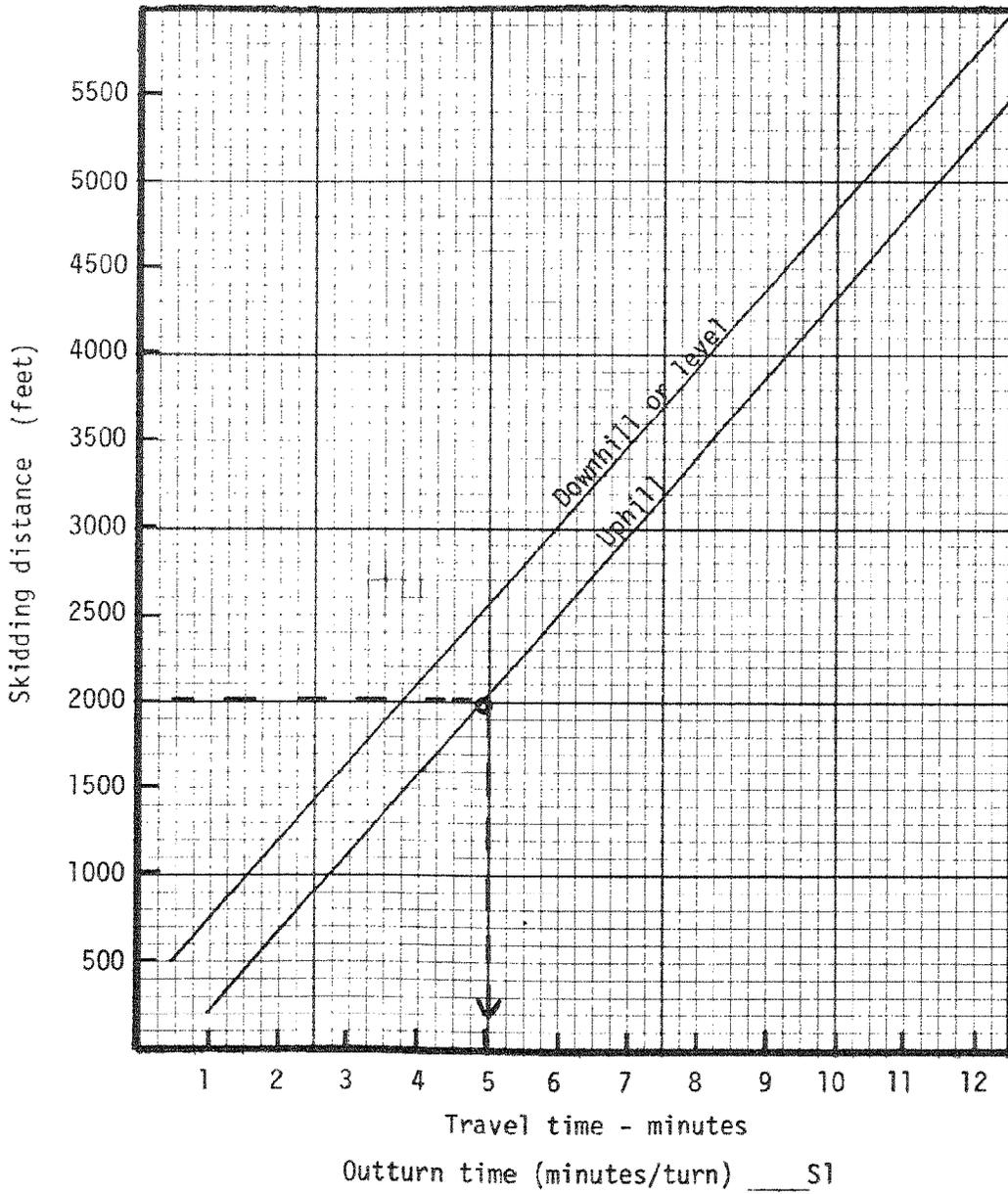
Example:

Skid distance = 2,000 feet

Slope in direction of outturn = uphill

S1, outturn time = 5 minutes per turn

Figure 12.--Nomogram for skidder outturn time



## HOOKING AND UNHOOKING TIME

S2 - Hooking and unhooking time includes all of the time required to hook up the chokers, winch the logs up to the skidder, and unhook the logs at the landing. The time required to perform these functions is estimated using the number of pieces skidded per turn and whether or not the trees are previously bunched. Record estimated minutes of hooking and unhooking time as S2.

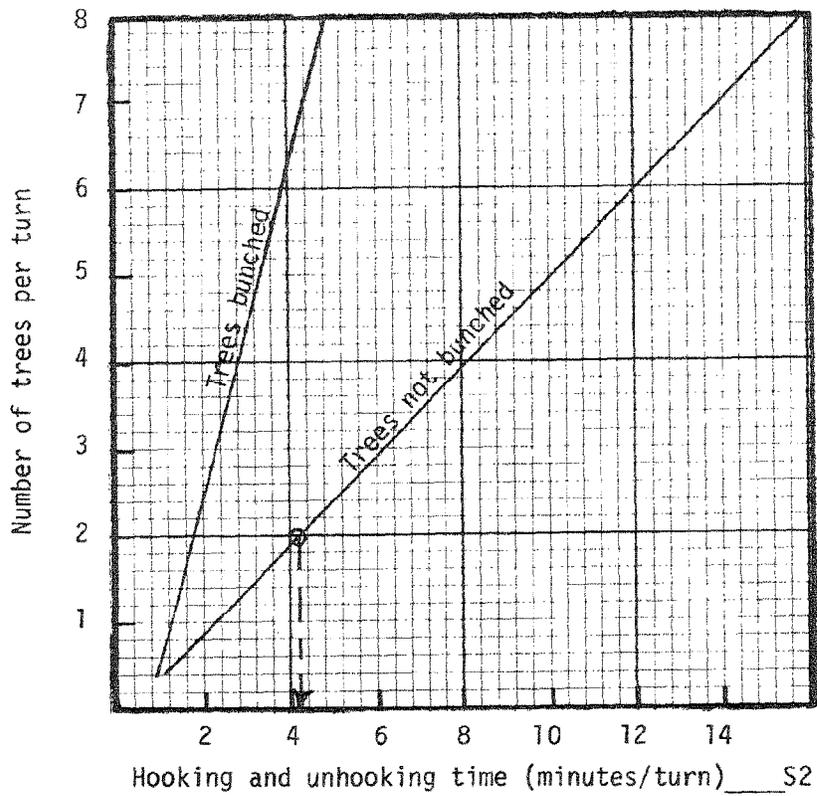
Example:

Number of trees per turn = 2

Trees not bunched

S2, hooking and unhooking time = 4.2 minutes per turn

Figure 13.--Nomogram for skidder hooking and unhooking time



### SKIDDING TIME

S3 - The estimate of skidding time is based upon five factors; number of trees per turn, average tree volume, skidding distance, slope in direction of skid, and whether the skidder was tracked or rubber-tired. Record minutes of skidding time as S3.

Example:

Trees per turn = 2

Average tree volume = 200 board feet

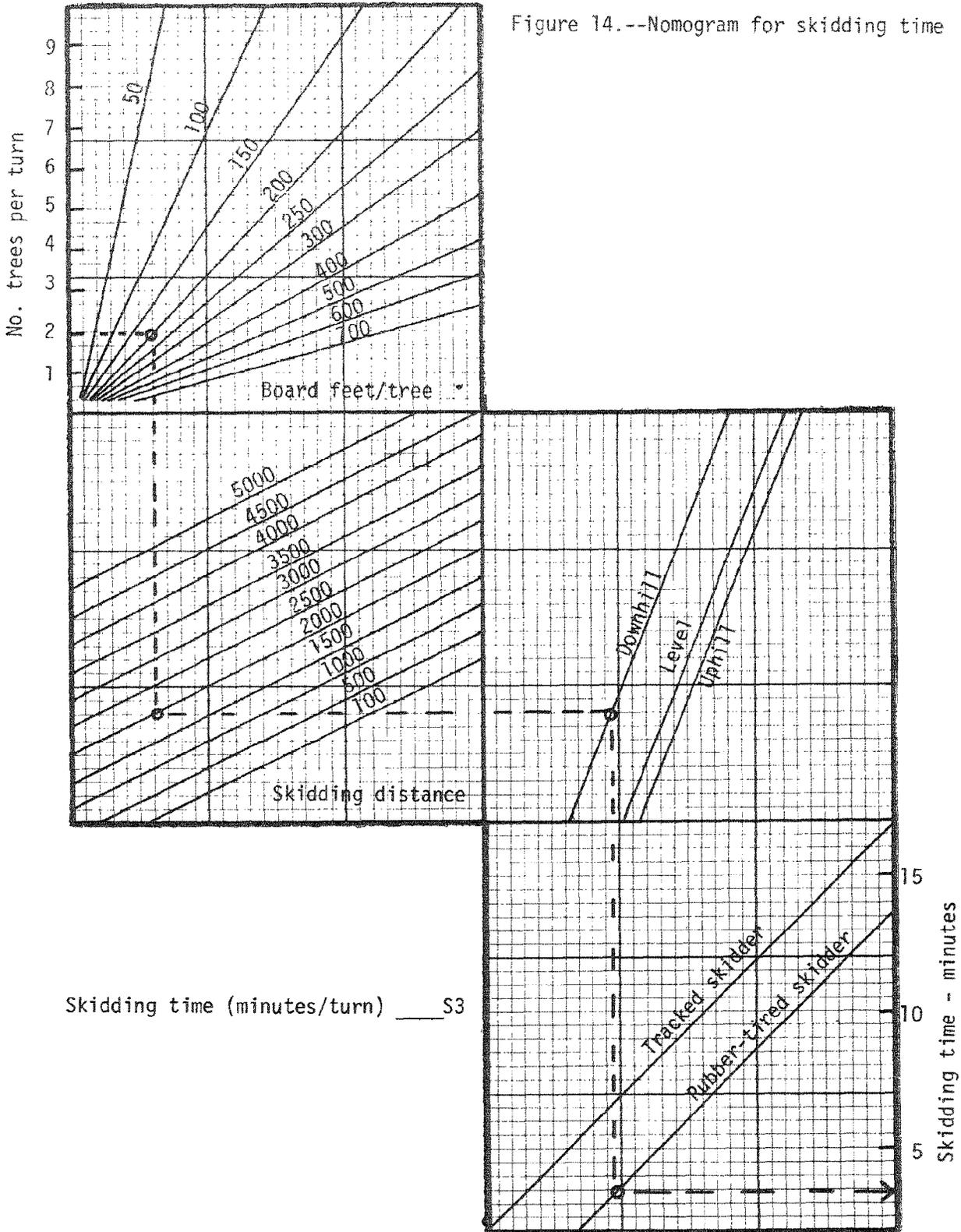
Skidding distance = 2,000 feet

Skid loaded = downhill

Skidder type = rubber-tired

S3, skidding time = 3.5 minutes per turn

Figure 14.--Nomogram for skidding time



Skidding time (minutes/turn) \_\_\_\_ S3

SELF-CAUSED DELAY TIME

Self-caused delay time can be estimated using the table below. The criteria for ranking operator aggressiveness are listed below:

Aggressiveness:

High.--An operator whose every movement was of a productive nature--no lost motion; whose delay time was nearly always unavoidable; who performed his duties at a safe but fast pace; and who possessed an obvious interest in producing for himself and the company.

Average.--An operator who possessed some, but not all, of the above traits.

Low.--An operator who possessed none of these traits.

Self-caused skidder delay time can be estimated through on-the-site observations. In either case, average self-caused skidder delay is measured in minutes per cycle and recorded as S4.

Aggressiveness rank	Average delay per turn
High	1.2 minutes
Medium	2.4 minutes
Low	3.7 minutes

Average skidding delay \_\_\_\_\_ S4  
(minutes per turn)

AVERAGE CYCLE TIME

In the spaces below, list all four of the skidding cycle time elements, S1, S2, S3, and S4. The sum of S1 + S2 + S3 is equal to skidder operating time per cycle, or 53.5. Average skidder cycle time is the total of S1 + S2 + S3 + S4. This is expressed in minutes per turn and recorded as S5.

Example:

Outturn time, S1 = 5 minutes

Hookup time, S2 = 4.2 minutes

Skidding time, S3 = 3.5 minutes

Machine operating time, S1.5 = 12.7 minutes per cycle

Self-caused delay time, S4 = 2.4 minutes

Total cycle time, S5 = 15.1 minutes per cycle

AVERAGE CYCLE TIME

- SKIDDING -

S1 \_\_\_\_\_

S2 \_\_\_\_\_

S3 \_\_\_\_\_

Machine operating time per cycle ..... 53.5  
(S1 + S2 + S3)

S4 \_\_\_\_\_

Total cycle time ..... S5  
(S1 + S2 + S3 + S4)

Minutes per turn

## URNS PER SHIFT

S6 - Estimate the number of turns each skidder will make per shift. This estimate is based upon the average cycle time, S5; the number of hours worked per shift; and the mechanical availability of the skidders.

Mechanical availability is the percent of scheduled machine operating times a machine is mechanically fit to do productive work.

Expected number of turns per shift per skidder is recorded as S6.

Example:

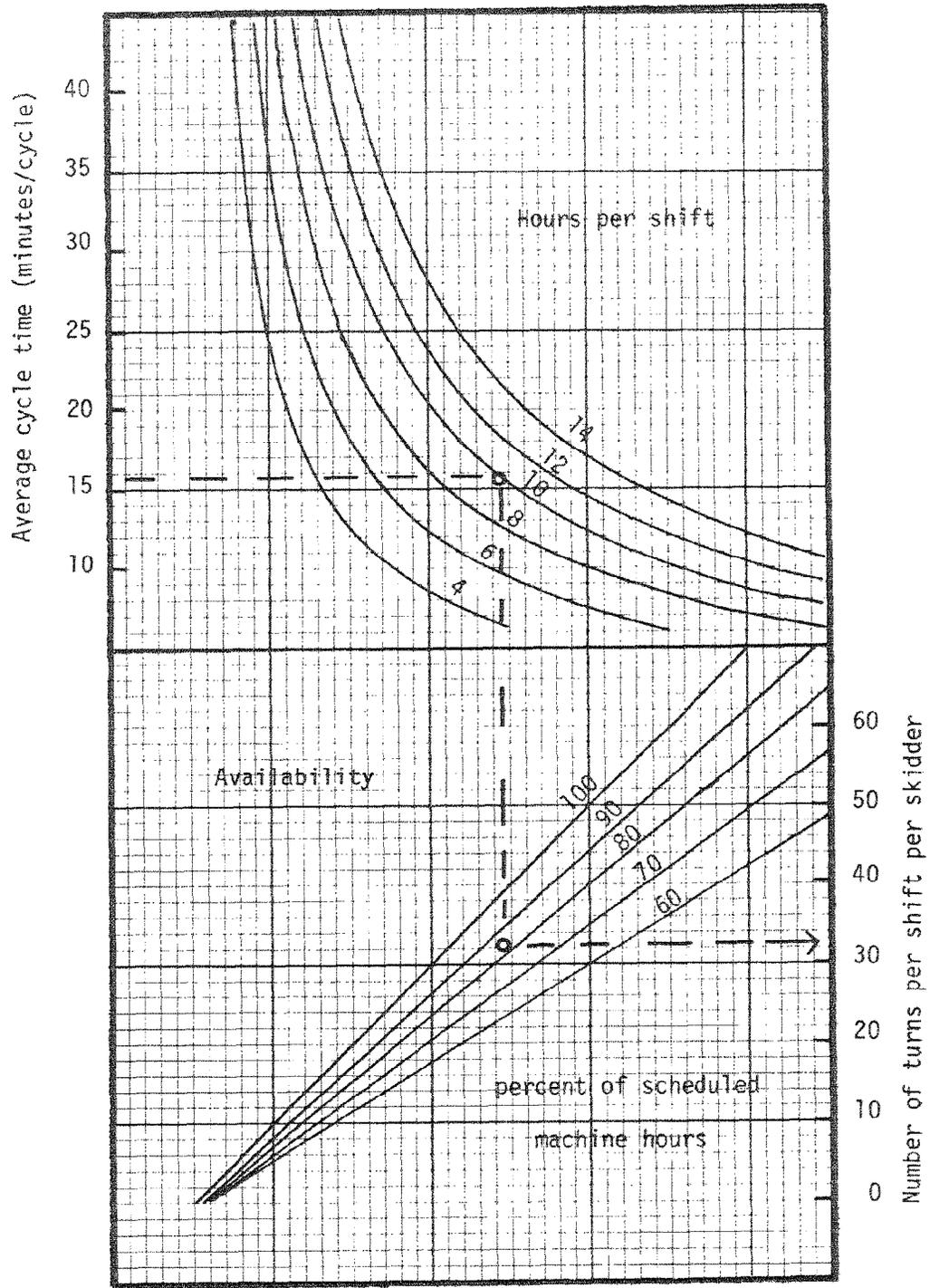
S5, average cycle time = 15.1 minutes

Hours worked per shift = 10

Availability = 85 percent

S7, turns per day per skidder = 31

Figure 15.--Nomogram for the number of turns per skidder per shift



Expected number of turns per skidder per shift \_\_\_ S6

### ESTIMATED SKIDDING PRODUCTION RATE

S7 - Four factors are used to estimate potential skidding production; number of turns per shift per skidder, S6; average number of logs per turn; average log volume; and the number of skidders in the system. Potential skidding production is measured in MBF per shift and recorded as S7.

Example:

S6, turns per day per skidder = 31

Pieces skidded per turn = 2

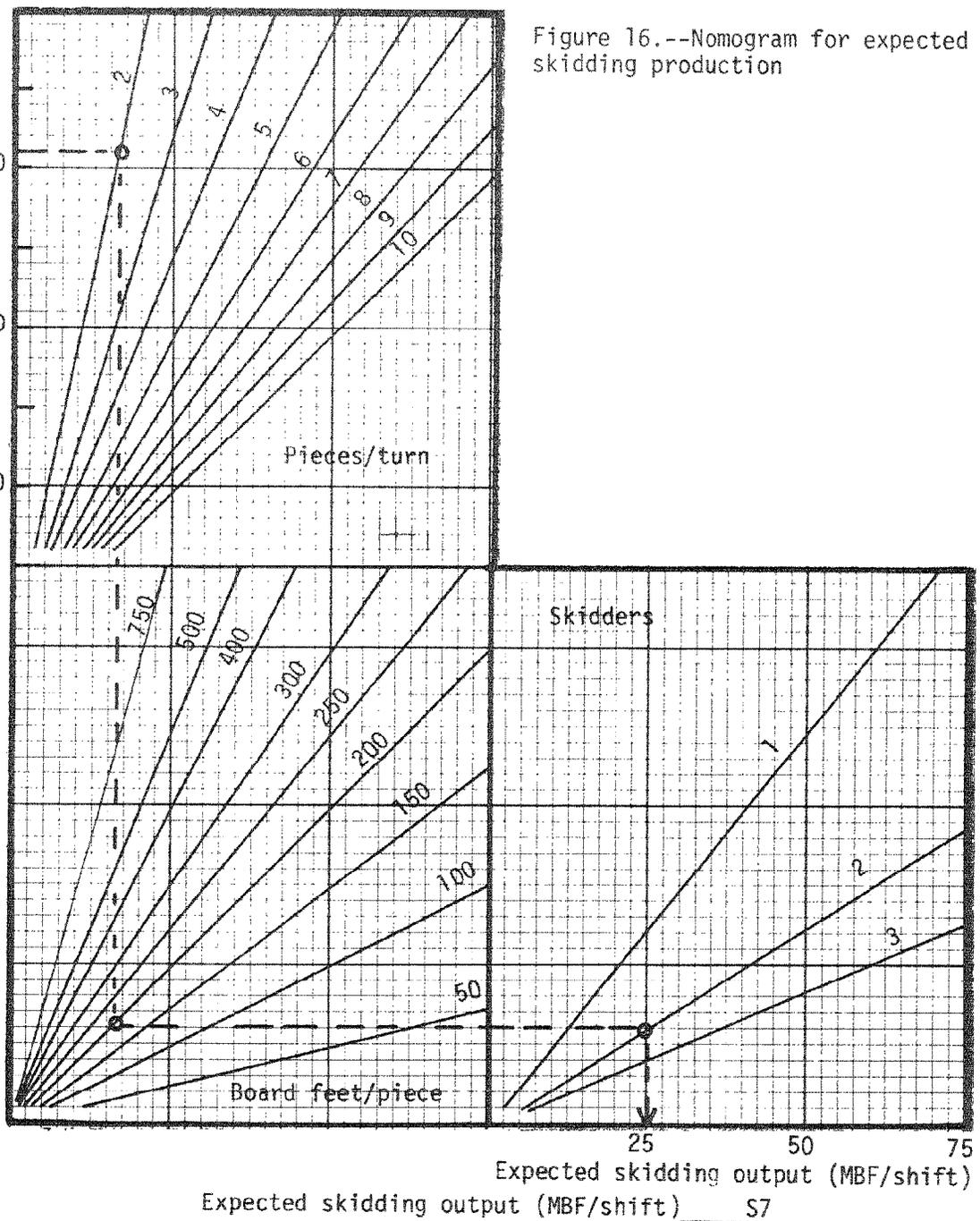
Average volume per pieces = 200 board feet

Number of skidders = 2

S7, potential skidding production = 25 MBF per shift

Expected No. turns/day/skidding - S6

Figure 16.--Nomogram for expected skidding production



## POTENTIAL TRUCKING PRODUCTION

Trucking production is predicted by first estimating truck cycle times which include loading time, driving time, delay time, and unloading time. Average cycle times and hours worked per shift are then used to determine the number of round trips per shift each truck will make. From trips per day per truck, volume per truckload, and number of trucks in the system, potential loading and trucking production is estimated. This estimate is expressed in MBF per shift.

### LOADING TIME

H1 - Estimate loading time using average load volume and the average volume of the logs being loaded. Record this estimate as H1, minutes per load.

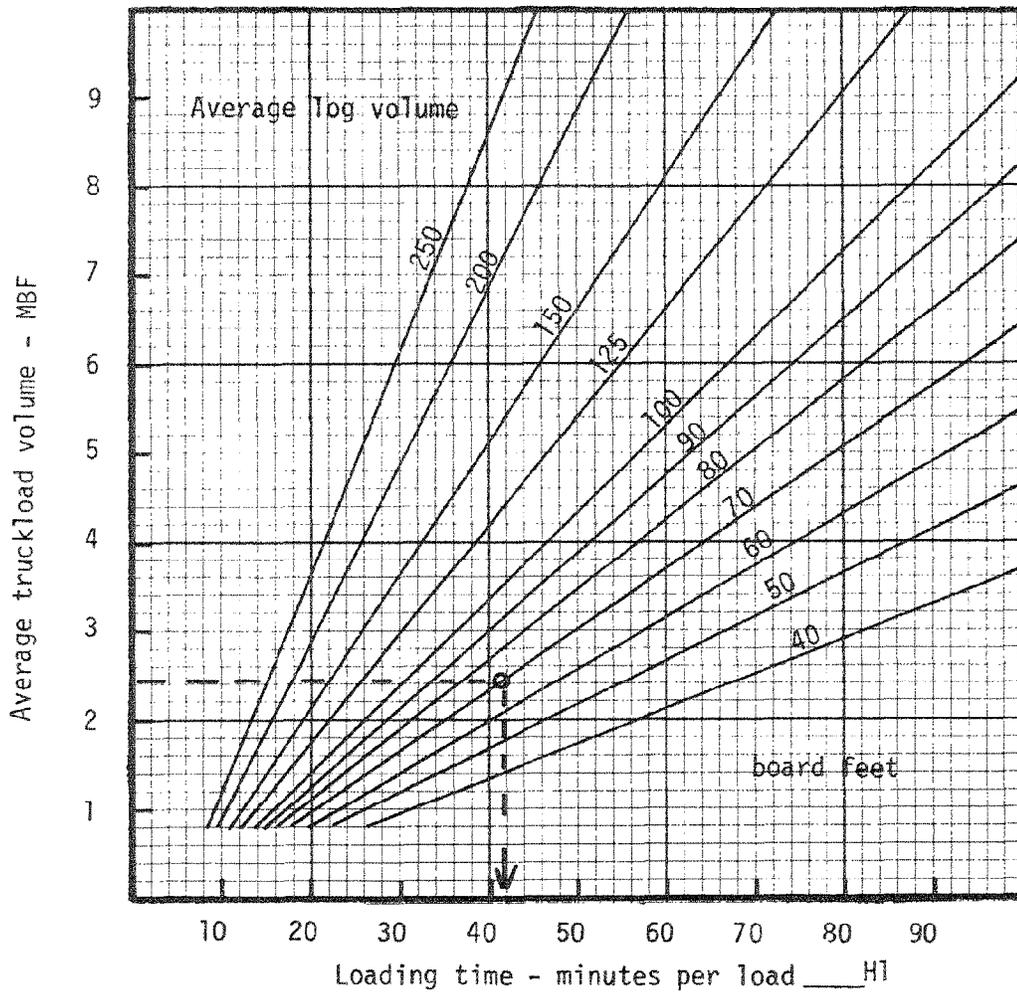
Example:

Average log volume = 70 board feet

Truck capacity = 2,500 board feet

H1, loading time = 42 minutes per load

Figure 17.--Nomogram for truck loading time



## TRAVEL TIME

H2 - Round-trip travel time is estimated using the distance traveled over two-lane paved roads, one-lane paved roads, gravel roads, and woods roads. Travel time is measured in minutes per round trip and recorded as H2.

Examples:

Distance one way: Two-lane paved roads = 20 miles

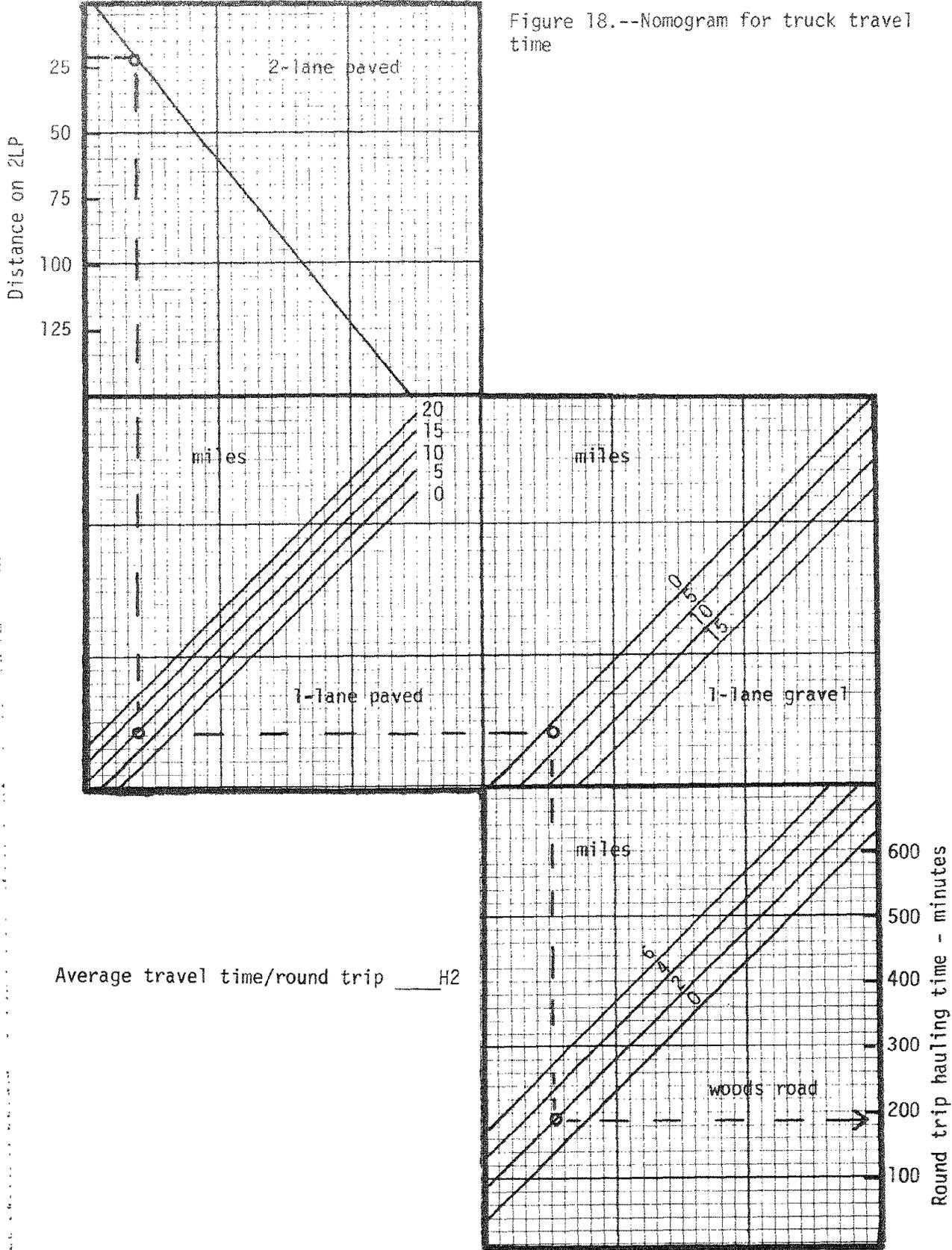
One-lane paved roads = 10 miles

One-lane gravel roads = 2 miles

Woods roads = 2 miles

H2, round-trip travel time = 190 minutes

Figure 18.--Nomogram for truck travel time



UNLOADING TIME

Unloading time for tandem-axle trucks averaged 7 minutes per load. For other types of trucks such as trailer trucks, use average from time study of individual operations.

Unloading time (minutes per load) \_\_\_\_\_ H3

DRIVER-CAUSED DELAY

Average driver-caused delay time, H4, can be estimated using either the 24 minutes per trip we obtained from our time studies or your own estimate based upon personal observations. This time element includes only driver-caused delays, not delays caused by the system such as delays incurred by trucks waiting to load at the landing. Whichever estimate is used, record minutes of delay time per trip as H4.

Driver-caused delay \_\_\_\_\_ H4

(minutes per trip)

AVERAGE CYCLE TIME

Record all four trucking time elements below. The sum of these four time elements is equal to the average trucking cycle time, H5.

H1, loading time = 42 minutes  
H2, travel time = 190 minutes  
H3, unloading time = 7 minutes  
H4, self-caused delay time = 24 minutes  
H5, total 263 minutes per trip

H1 \_\_\_\_\_ loading time  
H2 \_\_\_\_\_ travel time  
H3 \_\_\_\_\_ unloading time  
H4 \_\_\_\_\_ self-caused delay time  
H5 \_\_\_\_\_ average total cycle time  
(minutes per trip)

### TRIPS PER DAY PER TRUCK

Enter the nomogram on the opposite page with average truck cycle time, H5; select the appropriate number of hours worked per shift; and the truck availability level to determine the number of trips per shift each truck will make, H6.

Example:

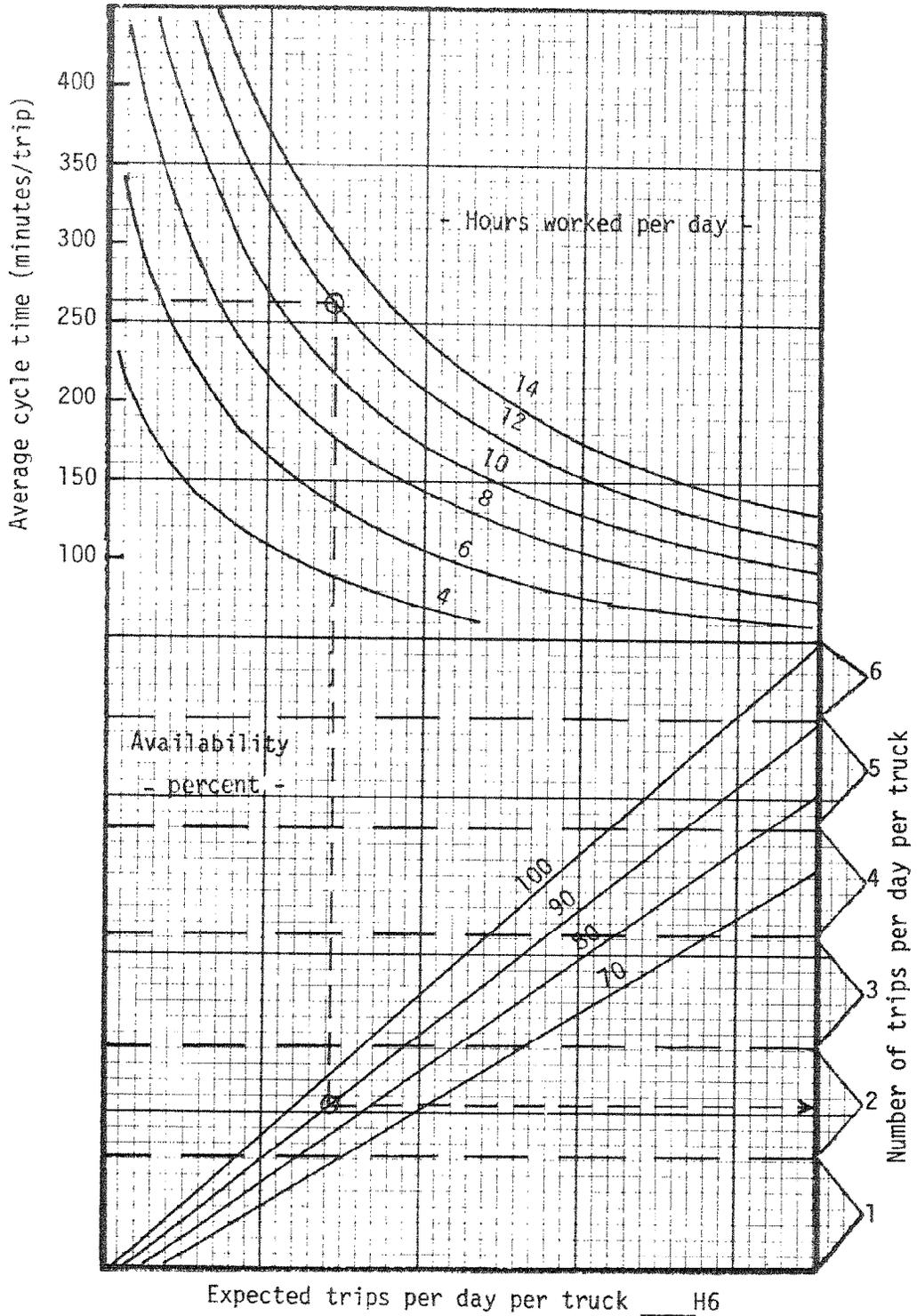
H6, total round-trip time = 263 minutes

Hours worked per shift = 12

Availability = 90 percent

H6, trips per day per truck = 2

Figure 19.--Nomogram for number of trips per day



ESTIMATED TRUCKING PRODUCTION RATE

Use the number of trips per shift per truck (H6), truckload volume, and number of trucks in the system to estimate potential loading and trucking production. Potential loading and trucking production is measured in MBF per shift and recorded as H7.

Example:

H6, trips per day per truck = 2

Volume per truckload = 2,500 board feet

Number of trucks = 3

H7, potential trucking production = 15 MBF per shift

SYSTEM PRODUCTION RATE

(MBF PER DAY)

List the values for F7, S7, and H7 in decreasing order in the spaces below:

---

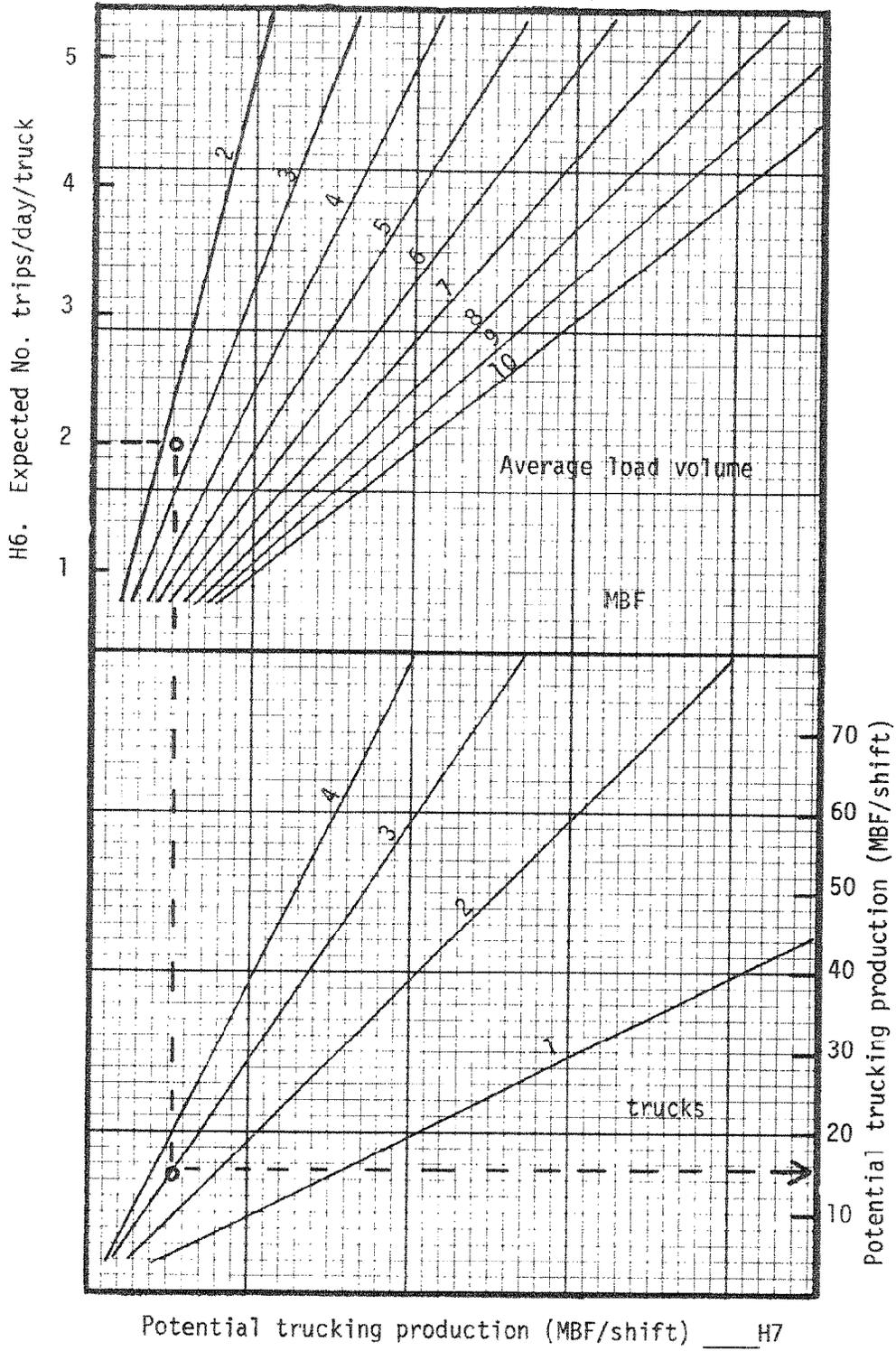
---

"Weak Link" and estimated system production rate

---

SYS1

Figure 20.--Nomogram for trucking production rate



## TOTAL LOGGING COST

On the logging cost worksheet, page 61, list the required production variables, operating condition items, operating cost rates, system fixed cost rate, and system production rate.

A separate operating cost per unit of production is calculated for chain saws, skidders, loaders, and trucks. These four costs are then totaled to obtain the total operating cost per MBF of log production.

Fixed costs per MBF are derived using total systems fixed cost per shift and the volume of production per shift. Fixed cost per MBF is then added to operating cost per MBF to come up with the total cost per unit of production.

### CHAIN SAW OPERATING COST

This includes the cost of operating chain saws for felling, limbing, and bucking. Enter the topmost nomogram with the average dbh of trees harvested, intersect the line representing the average height of trees being harvested, drop down and read minutes of chain saw time required per tree bucked. Record bucking time and add to it the time required for felling and limbing (F2.5). The sum of these two time elements represents total chain saw time required per tree which is then entered into the lower left nomogram and used with average tree volume and the operating cost rate for chain saws to derive an estimate of chain saw operating costs per MBF of logs produced.

Record this cost in the space allotted on the logging cost worksheet.

Example:

Average dbh = 18 inches

Average tree height = 1.5 logs

Sawing time for bucking = 1.8 minutes per tree

F2.5, sawing time for felling and limbing = 4.1 minutes  
per tree

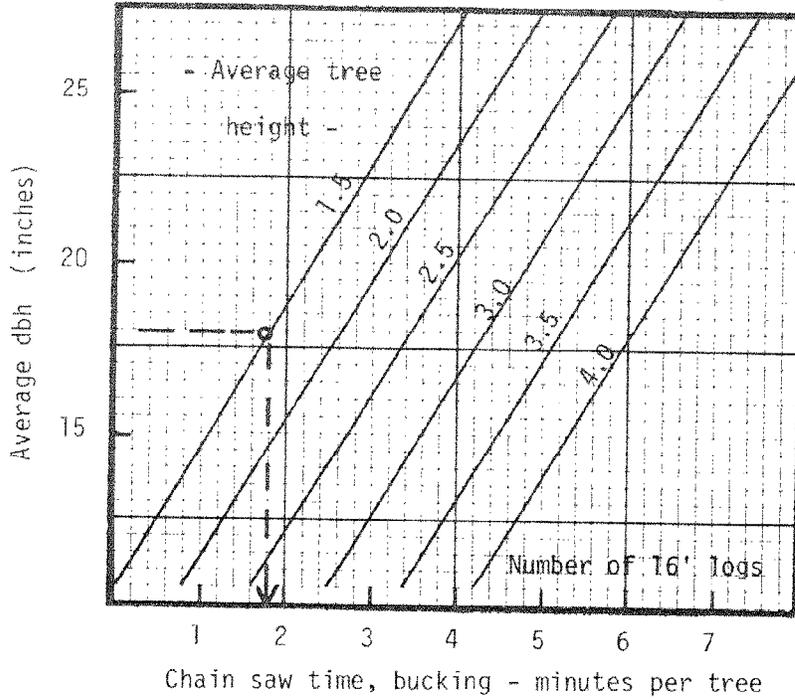
Total chain saw time per tree = 5.9 minutes

Average board foot volume per tree = 200

Chain saw operating cost rate = \$1.50 per machine hour

Chain saw operating cost = \$0.70 per MBF

Figure 21.--Nomogram for chain saw bucking time



F2.5. Chain saw operating time - felling + limbing - minutes/tree \_\_\_\_\_ +  
 Total chain saw time - minutes/tree

Total chain saw time  
 - minutes per tree -

4 6 8 10 12 14 16

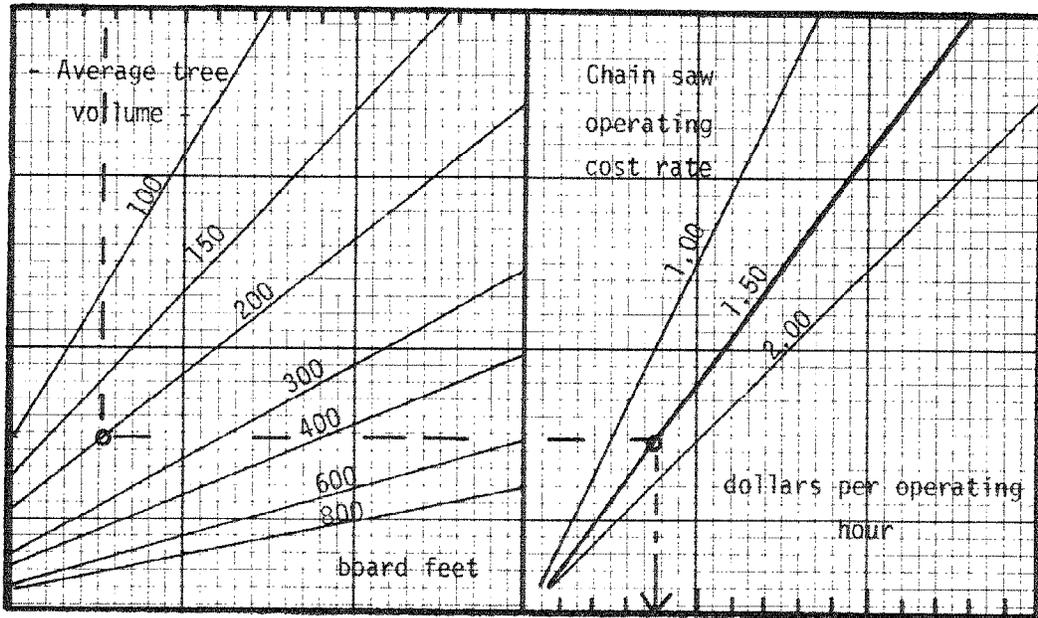


Figure 22.--Nomogram for chain saw operating costs

Chain saw operating cost \_\_\_\_\_ \$/MBF

### SKIDDER OPERATING COSTS

Operating costs for each 1 MBF of logs skidded are determined using skidder operating time per turn (\$3.5), average volume of logs skidded per turn, and the operating cost rate for the skidder. Record skidding operating costs on the logging cost worksheet.

Example:

Skidder operating time = 13.1 minutes per turn

Average volume per turn = 500 board feet

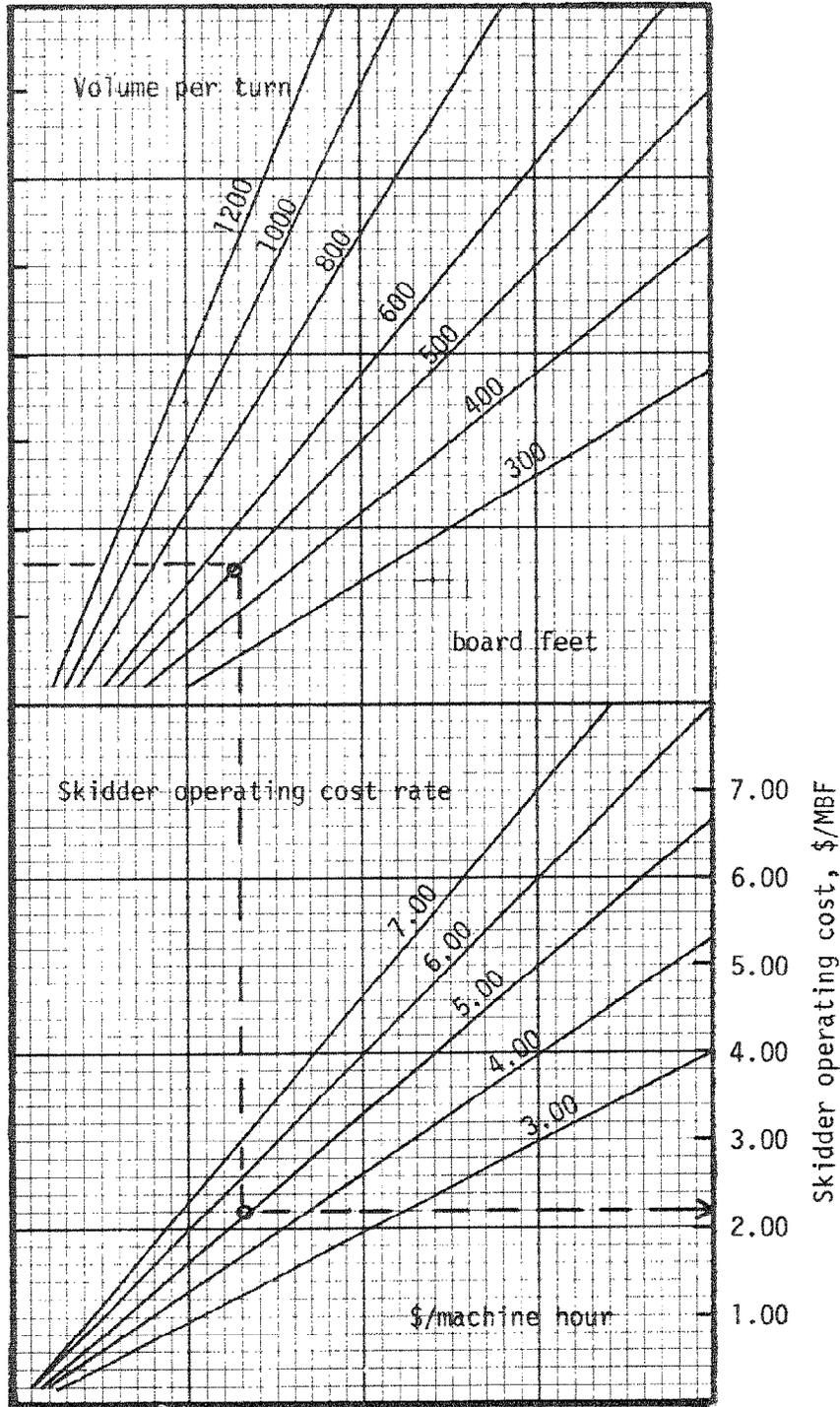
Skidder operating cost rate = \$5.00 per machine hour

Skidder operating cost = \$2.00 per MBF

Figure 23.--Nomogram for skidder operating costs

S3.5. Skidder operating time

- minutes per turn -



### LOADER OPERATING COSTS

Loader operating costs per MBF of logs loaded are estimated using loader operating time per load (H1), volume per truckload, and the loader operating cost rate. Record loader operating costs on the logging cost worksheet.

Example:

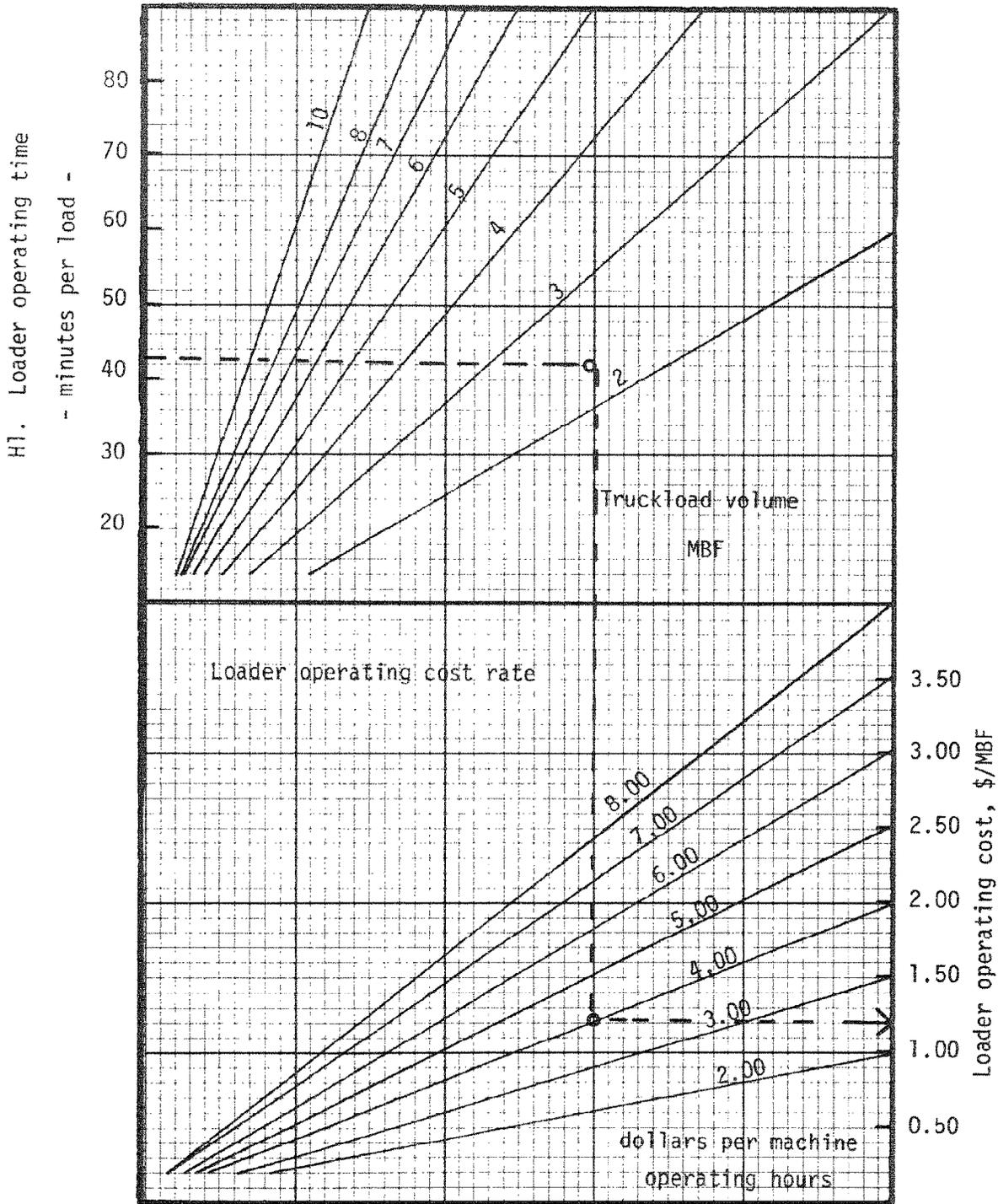
H1, loader operating time = 43 minutes per load

Truckload volume = 2.5 MBF

Loader operating cost rate = \$4.00 per machine hour

Loader operating costs = \$1.20 per MBF

Figure 24.--Nomogram for loader operating costs



### TRUCK OPERATING COSTS

Truck operating costs per MBF of logs hauled are estimated using round-trip travel time (H2), load volume, and the truck operating cost rate. Record truck operating costs on the logging cost worksheet.

Example:

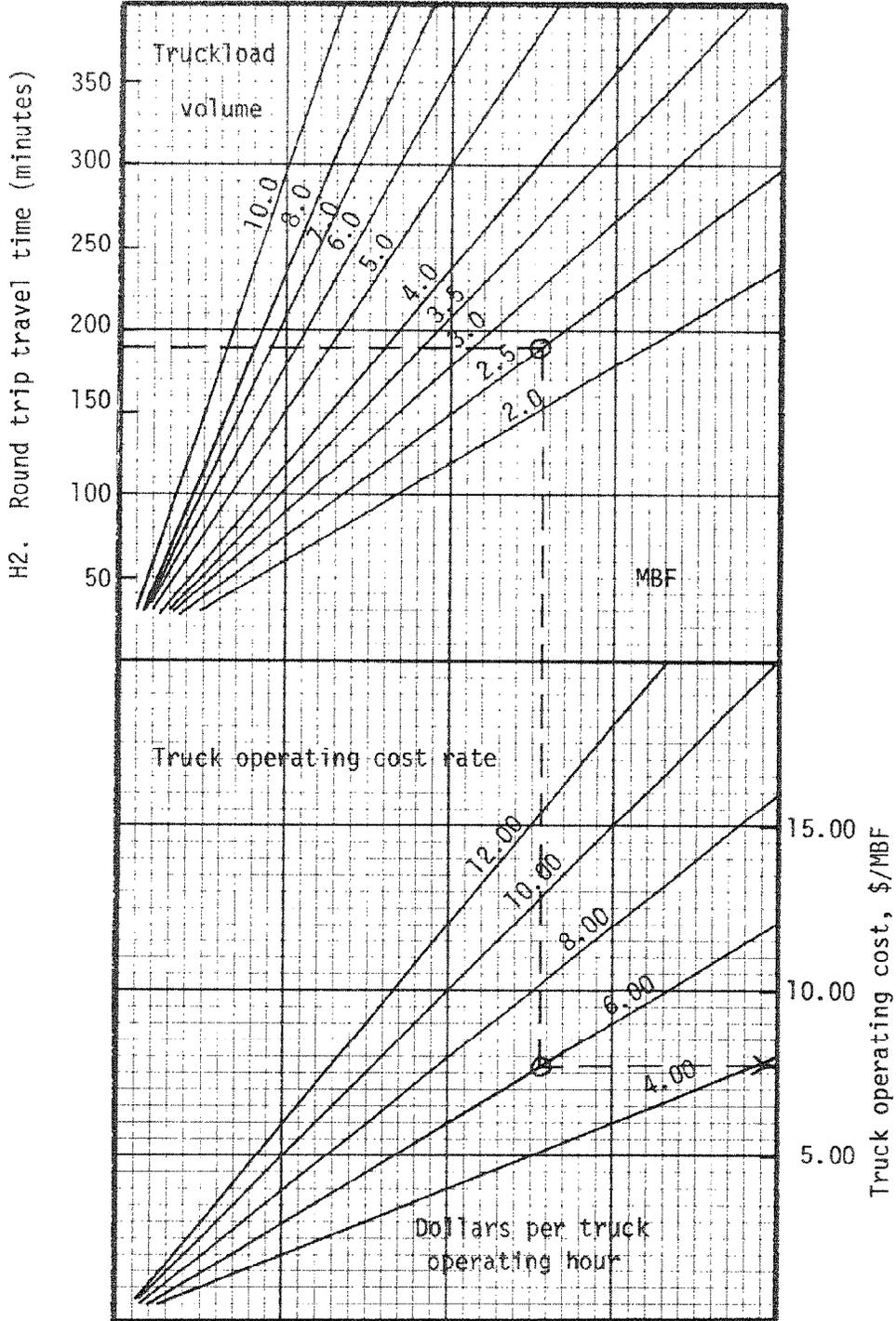
Round-trip travel time = 190 minutes

Truckload volume = 2.5 MBF

Truck operating cost rate = \$6.00 per machine hour

Truck operating costs = \$7.60 per MBF

Figure 25.--Nomogram for truck operating costs



### FIXED COSTS PER MBF

Transfer Systems Fixed Cost (FC-11) from page 14 to page 61. Also record system output (SYS1) from page 50 on page 61. Use the nomogram on the next page to derive fixed costs per MBF by entering Systems Fixed Cost and selecting the appropriate systems production level (SYS1).

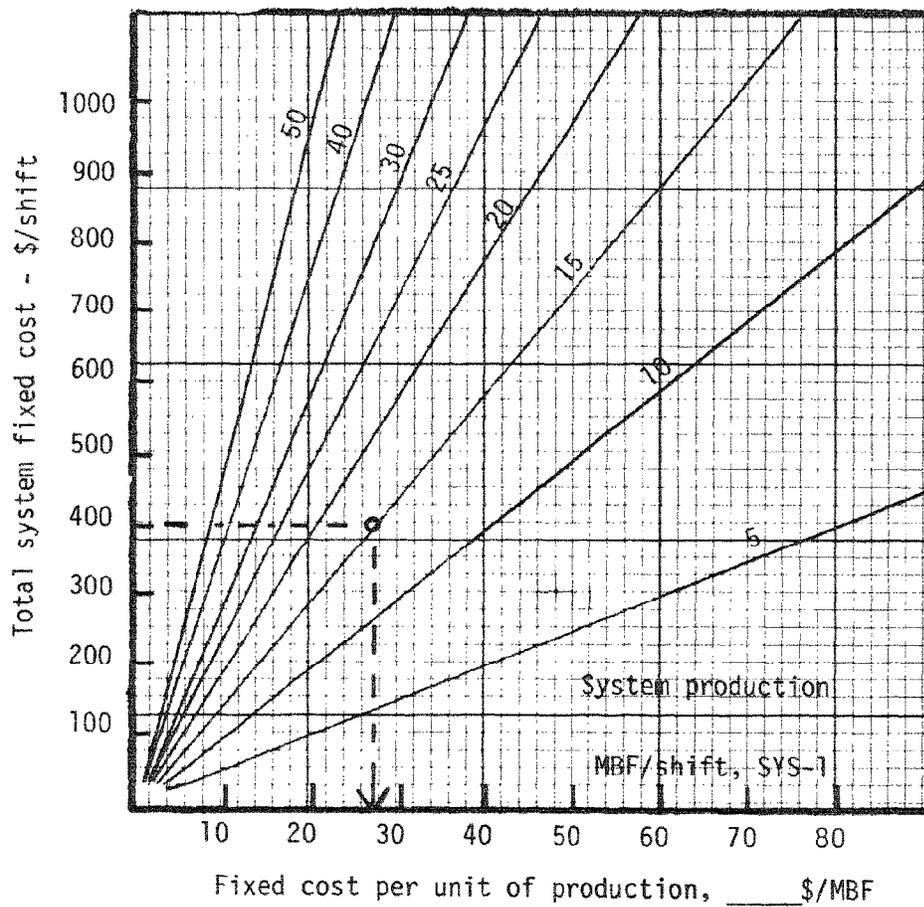
Example:

FC-11, total systems fixed cost = \$400.00 per shift

SYS1, systems production = 15 MBF per shift

Systems fixed cost = \$27.00 per MBF

Figure 26.--Nomogram for fixed cost per unit of production



LOGGING COST WORKSHEET

Production variables from operating cost worksheet and production rate analysis				Operating cost rates (From op. cost worksheet)	Operating cost \$/MBF
Chain saw	Ave. dbh _____ ins	Ave. tree height _____ logs	F2.5 _____ min.	\$ _____ / Chain saw oper- ating hour	\$ _____
Skidder	S3.5 _____ min./turn		Ave. vol./turn _____ bd. ft	\$ _____ / Skidder oper- ating hour	\$ _____
Loader	H1 _____ min./load	Ave. truckload volume _____ bd. ft		\$ _____ / Loader oper- ating hour	\$ _____
Trucks	H2 _____ min./trip	Ave. truckload volume _____ bd. ft		\$ _____ / Truck oper- ating hour	\$ _____

System operating cost \$ \_\_\_\_\_ /MBF

SYS-1, System production rate \_\_\_\_\_ MBF/shift

System fixed cost rate \$ \_\_\_\_\_ /shift

System fixed cost \$ \_\_\_\_\_ /MBF

Total logging cost \$ \_\_\_\_\_ /MBF

## NOTES ON THE APPLICATION OF WEAK LINK

The key to using Weak Link lies with the proper input data. These data should describe as accurately as possible the situation you wish to evaluate. The operating conditions and the timber harvest system are to be defined on the worksheet preceding the analysis. When evaluating a current operation, describe the current operating conditions and the current system on these worksheets. When evaluating the potential results of a change in either operating conditions or the system itself, you need only change the input data on the worksheets to reflect these changes. In either case, once the worksheets are complete, the Weak Link analysis is performed the same way each time.

The estimated total logging cost on page 61 will pertain only to the particular combination of harvesting system and operating conditions used initially to predict the cost and production rates. Any changes in either the composition of the harvesting system or the nature of the operating conditions could alter the final cost estimate.

Although the Weak Link analysis is lengthy, it is unlikely that users will have to complete the entire process every time they use it. For the most part, the numbers of men and machines will remain unchanged and Weak Link will be used to evaluate the potential impact of changing operating conditions. As a result, the user would have to use the cost rate analysis on pages 5 to 20 only once, and apply the results to all subsequent applications.

The final results from the Weak Link analysis, system output, and cost per MBF, are very important to loggers. Managers should also keep tabs on the Weak Link in the logging system. Perhaps the single most important application of the Weak Link analysis is the identification of potential bottlenecks in the flow of logs and demonstrating the effect that the Weak Link has upon logging costs. This process allows the logger to focus his management efforts where they are most needed and invest his resources where they will yield the highest return. Improving the productivity of the Weak Link component can have a very significant impact upon system production costs, more so than indiscriminately attempting to make improvements throughout the system.

For example, with the sample data used to demonstrate how Weak Link works, trucking was the bottleneck which limited the system production rate to 15 MBF per shift. Using the truck production nomograms, we find that the addition of another truck would boost trucking production to approximately 20 MBF per shift.

If another truck and driver could be added to the system for \$50.00 per shift, the system fixed cost rate would increase to \$450.00 per shift. When the system fixed cost rate is \$450.00 per shift, and the system production rate is 20 MBF per shift, fixed costs per unit will drop from \$27.00 to \$22.50. The reduction in the total logging cost would amount to \$4.50 per MBF.

If \$100.00 per shift was required to add a truck and driver, the total logging cost would be reduced by \$2.50 per MBF. In fact, the cost of adding a truck and driver could go as high as \$140.00 per shift before the cost of logging at the 20 MBF per shift rate is as high as it was at the 15 MBF per shift rate. These evaluations are very easily made using the nomogram on page 60.

Also notice that we are not looking for changes in trucking costs, rather we are relating changes in trucking production to the cost input - production output of the entire system. And once more, the problem can be worked out without working through the entire Weak Link analysis.

If one particular element in the timber harvesting system is always the Weak Link, the logger may be paying for more capacity than he can hope to realize. The manager has two routes to take to improve the balance of his system. He can add men and machines to bolster the Weak Link, or he can reduce excess capacity by eliminating men or machines when practical.

When a particular component is not the Weak Link, changes in operating procedures or operating conditions that affect the productivity of that component will generally affect the operating costs only. However, such changes should not be ignored. With today's high cost of fuel and supplies, operating cost reductions can result in significant savings.

Finally, there certainly is no easy way for loggers to get the information they need to manage their operations effectively. However, Weak Link does provide one method of logging analysis that loggers could learn to integrate into their day-to-day operations.

LIBRARY CARD

Baumgras, John E., and A. Jeff Martin.

1978. The weak link logging systems analyzer. Northeast. For.  
Exp. Stn., Broomall, Pa.

63 p., illus. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-40)

The Weak Link Logging Systems analyzer is a method of systems analysis that loggers can use to locate production bottlenecks, determine expected production, and estimate harvesting costs. With data supplied by the user, the three-part Weak Link program develops cost rates for the machines and the logging system, and production rates for each phase of the operation; these data are combined in a production-cost analysis that determines logging costs in dollars per Mbf.

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Keywords: logging, harvesting costs