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Factors Related to Performance Variation Among Logging-Machine Operators
Performance et rendement chez des opérateurs de machines

Richard T. Barth and Philip L. Cottell

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Article abstract

Despite the economic importance of large variations in individual productivity of logging-machine operators, few studies have attempted to examine the source of such variations. Based on data obtained for a total of 757 shifts of tree-felling activity, this exploratory study attempted to: (a) document variation in on-the-job performance and assign the variation to sources « within individual operators », « between operators », or « between firms »; (b) relate ob-served performance measured operator characteristics (ability and motivation); and (c) suggest ways in which average levels of job performance could be improved.

Factors Related to Performance Variation

Philip L. Cottell
and
Richard T. Barth

Despite the economic importance of large variations in individual productivity of logging-machine operators, few studies have attempted to examine the source of such variations. Based on data obtained for a total of 757 shifts of tree-felling activity, this exploratory study attempted to: (a) document variation in on-the-job performance and assign the variation to sources «within individual operators», «between operators», or «between firms»; (b) relate observed performance measured operator characteristics (ability and motivation); and (c) suggest ways in which average levels of job performance could be improved.

The performance of logging-machine operators is a major factor determining logging productivity and cost, as well as the success or failure of new technology. Even in situations where conditions of the forest, terrain, and machines are relativetly uniform, it is common to observe wide variation in performance among individual logging-machine operators and crews. While such variation is widely rec-

COTTELL, P. L., Associate Professor, Faculty of Forestry, University of British Columbia, Vancouver, B.C.

BARTH, R. T., Associate Professor, Faculty of Commerce and Business Administration, University of British Columbia, Vancouver, B.C.

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** The order of authors is random.

ognized in the logging industry, it has been only sparsely documented. Even less is understood about the specific sources of this variation, the human and other factors with which it may be associated, or the nature of the relationships involved. Given this state of affairs, the objectives of the present study were to: (a) measure and document variation in work performance among logging-machine operators, and to assign relative contributions to this variation from sources within operators, sources between operators within a given firm, and sources between firms; (b) relate individual operator characteristics of background, ability and motivation to work performance in the use of logging machines, taking into account differences in environmental and operational factors; and (c) suggest ways in which performance-related criteria could be used to raise average levels of work performance in the operation of logging machines.

A recent review noted the lack of studies directed at enhancing our understanding of the human component of logging activities, and pointed out that logging research has traditionally reflected a primary concern with trees, machines that harvest trees, and physical processes designed for the initial conversion of harvested trees.[1] Even so, one study[2] of wheeled skidding concluded that «... it seems likely that a high proportion of the variation in productivity will be attributable to non-physical factors, including skills, motivation, supervision...». Others have indicated that the skill and motivation of the skidder operator are important factors,[3] that fluctuations in motivation are closely related to productivity variation and the effect of workers' attitudes upon productivity is important,[4] or have suggested that «the greatest and fastest increase in productivity can be achieved by ... more emphasis on the problem of operator motivation and incentive...».[5]

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[1] D. A. SCOTT, The Use of Psychology in Logging Research.« Fifty-sixth Annual Meeting of the Woodlands Section, Canadian Pulp and Paper Association, Montreal, 1975.

[2] W. D. BENNETT, H. I. WINER and A. BARTHOLOMEW, «Measurement of Environmental Factors and Their Effect on the Productivity of Tree-Length Logging with Rubber-Tired Skidders,» *W.R.I.* 166, Pulp and Paper Research Institute of Canada, Montreal, 1965.

[3] J. A. MCINTOSH and L. W. JOHNSON, «Comparative Log Skidding Performance,» B. C. *Logging News*, Vol. 1, 1974, pp. 13, 14, 16, 18.

[4] P. L. COTTELL, H. I. WINER, and A. BARTHOLOMEW, «Alternative Methods for Evaluating the Productivity of Logging Operations,» *W.R.* No. 37, Pulp and Paper Research Institute of Canada, Montreal, 1971.

[5] S. A. AXELSSON, «Repair Statistics and Performance of New Logging Machines; Koehring Short-Wood Harvester/Report 1,» *Research Report No. 47*, Pulp and Paper Research Institute of Canada, Montreal, 1972.

A Swedish study[6] compared two 25-man groups («top men» vs. «average men») of experienced manual wood cutters in terms of piece-rate earnings, work output, and a variety of personal characteristics which included: anthropometric data and strength; physiological work capacity; health; adjustment to the job and physical reaction to strain; tests of intellectual ability; and, working technique and tools. As expected, high physical endurance was characteristic of the «top men», who experienced less fatigue for a given work load. Neither technical nor intellectual ability differed between the two groups. A study by Andersson *et al.*[7], designed to validate psychological test batteries being used for the selection of tractor operators in logging, involved 207 tractor operators who were administered tests, underwent training, and had their job performance later evaluated. The job success criterion was based on performance results and time studies. The tests were found to be useful for predicting training results as well as later on-the-job performance, including operator productivity. Hall, Persson, and Pettersson[8] examined the development of training programs for operators of tree processors. A group of 28 operator trainees took part in psychological tests and tests of knowledge of machinery prior to training, and in interviews during training. They were interviewed again four months after training. Their productivity and work methods were evaluated during the first week after training, and at one and four months afterward. Nearly all attained the production goal within a month in operations, and no operator's productivity deviated significantly from the group average. Little further improvement in productivity was observed after four months. In contrast to the findings of Andersson *et al.*[9], neither psychological test scores, knowledge of machinery, age, nor previous experience predicted future productivity of the trainees. Hall *et al.*[10], suggested the likelihood that critical levels exist for several of the factors, which could be important in selection. These three studies indicated that the relative importance of different physical and psychological human factors varies with the nature of the job. In two of the

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[6] J. E. HANSSON, «The Relationship Between Individual Characteristics of the Worker and Output of Work in Logging Operations.» *Studia Forestalia Suecica*, No. 29 Skogshogskolan, Stockholm, 1965.

[7] L. ANDERSSON, L. BERGSTROM, A. KRANTZ, G. LENNERHEIM, and B. PETTERSSON, «Selection of Tractor Operators by Means of Psychological Tests.» *Report No. 7*, Skogsarbeten, Stockholm, Sweden, 1968.

[8] B. HALL, A. PERSSON, and B. PETTERSSON, «Training of Processor Operators,» *Report No. 11*, Skogsarbeten, Stockholm, Sweden, 1972.

[9] ANDERSSON *et al., op. cit.*

[10] HALL *et al., op. cit.*

studies, certain personnel characteristics were associated with productivity; in the third study they were not. One cannot reject the possibility that differences in operating conditions, organizational characteristics, group norms and individual motivation may have obscured some of the expected relationships.

A series of studies by Latham and Ronan[11], and Latham and Kinne[12,13], examined the effect of goal setting and supervision on the performance of pulpwood producers in the Southern United States. These studies dealt with logging crews, rather than individual operators. Producers (contractors) who set production goals and stayed on the job with their crews tended to have higher man-day productivity than producers who did not set goals or actively supervise. In the 1974 study by Latham and Kinne, 20 pulpwood-logging operations were matched and randomly assigned to either a one-day training program in goal setting or a control group. Data on six criteria (absenteeism, injuries, and two measures of production and turnover, respectively) were collected for 12 consecutive weeks. The results showed that training in goal setting can lead to an increase in production and a decrease in absenteeism.

APPROACH

Regardless of their focus (i.e., individual vs. crew or work group), a limitation of the studies reviewed above is that the set of independent variables included in a given study has not encompassed the main categories of factors likely to affect performance. The approach of the present study gave consideration to two sets of performance determinants: individual determinants of performance, comprising ability and motivation; and organizational or environmental determinants.[14] This

[11] G. P. LATHAM and W. W. RONAN, «The Effects of Goal-Setting and Supervision on the Motivation of Pulpwood Workers.» APA Harvesting Research Project, Atlanta, Georgia, 1970.

[12] G. P. LATHAM and S. B. KINNE, «Improving Job Performance Through Training in Goal Setting», *Journal of Applied Psychology*, Vol. 59, 1974, pp. 187-191.

[13] G. P. LATHAM and S. B. KINNE, «Goal Setting as a Means of Increasing the Performance of the Pulpwood Harvester,» APA Harvesting Research Project, Atlanta, Georgia, 1971.

[14] This view of performance determinants is taken from L. L. CUMMINGS and D. P. SCHWAB, *Performance in Organizations: Determinants and Appraisal.* Glenview, Ill.: Scott, Foresman and Company, 1973; and E. E. LAWLER, III, *Motivation in Work Organizations*. Monterey, Cal.: Brooks/Cole, 1973. It should be noted that the term «ability» includes all aspects of training, experience, talent and aptitude that are necessary to perform well in a given situation. Aptitude refers to how much a person's response capabilities can be developed.

conceptual view of performance determinants yielded the following array of factors as possible sources of performance variation:

Environmental and operating factors:

(a) forest conditions
(b) terrain conditions
(c) climatic conditions
(d) machine characteristics

Personal characteristics of operators:

(a) background, training and experience
(b) aptitudes
(c) attitudes, interests and motivation
(d) physiological factors

Characteristics of the job:

(a) type of firm
(b) goals and incentives, including method of payment
(c) supervision
(d) operating methods (technique)

Each category includes a variety of factors that may act individually, or in combination, to influence operator performance. Factors such as machine type, firm type, and forest condition can be partly controlled through an appropriate study design.

A study intended to evaluate operator performance raises two other questions. First, what is performance? And second, what aspects of actual performance can be included? Two objective, relevant, and measurable performance criteria are (a) quantity of production (e.g., the rate of tree harvesting or log production per productive machine hour, or per shift), and (b) quality of production (e.g., adherence to specifications, and minimizing damage to end product values in log production).

METHODOLOGY

Sample and Field Sites

Subjects for the study were operators of tractor-mounted hydraulic tree shears used in industrial timber felling. This choice offered the following advantages: (a) the machines are simple, reliable and in widespread use; (b) felling is the first production phase in timber harvesting, thus likely to be less influenced by interactions with other processes than, say, log skidding and hauling; (c) output performance is easily measurable. Sampling was limited to the North-Central part of British Columbia, Canada. This served to control variation in the major environmental factors (forest stand, terrain, climate) and logging techniques, making it easier to assess the effects of human factors on performance. Operating conditions were recorded for each cutting block (the area assigned to a given operator for cutting trees).

The sampling design had to meet two requirements. First, the sample had to be reasonably representative of the population of tree-shear operators in the study region, so that conclusions could be generalized. Second, the sample had to permit a test of the extent to which variation in performance levels was attributable to differences between operators. A list was made of firms in the study region currently using two or more tree shears. (A «firm» included the major wood-using company, together with its logging contractors and subcontractors.) A random sample was drawn, with probability of selection proportional to the number of shears — roughly equivalent to the number of shear operators — in each firm. All shear operators in the selected firms were eligible for inclusion in the study.

Data collection involved the following phases: (a) interviews to obtain information on individual characteristics; (b) recording environmental (forest, terrain) conditions encountered by each operator over the study period; and (d) recording machine characteristics, operating methods and conditions, and organizational context for each operator.

Measures

Subjects completed questionnaires dealing with personal background and work experience, job attitudes and interests, supervision, and motivational factors. Some questionnaire items appeared on cards, which respondents placed into appropriately labelled slots in an «answer box» for later coding. Physical condition of the operators was assessed using a simple fitness test, and visual depth perception was measured with a portable two-peg apparatus.

Motivation. Before preparation of this measurement device was undertaken, it was necessary to decide on a list of outcomes. Three sources were used: (1) the literature[15,16] on expectancy theory; (2) the

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[15] V. H. VROOM, *Work and Motivation.* New York: Wiley, 1964.

[16] For reviews of expectancy theories of motivation, see T. R. MITCHELL and A. BIGLAN, «Instrumentality Theories, Current Uses in Psychology,» *Psychological Bulletin,* Vol. 76, 1971, pp. 432-454; and G. H. HENEMAN and D. P. SCHWAB, « Evalua-

literature available on performance and satisfaction in the forest industry; and (3) knowledge and intuition gained through experience with the logging industry.

One part of the questionnaire was used to obtain measures of the *instrumentality* of higher performance for the attainment of each of 13 outcomes (see Figure 3), ranging from intrinsic ones such as «a feeling of accomplishment» and «being known as a capable operator», to extrinsic ones in terms of pay, job security, and promotion.

A five-point, agree-disagree Likert rating format was used. The following statement preceded the list of the 13 outcomes: «If you increased your weekly production by 20% without abusing your machine,[18] you would expect to gain (outcome).» In contrast to many other studies, the scale used here allowed respondents to provide responses which indicated whether good performance increased *or* decreased the chances of obtaining a particular outcome.

Responses pertaining to the *importance* of each outcome were provided on a five-point scale ranging from «no importance» through «moderately important» to «great importance.» The *expectancy* measure was based on an item asking for the respondent's degree of agreement or disagreement (five-point Likert format) that he could attain 20% higher production by «working harder». For exploratory purposes, subjects also indicated whether they felt production could be increased as a result of: doing what the boss says; taking a training course; getting more experience; or, observing a better operator for a period of time.

Aptitudes. Subjects were asked to complete those parts of the General Aptitude Test Battery (GATB)[18] that seemed relevant to occupations involving the operation of heavy equipment. Standard procedures for administration of the GATB were rigorously followed in assessing: Coordination (K), Spatial Aptitude (S), Form Perception (P), and Manual Dexterity (M).

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tion of Research on Expectancy Theory Prediction of Employee Performance,» *Psychological Bulletin*, Vol. 77, 1972, pp. 1-9.

[17] A figure of 20% was arbitrarily chosen, as it would represent a significant increase in performance that could conceivably be attained by a majority of operators.

[18] A full description of the GATB is provided in four separate sections (Administration and Scoring; Norms and Occupational Aptitude Pattern Structure; Development; Norms, Specific Occupations) of the test manual published by the U.S. Department of Labor (1966), and adapted/used by the Canada Department of Manpower and Immigration since 1966.

Visual Depth Perception and Physical Fitness. A simple two-peg apparatus was used to measure the visual depth perception of each subject. A depth perception score was obtained by summing the distances (taken over three trials for each subject) by which the location of a movable peg differed from the position of a fixed peg in the apparatus.

The physical fitness of each subject was evaluated using a test which provided a fitness score based on measures of strength, stamina, suppleness and weight.[19]

Other Measures. Along with demographic items and the section on motivation, the questionnaire contained the following: (a) Four statements regarding the participant's attitude toward the firm (e.g., «this firm is better to work for than most in the local logging business»); (b) Four items designed to provide an indicator of «sense of competition» (e.g., «you like to cut a few more trees per day or week than the other operators»); (c) Four items pertaining to work groups, adapted from the group cooperation scales of Seashore;[20] (d) Nine job involvement questions; (e) Several items asking for self-rated effort («you work harder than the average operator»), ability («you can do your work well»), and performance; and (f) Thirteen items selected from the Leadership Behavior Description Questionnaire to assess the operators' supervisors along the Structure and Consideration dimensions.[21]

Environmental and Operating Factors

Forest stand information came, in all cases, from available maps and inventory data supplied by the firms involved in the study and local forest consultants. These data met the standards of accuracy required by the British Columbia Forest Service. Each shift worked could be related to a cutting block of known forest and terrain conditions. Factors[22] recorded included: the number of merchantable and unmerchantable stems and volume per acre, species distribution, windfall,

[19] A syndicated publication attributed the test to Sports Participation Canada, although it was not officially endorsed by that organization. At the time of the study, it was the simplest and most portable test available, and appeared sufficient for exploratory purposes.

[20] S. E. SEASHORE, «Group Cohesiveness in the Industrial Work Group.» Institute for Social Research, University of Michigan, 1954.

[21] R. M. STODGILL, «Manual for the Leadership Behavior Description Questionnaire, Form XII». Ohio State University, Columbus, Ohio, 1963.

[22] W. D. BENNETT, «Identification and Measurement of Key Environmental and Operating Factors in Logging Operations.» *W.R. No. 30,* Pulp and Paper Research Institute of Canada, Montreal, 1970.

terrain class and predominant slope. Measures of forest and terrain conditions used in the study reflect average values for the cutting block, with each forest-cover type weighted in proportion to the area it occupied within the block.

Criterion Measures. The study included two aspects of work performance of tree-shear operators: productivity, and quality of felling. Productivity was taken as the rate of production, in terms of the number of trees cut per productive machine-hour (PMH) spent in felling. As each operator joined the study, his machine was fitted with a Model K Servis Recorder. The operator was provided a hand tally counter for counting merchantable trees cut (live coniferous trees, of at least 7.1 inches diameter 4.5 feet above ground level, containing 50% or more of sound wood). Each operator was instructed in the use of the Servis Recorder, and in the manner of completing the shift report form on the face of the charts. Operators recorded productive tree-felling time, «other» productive time such as skidding felled trees, delay times and causes according to standard time definitions,[23] the cutting block identification number, and the number of merchantable trees felled.

Two aspects of the quality of operator performance were examined: the extent of butt damage to felled trees, and the felling pattern. The first affects product recovery, and so the end value of logs. The second influences the productivity of subsequent skidding operations, and so the cost of logs. The field study crew, during each return visit to the operators, randomly sampled a number of sound, felled trees representing the local range in butt diameter and species being harvested to determine whether there were any differences between operators in the ability to control butt damage during shearing. Felling pattern was evaluated on the basis of observation, operator interviews, and through discussions with supervisors and skidder operators.

RESULTS AND DISCUSSION

The 34 tree-shear operators participating in the study represented nine «firms», comprising 25 individual logging companies and contractors. Collectively, the sample constituted about 50% of the firms and shear operators available in the study region at the time.

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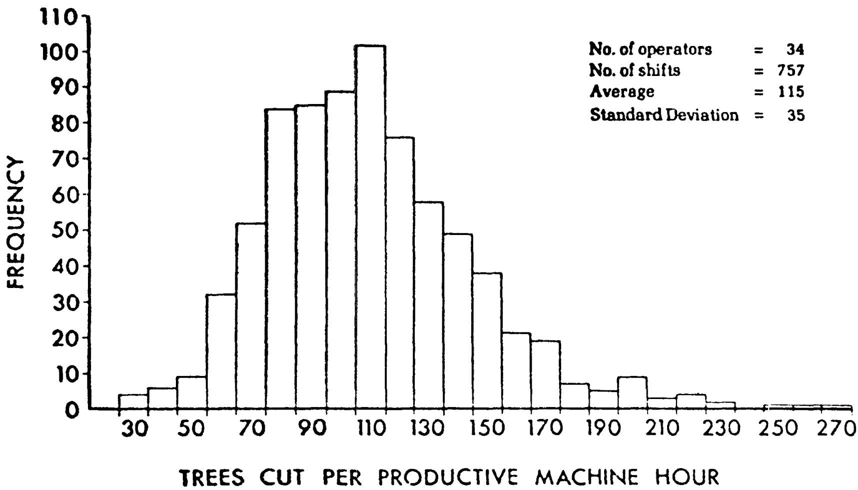
[23] J. A. BÉDARD, D. H. W. DIBLEE, and D. C. HORNCASTLE, «Standard Definitions for Machine Availability and Utilization.» *W.S.I.* No. 2428 (B-1), Canadian Pulp and Paper Association, Montreal, 1968.

Characteristics of the operators as a group can be summarized as follows: 32 were native to Canada, although only three were native to British Columbia. Two-thirds came from a rural family background, with the father employed in agriculture or the forest industry. The average age was 35 years, and an eight-grade education was most common. None had completed high school. Twenty-eight were married, with an average of 2.5 dependents. Work experience ranged from five to 39 years (average 18.9 years) in the labour force, with the majority having been employed in forest work for over eight years. Only one operator had had vocational training in the operation of tractors. Experience on tree shears varied from one month up to five years, with half of the operators having operated shears for nine months or less.

The usable data available for analysis represent 757 shifts of tree-felling activity. Felling occurred in 86 separate cutting blocks. Figures 1 and 2 summarize the sample with respect to the productivity criterion. A wide range of values is evident.

FIGURE 1

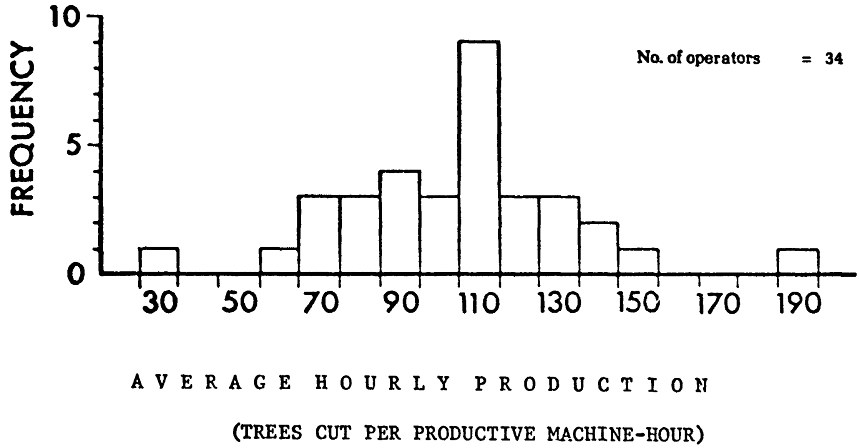
Distribution of Trees Cut per PMH, for Individual Shifts



For example, Figure 1 reveals that productivity for individual shifts ranged from 30 to over 230 trees cut per PMH. On the basis of average productivity, (Figure 2) more than three-quarters of the operators fell into the range 70-130 trees per PMH. This represents a variability in operations that is of practical importance.

FIGURE 2

Distribution of Operators According to their Average Productivity Over the Study Period



The data were further examined using Analysis of Variance. Since the choice of firms was randomized, a random-effects ANOVA model was called for.[24] This analysis revealed that about one-third of the observed variance in productivity was assignable to the source « shifts within operators. » Possible explanations could include day-to-day changes in the condition of the machine or its operator, forest and terrain conditions, and weather. The next source level, « between operators within firms, » accounted for almost two-thirds of the observed variance. In other words, most of the observed variation was assignable to differences between operators. The source level « between firms » accounted for only a small proportion of variance.

General Aptitudes

Results from administration of the tests to shear operators (Table 1)

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[24] Sample size varied among firms, requiring altered analytical procedures. See G. W. SNEDECOR and W. G. COCHRAN. *Statistical Methods* (Sixth Ed.) Ames, Iowa: Iowa State University Press, 1967 (pp. 289-294).

TABLE 1

GATB Aptitude Scores

Trait	*Range*	*Average*	*Standard Deviation*	*n*[1]
Motor co-ordination	49-117	81	23	33
Manual dexterity	47-112	76	22	33
Form perception	59-134	94	19	34
Spatial aptitude	68-117	94	14	34

[1] An injury prevented one subject from taking the tests of motor co-ordination and manual dexterity.

showed a good range in scores for each aptitude measure, which permitted some evaluation of the degree of association between aptitudes and performance. The motor co-ordination and manual dexterity scores for shear operators were noticeably below established norms for the general working population. Scoring for the GATB is set up to that a random sample from the working population would, on the average, score 100, with a standard deviation of 20. A score of 80 is one standard deviation below the average and represents the 16th percentile for the general working population.[25]

Visual Depth Perception and Physical Fitness

Nine of the 34 operators scored «poorer than normal» in depth perception. With respect to physical fitness, one-half of the sample scored fewer than 30 points (20-29 points being defined as «below average»). Fourteen scored in the «average» category (30-39 points), two scored «above average» (40-45 points), and only one scored in the «extremely fit» category (46-50 points).

Motivation

Figure 3 summarizes job-factor importance ratings for the 13 outcomes considered in this study. Highly rated in importance were the job factors: «reputation in the industry,» «steady job,» «control over work pace,» «sense of accomplishment,» «good pay,» and general «job satisfaction.» Of somewhat lower importance, on the average, were factors: «respect from supervisor and fellow workers,» «more say in the job,» and «time with the family.» Rated relatively low in importance were the job factors: «assignment to a more pleasant job,» «promotion,» and «time to talk on the job.»

[25] Section II: The Manual for the General Aptitude Test Battery, p. 359.

FIGURE 3

Importance of 13 Job Factors

IMPORTANCE RATING OF...

job factor	*low* 1 2 3 4 *high* 5	*Avg.*	*S.D.*
Being Know as capable		4.5	0.8
Feeling of accomplishment		4.4	0.9
Control work pace		4.4	1.0
Steady job		4.4	1.0
Good pay		4.3	1.0
Job satisfaction		4.3	1.1
Respect from supervisor		4.1	1.0
More say in job		3.9	1.2
Respect from fellows		3.8	1.2
Time with family		3.8	1.2
More pleasant job		2.9	1.4
Promotion		2.7	1.4
Time to talk on job		2.3	1.2

Instrumentality ratings of higher production for the 13 outcomes are shown in Figure 4. Respondents generally agreed that increased productivity had a high degree of instrumentality in achieving: « a sense of accomplishment, » « job satisfaction, » « reputation in the industry, » and « control over work pace. »

FIGURE 4

Instrumentality of Higher Production

INSTRUMENTALITY OF HIGHER PRODUCTION

for...	*least* 1 2 3 4 5 *greatest*	*Avg.*	*S.D.*
Accomplishment		4.3	0.6
Job satisfaction		3.9	0.8
Reputation		3.9	0.8
Control work pace		3.8	1.0
Respect from supervisor		3.4	1.0
More say in job		3.4	1.0
Respect from fellows		3.3	1.1
Security		3.3	1.2
Pay		3.2	1.4
Time with family		3.2	1.1
Promotion		2.4	0.8
More pleasant job		2.4	0.8
Time to talk to others		2.2	0.7

They perceived a weaker connection between increased productivity and the outcomes of: «respect from supervisor and fellow workers,» «more say in the job,» «job security,» «pay,» and «time with the family.» They generally disagreed that increased productivity would lead to: «promotion,» «assignment to a more pleasant job,» or «more time to talk to others on the job». An examination of expectancy ratings (Figure 5) revealed high agreement with respect to «more experience,» (4.0), «watching a better operator,» (3.9), and «working harder,» (3.3).

FIGURE 5

Expectancy of Five Behavioural «Routes» to Higher Production, as Rated by Shear Operators

EXPECT HIGHER PRODUCTION

from...	*disagree* 1 2 3 4 5 *agree*	*Avg.*	*S.D.*
More experience		4.0	1.0
Watching better operator		3.9	0.8
Working harder		3.3	1.1
Doing as boss says		2.4	0.8
Training course		2.3	1.0

Analysis

Data based on the «other measures» listed in the methodology section were not highly correlated with productivity. The correlation matrix for the main factors retained in the analysis is shown in table 2.

Regression models[26] examined resulted in the following equation relating observed productivity (with an adjustment for environmental conditions) to operator characteristics:

[26] Analyses used the forward inclusion (step up) procedure provided in J. H. BJERRING and P. SEAGRAVES, «U.B.C. TRIP — Triangular Regression Package.» Computing Centre, University of British Columbia, Vancouver, 1974. The unit of observation was an operator cutting in a defined block of timber. Calculations were based on 82 such observations, for 33 operators (one operator was omitted because he could not take the manual dexterity test). Plots of residuals carried out according to established procedures (see N. DRAPER and H. SMITH, *Applied Regression Analysis*. New York: Wiley, 1966, Chapter 3) revealed no evidence of serious heteroscedasticity, nor non-linear effects or other factors that should have been included in the expression. Regression analysis using «trees felled per shift» as the dependent variable produced essentially the same results. The variables «trees per acre» and «PMH per shift» adjusted for differences in operating conditions and shift length, and the same four measures of operator characteristics were statistically significant.

TABLE 2

Simple Correlation Coefficients (r) for Variables in the Regression Analysis.

	S	*P*	*K*	*M*	*D*	*FS*	*EXP*	*E*	*T*	*Y*
Spatial Aptitude (S)	1.									
Form Perception (P)	.52	1.								
Motor Co-ordination (K)	.59	.68	1.							
Manual Dexterity (M)	.21	.53	.61	1.						
Depth Perception (D)	.34	−.10	.21	−.12	1.					
Fitness Score (FS)	.10	.03	− 01	.33	−.02	1.				
Experience With Shear (EXP)	−.16	−.47	−.27	−.13	.23	.09	1.			
Motivation Score (Expectancy) (E)	.13	−.003	−.24	−.15	−.08	.21	−.05	1.		
No. Trees/Acre (T)	−.16	.04	− 13	.01	−.08	−.13	.20	.09	1.	
Trees Cut Per PMH (Y)	−.25	−.01	−.10	.32	−.45	.12	.24	.23	.45	1.

NOTES: 1. Number of operators = 33, since one was omitted because he did not take M test. ($r_{.05} = .33$)

2. Number of cutting blocks = 82. ($r_{.05} = .21$) T and Y are average values for each cutting block. Other environmental variables examined are omitted from table for brevity.

3. D is binary variable. If normal depth perception, D = O; if poorer than normal, D = 1.

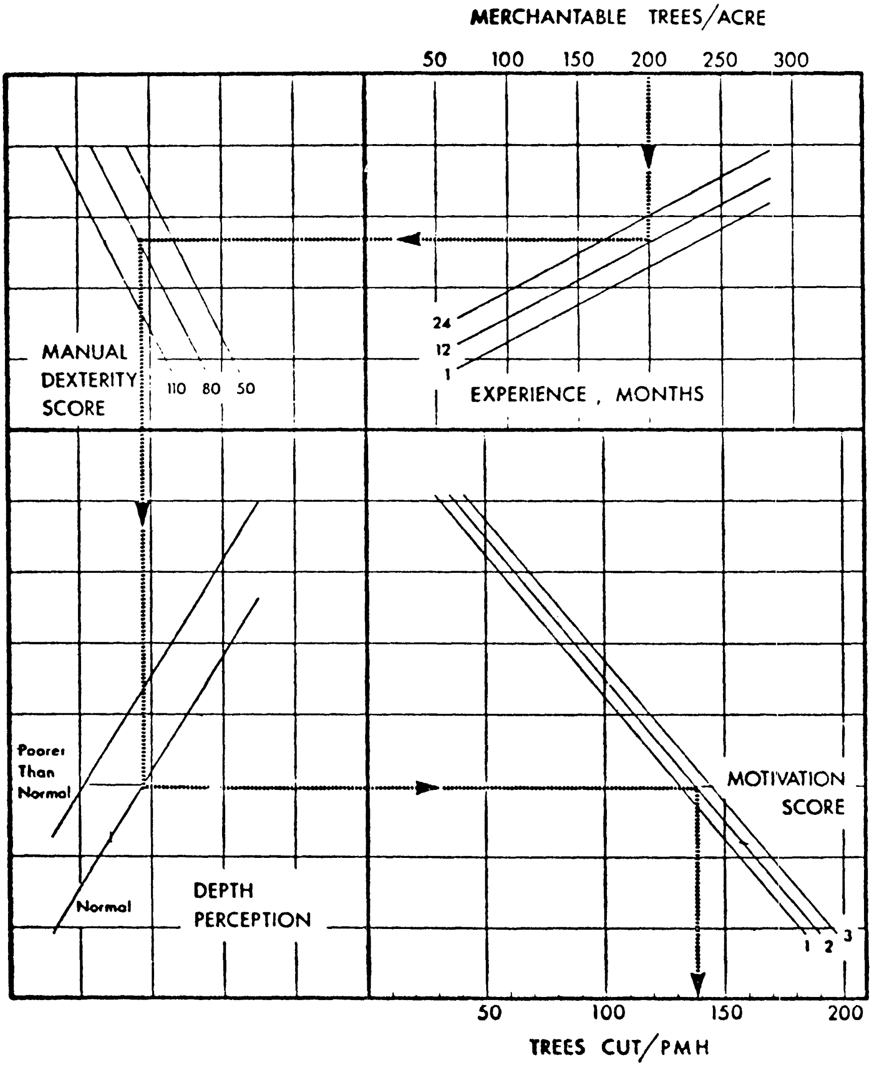
Trees cut per PMH = 22.92 + 0,21 (no. of merchantable trees/acre, T)
+ 0.65 (months experience, EXP)
+ 0.65 (manual dexterity score, M)
−33.85 (if depth perception poorer than normal, D)
+ 6.37 (motivation expectancy score, E)

($R^2 = 0.59$, $S.E._y = 23$, and all regression coefficients significant beyond the $p < .01$ level.)

Figure 6 illustrates the calculated relationships among these variables in the form of a monogram. The first three factors pertaining to operator characteristics — experience, manual dexterity, and depth

FIGURE 6

Nomogram Showing Calculated Relationships Between Performance (Trees Cut per PMH) and Measures of Operator Characteristics, with Initial Adjustment for Forest Stand Factors



perception — can be readily determined in the interview-testing phases of the selection process. Length of experience is of logical importance, since it relates to the variety of situations the operator has learned to deal with. For the range of experience observed, the nomogram indicates that each additional month of experience contributed 0.65 tree per PMH to productivity. An operator with one year of experience, for example, cut about seven trees per PMH more than an operator with one month of experience, other factors being equal. Manual dexterity is presumably associated with an operator's ability to co-ordinate visual information with arm and hand movements in tractor driving. In this study, the difference between operators scoring 80, versus operators scoring 100 (the general population average) was about 13 trees per PMH, other factors being equal. Depth perception might logically affect the operator's skill in planning the sequence of felling, in driving from one tree to the next, and in positioning the shear accurately on the tree to be felled. Figure 6 indicates that operators in this sample who scored «poorer than normal» in depth perception averaged about 34 fewer trees per PMH than operators who scored «normal,» other factors being equal. The fourth factor — motivation — is explanatory in nature rather than predictive, since it would be difficult to assess motivation reliably in the job selection process.[27] It is within the organizational structure of the firm (e.g., supervision, reward system, job re-design) that adjustments may be made to elicit appropriate levels of motivation on the part of employees having the requisite abilities and skills. No statistically significant relationships were found relating operator characteristics to measures of the quality of job performance.

The results from this study cannot necessarily be generalized to operators of *other* types of equipment. Different operator characteristics undoubtedly influence performance in other phases of logging, such as skidding, loading and truck driving. Separate studies would be required to establish this.

Studies of operator performance should lead to improved criteria for the recruitment of logging-machine operators, and selection for training. The forest industry and logger training schools in Canada recruit and select large numbers of forest workers each year. Selection often is based on minimal information about the candidates, and interpretation is subject to the considerable bias of recruiting officers' inevitably limited personal experience. Some good candidates are chosen, but so are many that turn out to be unsuited for the work. Among tree-shear operators, length of experience was associated with

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[27] Motivation may be considered as a «will do» factor, in contrast to certain «can do» or «can learn» factors pertaining to ability and aptitude. Existing tests do not predict motivation well. See L. W. PORTER, E. E. LAWLER, III, and J. R. HACKMAN, *Behavior in Organizations*. Toronto: McGraw-Hill, 1975, pp. 148-149.

output performance — a result that supports the position of personnel officers who look for suitable experience in job applicants. But seldom are there enough experienced operators to fill the positions available, which makes experience a less-than-ideal criterion for recruiting. It is necessary to consider the individual's potential, as related to job requirements. Better recruitment criteria that indicate the individual's likely ability to perform the job would help recruiters maximize the percentage of «correct» decisions — i.e., accept suitable candidates and reject unsuitable ones.

For this approach to be effective there must be considerable development in the measurement of human factors in logging, and in the models which purport to show how these factors influence job performance. There also is a need for a richer definition of performance, other than the simple measure of output per unit of time. Performance includes subtle aspects of job quality, safe working practices, care of machines, regular attendance, job stability and co-operation with other crew members. In particular, the relationships of individual performance to crew or system output need to be considered. If the system cannot process all of his production, the individual operator cannot be faulted for lower than maximum effort. Group cohesion and teamwork among logging crew members, examined only tentatively in this study, need to be assessed quantitatively and related to individual and system performance.

Man-machine relationships need to be examined more critically in order to develop effective, productive logging-system designs. There are new machines presently entering the woods which have serious design problems that limit the operator's potential performance. Inspection of the operator's workplace (cab) will commonly reveal equipment deficiencies which reduce his efficiency and comfort. The present state of workplace design offers significant opportunity for the application of human factors principles.

Analysis of the jobs and requisite skills in logging would provide better understanding of the work requirements, and of the abilities and acquired skills that operators need for successful performance. This could lead to better machines, and better selection and training of personnel, with consequent increases in the level of productivity of operators. Such tasks obviously call for the assistance of people trained in the required fields — psychology, ergonomics, organizational behaviour. Specialists in these behavioural sciences have developed approaches and procedures that can help with some of the human problems in logging.

Progress in this field of endeavour depends upon increased knowledge of human factors in logging, and getting that knowledge applied in a practical way. Neither logging companies, training specialists, researchers nor governments can do this successfully on their own — it requires co-ordinated effort and commitment over time. A beginning could be made through a limited programme to assess the abilities and interests of candidates applying to logger training courses. Follow-up of graduates would determine their subsequent success on the job. If patterns were found between measurable trainee characteristics and job performance (for example, if the relationships tentatively identified in this study were supported) they could provide a basis for selection of suitable trainees, and other employees, in the future.

SUMMARY AND CONCLUSIONS

Observations of more than 700 shifts worked by 34 operators of tractor-mounted, hydraulic tree-felling shears in North-Central B.C. revealed important variation in output performance. Operators' felling productivity ranged from below 50 to over 150 (average 115) trees per productive machine-hour. Two-thirds of this variation was attributable to differences « between operators within a firm, » and about one-third to day-to-day differences « within operators. » Operator performance (adjusted for different forest conditions through the variable « number of trees per acre ») was significantly associated with the following measures of operator characteristics:

— length of experience in operating shears
— manual dexterity
— visual depth perception
— motivation (based on expectancy scores).

Experience, manual dexterity and depth perception are potentially useful in the selection and placement of logging personnel, but motivation cannot be readily assessed in a selection procedure. Adjustment of organizational factors (such as supervision, work rewards) within the employing firm offers the principal opportunity to influence operators' motivation toward higher performance.

It is suggested that future research in this area should include:

— development of procedures for evaluating important qualitative aspects of performance, in addition to quantity of production, for various logging occupations;

— improvement in theoretical models relating the characteristics of operators and their work groups to job performance;

— examination of human factors in logging-machine design (ergonomics) to facilitate job performance, reduce the necessary training time and improve the occupational safety and health of operators;

— acquiring data pertaining to the question of whether operators with high production levels per productive machine hour accomplish this at the expense of more machine breakdowns, delays, or a higher accident rate.

— the gathering and presentation (in handbook form) of information on superior work techniques in different logging occupations, for the benefit of operators and supervisors at all experience levels;

— consideration of ways to develop a practical programme to test the usefulness of personnel evaluation procedures for predicting the likely success of new employees, or trainees, in different logging occupations.

Performance et rendement chez des opérateurs de machines

La performance et le rendement des opérateurs de machines utilisées en exploitation forestière varient considérablement. Les compagnies forestières désirent évidemment embaucher des opérateurs qui fourniront un rendement élevé et soutenu. Elles aimeraient également pouvoir sélectionner et former des stagiaires aptes à devenir d'excellents opérateurs. L'embauche, la mobilité de la main d'œuvre et la formation professionnelle sont des activités coûteuses et les employeurs cherchent donc des méthodes de sélection qui faciliteraient le choix des candidats les plus prometteurs. Une sélection plus efficace est possible à condition de mieux comprendre comment certaines caractéristiques d'un opérateur telles qu'aptitudes physiques et intellectuelles, histoire personnelle, motivation et expérience peuvent influer sur son rendement au travail.

Les variations dans le rendement de 34 opérateurs de machines équipées de sécateurs hydrauliques sont le sujet de la présente étude dont les buts étaient de: (1) documenter les variations dans le rendement et de mesurer la variabilité «intra-opérateurs», «inter-opérateurs» et «inter-compagnies»; (2) établir la relation entre les caractéristiques de l'opérateur et son rendement; et (3) proposer des méthodes susceptibles d'augmenter les niveaux moyens de rendement.

Ces études, effectuées dans le centre-nord de la Colombie Britannique au cours de la période juin-décembre 1973, ont fourni des données sur 757 quarts d'abbattage dans 86 parterres de coupe identifiés. Durant chaque quart d'abattage d'une durée moyenne de 6.2 heures-machines productives (HMP), 115 arbres par HMP furent abattus pour une production moyenne totale de 701 arbres marchands. Le niveau moyen de production par opérateur variait de moins de 50 à plus de 150 arbres par HMP.

L'analyse des données a démontré qu'environ 1/3 de la variabilité dans le rendement était imputable aux différences quotidiennes intra-opérateurs et qu'environ 2/3 était attribuable aux différences inter-opérateurs... La variabilité inter-compagnie s'est avérée presque nulle.

Des entrevues et tests ont fourni des renseignements sur l'histoire personnelle, l'expérience professionnelle, l'attitude, la motivation, et sur certaines caractéristiques physiques et intellectuelles des opérateurs.

Compte tenu des différences entre les conditions de peuplement, des ajustements furent effectués et il fut ensuite possible d'établir une relation significative entre le rendement et les caractéristiques suivantes de l'opérateur:

— perception des distances
— durée de l'expérience sur la machine en cause
— dextérité manuelle
— degré de motivation

La perception des distances, l'expérience et la dextérité manuelle pourraient facilement être évaluées au cours d'un procédé de sélection. La motivation est plus immédiatement influencée par la modification des structures d'organisation et de supervision à l'intérieur de chaque compagnie.

Les suggestions proposées pour accélérer la progression des travaux dans ce domaine sont:

— Le développement de procédés pour évaluer non seulement les aspects quantitatifs, mais aussi les aspects qualitatifs du rendement, dans divers emplois de l'exploitation forestière.
— L'amélioration des modèles théoriques établissant la relation entre les caractéristiques des opérateurs et des groupes de travail en rapport avec le rendement.
— L'examen des facteurs humains dans la conception de machines (ergonomie) pour augmenter le rendement au travail, diminuer le temps de formation, améliorer la sécurité au travail et le bien-être des opérateurs.
— La préparation d'un recueil de renseignements sur les techniques supérieures de travail dans divers emplois pour le bénéfice des opérateurs et des contremaîtres à tous les niveaux.
— La formulation d'un programme pratique pour vérifier l'utilité des procédés d'évaluation du personnel afin de prédire le rendement éventuel de nouveaux employés, ou de stagiaires, dans divers emplois de l'exploitation forestière.