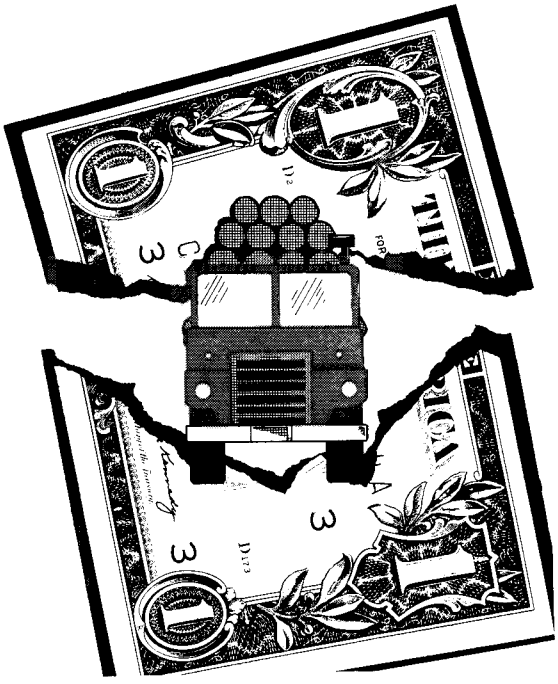
the relative importance of
FACTORS THAT DETERMINE LOG-HAULING COSTS

by A. Jeff Martin



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the relative importance of FACTORS THAT DETERMINE LOG-HAULING COSTS

HAULING COSTS are a major expense to lumbermen, but little is known about which factors affect hauling costs the most. A recent Forest Service study of hauling costs on 34 logging operations sheds light on which factors of cost are important and which might require less attention. These results should help lumbermen adopt a cost accounting procedure and help them with management decisions regarding roundwood transport.

The underlying reason that factors of hauling costs have been only vaguely identified is a lack of sound cost accounting. However, this deficiency is not peculiar to the wood industry, rather to all trucking operations *(4)*.

Accurate cost information requires elaborate records which are time-consuming and costly to keep. But perhaps recording all hauling cost components is unnecessary. Possibly some items should receive close attention in a cost accounting scheme, and others may need less emphasis or could be ignored. This study points out the relative importance of the various factors of log-hauling costs.

THE STUDY

Data were collected from 34 logging operations that used gasoline powered tandem-axle trucks in West Virginia during the summer of 1968. We tried to gather the following information from each trucking situation:

- Truck specification—cost, age, make, fuel required, anticipated life, and trade-in value.
- Hours of operation—per day, per week, and per year.
- Tire data—size, cost, and life.
- Repairs—kind and cost.
- Oil, lubrication, and preventive maintenance—frequency and cost.
- Operator's wage.
- Cost of insurance.

Table 1.—*Economic data from the sample*

Factors	Values
Purchase price of truck ..... dollars	13,221.00
Salvage value ..... dollars	1,514.00
Interest rate ..... percent	12.00*
Property damage and liability insurance .... $/year	193.00
License and other fees ..... $/year	1,000.00**
Operator's hourly wage ..... $/hour	1.89
Overtime rate	1.00*[1]
Social Security ..... percent	3.90**
Unemployment compensation ..... percent	5.00**
Industrial insurance ..... percent	6.05**
Administration ..... percent	20.00*
Fuel—gasoline ..... $/gallon	.34*
Oil ..... $/quart	.75*
Lubrication and preventive maintenance.. $/lube job	15.00*
Minor repair costs ..... $/year	25.00
Major repair costs ..... $/year	218.00
Tires ..... $/tire	142.00
Tubes ..... $/tube	17.00

[1] The regular-time hourly wage is multiplied by the overtime rate to obtain the overtime hourly wage. Hence, an overtime rate of 1.00 indicates no bonus is added to overtime hours.

* This information did not come directly from the sample. It was assumed for purposes of completing the analysis.

** Obtained from State (West Virginia) and Federal regulations.

- Cost of license and other annual fees.
- Gross vehicle weight.
- Fuel consumption.
- Travel times between landing and mill—by road surface type, both loaded and empty.
- Loading and unloading time.
- Delay time.
- Volume carried (board feet).

Table 2.—*Physical data from the sample*

Factor	Values
Distance on two-lane paved roads .....miles.....	21
Distance on one-lane paved roads .....miles.....	4
Distance on one-lane gravel roads .....miles.....	3
Distance on woods roads .....miles.....	1
Time on two-lane paved portion—empty .....minutes.....	34
Time on one-lane paved portion—empty .....minutes.....	10
Time on one-lane gravel portion—empty.....minutes.....	13
Time on woods road portion—empty .....minutes.....	14
Time on two-lane paved portion—loaded ...minutes.....	42
Time on one-lane paved portion—loaded ...minutes.....	12
Time on one-lane gravel portion—loaded ...minutes.....	16
Time on woods road portion—loaded .....minutes.....	20
Time required for loading .....minutes.....	32
Delay time .....minutes.....	45
Time required for unloading .....minutes.....	9
Volume of the truckload .....board feet.....	2,067
Hours worked .....per day.....	9
Days worked .....per week.....	5
Weeks worked .....per year.....	42
Hours worked .....per year.....	1,890
Expected truck life .....years.....	5
Vacation time .....weeks/year.....	None*
Average miles .....per gallon.....	4
Number quarts .....per oil change.....	12
Weeks between oil change	3
Weeks between lubrication and preventive maintenance	1
Oil added periodically .....quarts.....	1*
Days between the added oil	2*
Number of tires on truck	10*
Tire life .....miles.....	22,000

* This information did not come directly from the sample. It was assumed for purposes of completing the analysis.

These data were obtained from actual observations and by questioning operators on the 34 logging jobs. Reliability of the data varies with each item (for instance, data concerning truck purchase price and hourly wage are quite accurate; whereas data relating to the working period are based on less empirical evidence). However, for showing relative importance, these data should be quite satisfactory.

When summarizing the data from the sample trucking operators, we noticed a considerable range in values for some of the factors. For example, insurance premiums per truck ranged from $124 to $350 per year, and annual repair costs ranged from 0 to over $900. The data in tables 1 and 2 are averages and represent a condition that does not exist. However, our purpose is to measure the relative importance of these factors, so the average values will suffice.

COMPUTATION OF THE AVERAGE MACHINE RATE AND HAULING COSTS

The hauling cost calculations (fashioned after the methodology of Matthews *(3)* and Byrne *(2)*) are systematic procedures for computing the fixed, dependent, and operating costs on a per hour basis and the fuel cost on a per mile basis. To facilitate rapid computation and provide a medium for exploring the impact of changes in certain cost factors, a computer program was written. This program combines the cost elements in table 1 with the hauling distances, travel times, volume hauled, hours worked, and other factors in table 2 to generate the machine rate and hauling costs in the manner shown in tables 3 and 4.

SENSITIVITY ANALYSIS

The basic purpose of sensitivity analysis is to find out how the results of a model change when the data or parameters or assumptions of the model change *(1)*. For example, suppose we consider the following equation as a model: $Y=a+bX_1+cX_2$. To employ sensitivity analysis, we would first compute a value for

$Y(Y_1)$ using the equation in its present form. Then, holding everything else constant, we could increase the value of b by 25 percent and recompute our Y value. We now have two values of Y, Y_1 and Y_2, to compare. Suppose Y_2 is 10 percent greater than Y_1. Next we increase c by 25 percent and find that the new value of Y is 15 percent greater than Y_1. Thus, we can say that our model is more sensitive to changes in c than it is to changes in b. When a model is developed, we hope that the final results will not be very sensitive with respect to our assumptions. Thus, if the assumptions are not quite true, the results will not be way off *(1)*.

In our study, a set of equations and relationships (the model) was used to compute the hauling costs of roundwood from landing to mill (tables 3 and 4). The results of the computations were threefold: (1) a truck machine rate ($/hour) for the logging truck in question, (2) the cost of hauling logs per round-trip mile, and (3) the hauling cost per thousand board feet per round-trip mile.

Once the average values for a truck machine rate, cost per round-trip mile, and cost per thousand board feet per round-trip mile had been determined, we applied sensitivity analysis by repeating the computational process 41 times, increasing a different cost factor by 25 percent each time. When a given item was changed, all other factors were held constant; hence, the resulting machine rate, etc., (when compared to the average) reflects the impact of the component that was varied. For example, when the operator's hourly wage was increased by 25 percent (from $1.89 to $2.36), the machine rate increased by 9¼ percent (from $6.91/hour to $7.55/hour).

RESULTS

After all factors were tested, the relative importance of each was ascertained by calculating the impact a change in each factor had on the model. As an illustration, consider the effects of a 25 percent increase in the truck purchase price (from $13,221.00 to $16,526.25). This change produced nearly a 7 percent increase in the machine rate (from $6.91 per hour to $7.39 per hour). By

Table 3.—*Computation of the machine rate for average sample conditions*

Factors		Annual cost (1)	Hourly cost[1] (2)
Investment			
Truck purchase price	$13,221.00		
Less tires 10 tires @ $142.00/tire	$1,420.00		
10 tubes @ 17.00/tube	170.00		
Total cost for tires	1,590.00		
Net investment	$11,631.00		
Less salvage value after 5 years	1,514.00		
Amount to be depreciated	$10,117.00		
Fixed costs			
Depreciation—$10,117.00 ÷ 5 years		$2,023.40	$1.07
Interest—12% per year			
Average investment 8,538.20[2] × 0.12		1,024.56	.54
Insurance (property damage and liability)		193.00	.10
License and fees		1,000.00	.53
Dependent costs			
Driver's wage (no vacation and no overtime differential)		—	1.89
Social security 3.90% of 1.89		—	.07
Unemployment compensation 5.00% of 1.89		—	.09
Industrial insurance 6.05% of 1.89		—	.11
Administration 20.00% of 1.89		—	.38

Operating costs			
Oil			
(1) 42 weeks ÷ 3 weeks = 14 oil changes/year 14 × 12 quarts × $0.75/quart = ...	126.00		
(2) 1,890 hours/year ÷ 9 hours/day = 210 days/year 0.5 quarts/day × 210 days × $0.75/quart..	78.75		
Total		204.75	.11
Lubrication and preventive maintenance—once per week—42 times per year—42 lube jobs @ $15.00 each = ...		630.00	.33
Minor repairs		25.00	.01
Major repairs		218.00	.12
Tires 22,000 miles/set of tires ÷ 58 miles/trip[3] = 379 trips/set of tires. 379 trips × 2.68[4] hours/trip = 1,016 hours/set of tires. 1,590 dollars/set of tires ÷ 1,016 hours/set of tires = ...		—	1.56
Total costs (truck machine rate), $/hour		—	$6.91

[1] Column (2) = Column (1) ÷ 1,890 hours/year. However, certain items were computed directly.

[2] Average investment = (Purchase price − salvage value) (expected life + 1)/[(2) (Expected life)] + salvage value; from Matthews *(3)*.

[3] The total hauling distance per trip—twice the one-way haul of 29 miles.

[4] Total travel time = time required when empty plus time required when loaded (that is, 161 minutes or 2.68 hours.)

Table 4.—*Computation of hauling cost per round-trip and per MBF per round-trip mile based on average sample conditions*

Factors		Values
Travel time empty		
Two-lane paved portion	minutes.. 34	
One-lane paved portion	minutes.. 10	
One-lane gravel portion	minutes.. 13	
Woods road portion	minutes.. 14	
Travel time loaded		
Two-lane paved portion	minutes.. 42	
One-lane paved portion	minutes.. 12	
One-lane gravel portion	minutes.. 16	
Woods road portion	minutes.. 20	
Total travel time	minutes.. 161	
Loading time	minutes.. 32	
Delay time	minutes.. 45	
Unloading time	minutes.. 9	
Total hauling time	minutes.. 247	
Total hauling time	hours	4.12
Hauling distance		
Two-lane paved portion	miles.. 21	
One-lane paved portion	miles.. 4	
One-lane gravel portion	miles.. 3	
Woods road portion	miles.. 1	
Total one-way hauling distance	miles.. 29	
Total hauling distance per trip	miles	58.00
Hauling cost per round-trip mile:		
4.12 hours/trip ÷ 58 miles/trip = .071 hours/mile		
.071 hours/mile × $6.91/hour =	dollars	0.491
Fuel costs:		
$0.34/gallon ÷ 4 miles/gallon =	dollars	.085
Total cost per round-trip mile	dollars	0.58
Hauling cost per MBF per round-trip mile:		
$0.58/round-trip mile ÷ 2.067 MBF =	dollars	0.28

comparing the effects of changes in both hourly wage and purchase price, it can be seen that wages are more important (in relative terms); they have a greater impact on the transportation cost structure—the model is more sensitive to changes in the wage rate than it is to variations in purchase price.

Hourly wages have the greatest influence on truck machine rates, followed closely by the factors that determine the yearly operating period, namely, hours per day, days per week, and weeks per year (tables 5, 6, and 7). A similar relationship holds for the cost per round-trip mile and cost per thousand board feet per round-trip mile. However, the ranking is not so pronounced.

APPLICATION AND LIMITATIONS

In applying the results to a hauling operation, the user should not interpret the values in an absolute sense. These cost data were obtained from sample averages, consequently the results indicate what is typical for the region and not what will arise in a specific situation. Also, most of the factors vary with the passing of time.

The approach to using the results is not to consider the values themselves, but rather to consider the ranking of values. This portrays the relative importance of the various items. It pinpoints the factors that should receive major emphasis in the planning of log transportation and in the firm's record-keeping. For examply, it is more important to have accurate records on purchase price, hourly wages, and hours of operation, than on repair and fuel costs. It is better to buy expensive tires for a low-priced truck than it is to purchase cheap tires for costly rigs. It is more economical to haul bigger loads at slower speeds than to exceed speed limits with 2 or 3 logs on the truck. These examples indicate some of the comparisons that can be made from tables 5, 6, and 7.

Although sensitivity analysis is a useful managerial tool, it does have limitations:

- A thorough analysis of complex problems requires a large capacity, high-speed computer.

- It does not provide information concerning the interaction of various factors. For instance, truck prices increase every year and this contributes to a rise in repair costs; hence, the true effect of an increase in truck prices is underestimated when sensitivity analysis is employed.
- Many factors having a substantial impact on the results are not directly controllable by the firm. For example, neither the interest rate, nor the cost for license fees can be manipulated to suit the trucking contractor. Thus, sensitivity analysis measures the importance of all factors, but changes may be impossible.

Table 5.—*Results of sensitivity analysis on the truck machine rate*

Factor changed	Percentage change in machine rate when factor was increased by 25%[1]
Driver's hourly wage	9.26
Purchase price of truck	6.95
Tire costs	4.49
Interest rate	2.03
License and other fees	2.03
Administration cost	1.45
Cost of lubrication and preventive maintenance	1.30
Overtime rate	1.01
Tube costs	.58
Industrial insurance	.43
Cost of oil	.43
Major repair costs	.43
Property damage and liability insurance	.43
Unemployment compensation	.43
Social Security	.29
Number of quarts per oil change	.29
Oil added between oil changes	.14
Minor repair costs	.14
Loading time	None
Delay time	None
Unloading time	None
Truckload volume	None
Fuel cost	None
Average miles per gallon	None
Days between oil additions	None
Weeks between oil change	—0.14
Time on one-lane paved portion—empty	— .29
Time on one-lane paved portion—loaded	— .43
Time on one-lane gravel portion—empty	— .43
Time on woods road portion—empty	— .43
Salvage value	— .43
Time on one-lane gravel portion—loaded	— .43
Time on woods road portion—loaded	— .58
Weeks between lubrication and preventive maintenance	— .87
Time on two-lane paved portion—empty	—1.01
Time on two-lane paved portion—loaded	—1.30
Expected truck life	—3.33
Tire life	—4.49
Weeks worked per year	—6.80
Days worked per week	—7.96
Hours worked per day	—8.10

[1] Minus signs indicate a decrease in the machine rate.

Table 6.—*Results of sensitivity analysis on the cost per round-trip mile*

Factor changed	Percentage change in $/round-trip mile when factor was increased by 25%[1]
Driver's hourly wage	6.90
Purchase price of truck	5.17
Delay time	3.45
Fuel cost	3.45
Tire costs	3.45
Loading time	1.72
Time on two-lane paved portion—empty	1.72
Time on two-lane paved portion—loaded	1.72
Interest rate	1.72
License and other fees	1.72
Time on one-lane gravel portion—loaded	None
Time on woods road portion—loaded	None
Overtime rate	None
Administration cost	None
Cost of lubrication and preventive maintenance	None
Time on one-lane paved portion—empty	None
Time on one-lane gravel portion—empty	None
Time on woods road portion—empty	None
Time on one-lane paved portion—loaded	None
Unloading time	None
Truckload volume	None
Property damage and liability insurance	None
Social security	None
Unemployment compensation	None
Industrial insurance	None
Cost of oil	None
Number of quarts per oil change	None
Oil added between oil changes	None
Minor repair costs	None
Major repair costs	None
Tube costs	None
Days between oil additions	None
Salvage value	—1.72
Weeks between oil change	—1.72
Weeks between lubrication and preventive maintenance	—1.72
Expected truck life	—3.45
Average miles per gallon	—3.45
Tire life	—5.17
Weeks worked per year	—6.90
Days worked per week	—6.90
Hours worked per day	—6.90

[1] Minus signs indicate a decrease in the cost per round-trip mile.

Table 7.—*Results of sensitivity analysis on the cost per MBF per round-trip mile*

Factor changed	Percentage change in $/MBF/round-trip mile when factor was increased by 25%[1]
Driver's hourly wage	7.14
Purchase price of truck	3.57
Delay time	3.57
Fuel cost	3.57
Tire costs	3.57
Time on two-lane paved portion—loaded	3.57
Loading time	3.57
Time on two-lane paved portion—empty	None
Interest rate	None
License and other fees	None
Time on one-lane paved portion—empty	None
Time on one-lane gravel portion—empty	None
Time on woods road portion—empty	None
Time on one-lane paved portion—loaded	None
Time on one-lane gravel portion—loaded	None
Time on woods road portion—loaded	None
Unloading time	None
Salvage value	None
Property damage and liability insurance	None
Overtime rate	None
Social security	None
Unemployment compensation	None
Industrial insurance	None
Administration cost	None
Cost of oil	None
Number of quarts per oil change	None
Weeks between oil change	None
Oil added between oil changes	None
Days between oil additions	None
Cost of lubrication and preventive maintenance	None
Minor repair costs	None
Major repair costs	None
Tube costs	None
Weeks between lubrication and preventive maintenance	None
Expected truck life	—3.57
Average miles per gallon	—3.57
Tire life	—3.57
Weeks worked per year	—7.14
Days worked per week	—7.14
Hours worked per day	—7.14
Truckload volue	—21.43

[1]Minus signs indicate a decrease in the cost per MBF per round-trip mile.

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LITERATURE CITED

1. Boot, John C. G.
1967. MATHEMATICAL REASONING IN ECONOMICS AND MANAGEMENT SCIENCE. 178 pp., illus. Englewood Cliffs, New Jersey: Prentice Hall, Inc.

2. Byrne, James, Nelson, R. J., and Googins, P.H.
1960. LOGGING ROAD HANDBOOK —THE EFFECTS OF ROAD DESIGN ON HAULING COSTS. USDA Forest Serv., Agr. Handb. No. 183, 65 pp., illus.

3. Matthews, D. M.
1942. COST CONTROL IN THE LOGGING INDUSTRY. 374 pp., illus. New York: McGraw-Hill Book Co., Inc.

4. University Research Center.
1965. TRUCK COSTS—A COMPARISON OF PRIVATE OWNERSHIP AND FULL-SERVICE LEASING. 42 pp., illus. Univ. Res. Center, Chicago, Ill.

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