FERIC

FOREST ENGINEERING
RESEARCH INSTITUTE
OF CANADA

INSTITUT CANADIEN
DE RECHERCHES
EN GÉNIE FORESTIER

SPECIAL REPORT NO.2

A METHOD OF COMPARING LOGGING SYSTEM AND MACHINE CONCEPTS

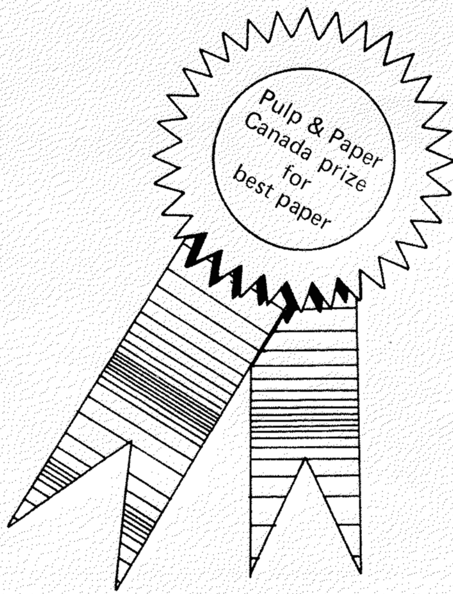
J.H. BOYD, ENG.
W.P. NOVAK

THIS REPORT WAS DELIVERED AS A PAPER AT THE 58th ANNUAL MEETING OF THE WOODLANDS SECTION, CANADIAN PULP AND PAPER ASSOCIATION IN MONTREAL, QUEBEC, MARCH 1977. IT IS REPRODUCED HERE AS A REPRINT OF THE ARTICLE CARRIED IN THE MAY 1977 ISSUE OF PULP AND PAPER CANADA WITH THE KIND PERMISSION OF THE WOODLANDS SECTION, C.P.P.A.

THE PAPER WON PULP AND PAPER CANADA'S ANNUAL AWARD FOR "BEST PAPER OF THE CURRENT MEETING".

245 HYMUS BLVD, POINTE CLAIRE, P.Q., CANADA H9R 1G6
2045 WEST BROADWAY, VANCOUVER. B.C., CANADA V6J 1Z5

Boyd and Novak try out their prizes.



Estimate wood cost, productivity and investment needs for 84 logging system combinations

by JACK BOYD and WAYNE NOVAK

IN RECENT YEARS, many new ideas for ways to mechanically fell, limb, top, bunch, transport, process, buck, and pile wood have been conceived, developed, and applied to Canadian logging. Some new system and machine concepts have failed in the process of converting idea into hardware. Some have succeeded in one place but not another. Only one or two mechanized system concepts have achieved wide application and success.

More and more frequently, as the less fortunate new system concepts fade and die, the argument is heard that the Canadian forest industries need a method of comparing system concepts which can be applied before large investments are made in machine and system development. Even for machines already in wide use, or in prototype operation, many observers are uncertain as to whether there is a potential advantage in productivity or wood cost if applied to their operations. Can full tree systems be developed to achieve lower wood cost than tree-length systems? Are automated tree-length harvesters likely to show a wood cost advantage over simpler non-automated machines?

Jack Boyd and Wayne Novak are with FERIC, Pointe Claire, Que.,

There are two dimensions of a logging system which determine levels of wood cost, productivity, and investment on a logging operation. The first is concept — the functions performed, the speed and arrangement of mechanisms to carry out those functions, and the size, weight, machine price, power and fuel consumption which are related to the design which performs those functions.

The second dimension of system achievement is performance potential of the system. Performance is the measure of engineering and design skill, quality of components and fabrication, and scope of support services provided by the manufacturer, which together constitute the level of achievement of the manufacturer in converting idea or concept into hardware. The performance dimension also includes a measure of operator and mechanic skills, application suitability, facilities for repair and service, and all other factors that permit one operation to be more successful than another, applying the same machine and concept.

How can conceptual performance be separated from the variations in achievement of engineer and designer, and from the varying capability of operators, mechanics, planners and supervisors? Although there are inherent differences between concepts, and one idea may be better than another, it is difficult to determine how much better.

If the conceptual difference between two systems is small, it is likely to be overpowered by small differences in the skill of engineer and designer, and in the quality of components, or by differences in operator attitudes and skills, mechanic capability and experience, or even by a bit of good or bad luck in applications. If the difference in potential between two concepts is very large, it is reasonable to wonder whether the weakness of a poor idea can be overcome by unusually effective design and engineering, or by an efficiency of operation never before achieved.

This report is an attempt to separate concept from performance, to separate idea from achievement, and to suggest the nature and scope of conceptual differences between machines and systems for logging. The report will also attempt to show the relative importance of concept and performance in logging systems currently in use, in systems tried and discontinued, and in a few systems still in prototype stages or simply on paper at the present time.

Influence of 'concept factors'

Some characteristics of logging machines are the result of the idea or concept from which the machine has developed. These concept factors are:

- Operating cycle time per tree: The inherent time required to carry out all of the essential functions to be performed with the power and mechanisms which are provided.
- Machine size, weight, price: These characteristics have an inherent relationship to the functions to be performed.
- Power and fuel consumption: The functions to be performed dictate horsepower required and duty cycle of the engine, which together set fuel consumption.
- Application factors: The machine concept sets the limitations of flotation, mobility, travel speeds, and other design characteristics. Tree size, species, and road spacing have an inherent limitation on machine performance and application.

While concept factors are not exactly equal for machines, their values can vary only through a restricted range, since they are determined primarily by the laws of science. It is not possible to fell and swing trees into bunches at speeds of 1000 mph, nor to operate a tree-length harvester with a one-hp engine, nor to design a ten-cunit transporter that weighs 1000 lb and costs $3000. Concept factors are limited to values that can be physically achieved. A major change in a concept factor is not a concept improvement, it is a new concept of machine or system.

Time studies on the Farmi-TJ-30 logging winch were recently conducted in New Brunswick. FERIC summer student John Crawford is shown collecting time and production data.

Table I: Assumptions of performance at four levels of achievement.

Ref	Factor	Standard 1 "Ultimate" Performance	Standard 2 "Industry Achievable" Performance	Standard 3 "Industry Average" Performance	Standard 4 "Minimum Achievement" Performance
R01	Scheduled machine days per year	365	315	225	175
R02	Scheduled hours per working day	24	24	18	16
R03	Aver. utilization of scheduled machine time	1.0	.80	.75	.60
RO5	Aver. operator efficiency during productive time	1.0	.85	.70	.60
R09	Aver. repair parts and labor cost, $ per PMH per $1000 of original price	.05 (100%-20,000hr)	.08 (100%-12,500hr)	.100 (100%-10,000hr)	.150 (100%-6,667hr)

Performance factors

Within the physical limitations of machine concept, there is a wide range of performance which depends upon factors unrelated to the functional ideas from which the machine has developed. These include:

- Engineering and design achievement: how effectively idea is converted into hardware.
- Component reliability, quality, operating cost.
- Training and support services provided by supplier.
- Suitability of sites selected by the user.
- Skill and capabilities of supervisors, mechanics and operators, parts clerks, and all other personnel involved in the field.
- User policies regarding hours of work, travel to and from site and location of operations and support services.
- Motivations and attitudes of personnel, basic human capabilities, and all of the factors which produce efficiency of effort.

The list of factors which can potentially affect machine or system performance is almost endless. Fortunately, there are natural limitations to the range of achieved performance resulting from the combination of all factors. In practice, substandard performance below a certain level is recognized and changed, while superior performance is recognized and copied. The effect of variation of all performance factors cumulatively is relatively easy to measure, since it produces a change in one or more of the following measures of performance.

- Operator efficiency: the ratio of productivity achieved to productivity measured for good operators in favorable conditions.
- Utilization of scheduled time: the ratio of productive hours to scheduled hours, reflecting both mechanical and non-mechanical downtime.
- Maintenance (cost) level: the cost of repair parts and labor per operating hour.
- Scheduling intensity: the fraction of total calendar time during which work is intended.

Performance variation can also appear in two measures which are beyond the scope of this report. The first is indirect costs of operation such as changes in support personnel, road costs, camp facilities. The second is policy on allocation of capital costs (depreciation). For this report, machine price only is assumed to be absorbed into the cost of wood produced over a five-year period, regardless of scheduling or performance.

Two answers to every question

Ask two users of the same machine whether the machine is well-engineered, and one is likely to rate the machine excellent while the other rates it terrible. Ask two machine designers whether a type of hydraulic pump is reliable, and one is likely to claim it is the best available while the other claims it is very undependable. Ask two supervisors whether an operator is efficient, and one may rate the man quite differently than the other.

In order to compare concepts (as opposed to comparing specific features of specific machines), it must be assumed that many reported performance characteristics of machines are unreliable, and that one machine is as likely to receive a poor operator as another. Such problems as low quality hydraulic hoses, unreliable valves, and uncomfortable seats must be accepted as potentially temporary problems, which may be corrected by a manufacturer in the next machine produced.

To compare concepts, it is assumed that all manufacturers have equal opportunity to improve machines, and all operations have equal opportunity to find good operators and mechanics, thus having equal opportunity to achieve performance within the conceptual limits of the system. Conversely, we must give all machines equal opportunity to be poorly designed or badly used, within the limits of the concept.

Comparing machines, concepts

A convenient way to compare machine and system concepts is to establish a number of industry norms of performance achievement, which correspond to observed performance levels of highly mechanized systems currently in use in the Canadian forest industries. This gives equal opportunity to all machines and systems to be in the highest, average, or lowest level of combined achievement of both manufacturer and user. It also estimates the range of wood cost, productivity, and investment if the machine or system were applied in the industry at present capability levels of users, and at the present achievement levels of manufacturers.

Table I lists the assumed values of performance factors for three levels of achievement which are typical of highly-mechanized systems in Canadian logging.

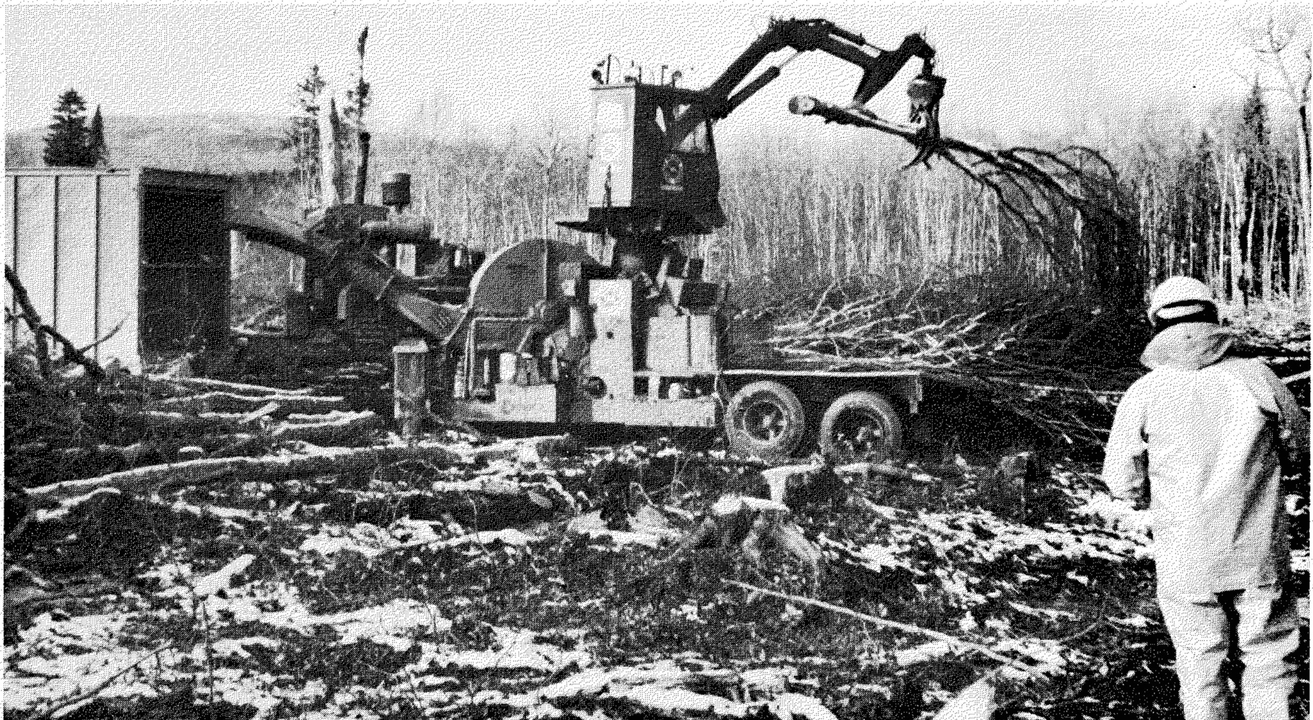
The Industry Achievable assumptions represent performance achieved by perhaps one operation in ten, using well-designed machines operating in appropriate conditions. Systems are intensively-scheduled, and operators are skillful and motivated. Maintenance costs are at the lowest levels usually achieved.

The Industry Average assumptions represent typical situations in many large operations, where two 9-hour shifts are scheduled for about 225 days per year, top-notch operators are not always available, maintenance costs are somewhat higher and utilization is down, both due to some continuing problems with machine design and to imperfect application and organization. Industry average conditions probably fit 50% of all system users.

The Minimum Achievement assumptions represent an operation having serious troubles, but not out of control. Scheduling is light, operator efficiency below average, and maintenance costs 50% above industry averages. Utilization is low due both to the maintenance problems and waiting delays, as well as general disorganization. Minimum achievement conditions are often seen during initial startup periods of new machines. Problems could be due to machine design, or user capability, or both.

A fourth level of performance is calculated for setting a top limit on achievement expectations. This is the estimated performance of the machine operated 24 hours per day, 365 days per year for 5 years at 100% utilization and 100% operator efficiency. Maintenance costs are assumed at the lowest conceivable level, and it is assumed that repairs and service are done so quickly that they result in no measurable loss of utilization. This is such an ideal situation, that estimates of performance at or very near this Ultimate figure should be viewed with distrust.

Performance between average and achievable should be the goal of every



Eugene Vajda, a FERIC technician, collects time data on a Morbark model 22 chiparvestor in New Brunswick.

operation. Performance approaching minimum achievement levels is a warning that conceptual potential is not being achieved, due to poor hardware or low operating capabilities or both.

Combining concept factors collected from field studies such as the FERIC evaluation reports, or from estimates based on data for similar machine functions with the assumptions of these measures of performance achievements, permits an estimate of wood cost, productivity, and investment required for machine and system concepts. The assumption of equal application suitability and equal performance levels achieved leaves only variation due to the concept factors of the machine or system.

Procedures for calculation

The procedures used for calculating cost, productivity and investment are straightforward, and vary only in detail from those applied by any system analyst. Particular care has been taken to avoid errors in logic. That is, as performance factors are varied, the effect on cost and production has been calculated according to the best estimate of how it actually changes. Fuel is consumed only when the machine is running; operators are paid for scheduled time, not by an artificial calculation of cost per productive hour. Useful machine life is a very uncertain figure, so all machines and systems must absorb their price into wood cost over five years, regardless of scheduling or performance.

The procedures, described in detail in Appendix A, are applied equally and mechanically to all machines and systems, leaving no room in the calculations for personal bias. Only for those new systems where good time study data is not available, does personal judgement have a potential effect, and that is only on the concept factors operating cycle time and machine price. All prices are brought to estimated 1976 levels. All labor is assumed at $10 per hour wage, fringe and bonuses. Productivity is based on the total labor input of mechanics and operators, since repair labor is high for most mechanical systems. All systems and machines have been estimated at average forwarding or skidding distances of 500 ft, and results apply to average stands of 6 cu ft per tree unless otherwise noted. Fuel cost is assumed to be $0.70 per imp gallon.

Logging systems performance

Estimates of performance for 35 machines used in Canadian logging at each of four levels of performance for average tree size of six cu ft per tree, are listed in Appendix B.

Appendix C lists the estimates of wood cost, productivity and investment in machines for 84 logging systems which produce eight-foot pulpwood at roadside, using various combinations of these machines. Systems have been ranked in order of wood cost estimated under the industry average assumptions of efficiency, utilization, and maintenance cost.

Fig. 1 provides the differences in system concept potential versus wood cost differences due to different levels of performances achieved within the limits of system concept. Each vertical line represents the range of wood cost likely to occur within any one system. The lowest point of the line is the estimated wood cost under Ultimate achievement conditions (100% operator efficency, 100% utilization, minimum maintenance cost). The intersection with the white line is the estimate of industry achievable wood cost, while the white dot represents the estimate of cost resulting from industry average performance assumptions for the same system (70% operator efficiency, 75% utilization, typical maintenance costs). The highest point on each system line is the wood cost under minimum achievement conditions of 60% operator efficiency, 60% utilization and maintenance costs 50% above industry average. Each system line has been located on the horizontal axis according to the estimated industry achievable cost. The horizontal location of a system is a measure of system potential, improving from right to left, while the vertical position along the line is a measure of performance within the concept potential, with best performance toward the bottom and deteriorating performance higher on the line. The resultant of system concept potential and performance

Appendix A: wood cost, productivity and investment calculations for machines and systems

1) Calculate scheduled machine hours per year
SMH/year = (number of days worked per year) x
(scheduled machine hours per day)

2) Calculate productive machine hours per year
PMH / year = (SMH / year from above) x (utilization)

3) Calculate productivity per PMH
Cunits / PMH = (6000 centiminutes per hour)
÷ (average harvesting time per tree in centiminutes)
x (average tree size in cubic feet) ÷ 100
x (operator efficiency during PMH)

4) Calculate cunits produced per year
Cunits / year = (cunits / PMH from 100 above) x (PMH / year from above)

5) Calculate allocation of machine price per year (depreciation)
Machine price per year = (1976 purchase price in $000)
x 1000
÷ (5 year usage)

6) Calculate fuel costs per year
Fuel Cost / year = (consumption in gal/PMH)
x (cost per gallon)
x (ratio 1.5 to allow for operating supplies)
x (PMH / year from above)

7) Calculate Cost of repair parts and labour per year
repair P&L Cost/year/ =
(rate of repair P&L cost in $ per PMH per $1000 of machine price)
x (machine price in $000)
x (PMH per year)

8) Calculate operator cost per year
Operator Cost per year = (SMH from above)
x (operator rate, wages and fringe $ per SMH)

9) Calculate total costs per year
Total costs per year =
(sum of 5, 6, 7, 8, above)

10) Calculate cost per cunit
Cost/cunit = (total costs per year from above)
÷ (total cunits produced in year from above)

11) Calculate cunits per scheduled machine hour
Cunits per SMH = total production per year from above
÷ (SMH per year from above)

12) Calculate total man hours of mechanic and operator
Man hours per year = SMH
+ [½ (Total repair cost from above) ÷ (Mechanic's hourly rate)]

Note: This assumes that labor cost is one-half of total repair cost at all rates of mechanic pay. When mechanic man-hours are available from estimates, the estimated man-hour figure should be used instead of this rule-of-thumb)

13) Calculate productivity in cunits per paid man-hour
Cunits/paid man-hr
= (Total production in year from above)
÷ (Total Man-hours per year from above)

14) Calculate investment in machine per cunit of production per year
Investment / cunit — year =
(machine price in $000 x 1000)
÷ (Total production in cunits per year from above)

Total system cost, productivity and investment can be found from the relationships:

15) Total wood cost of system = (sum of wood cost for all machines in system)

16) Total labor input to system =
(man-hours per cunit for machine 1)
+ (man-hours per cunit for machine 2)
+ (man-hours per cunit for machine 3)
etc. for n machines.

Then: System Cunits per man-hour paid =

17) 1 ÷ (total system man-hours per cunit)

18) Total system Investment =
(Sum of investment per cunit-yr of all machines in system)

MACHINE NUMBER & CHASSIS TYPE	MACHINE NAME AND DESCRIPTION	PURCHASE PRICE 1000's	FUEL GAL/ PMH	INDUSTRY AVERAGE PERFORMANCE: CMIN/ TREE	CUNITS/ YEAR	CT/ PMH	CT/ SMH	COST/ PMH	COST/ CT	CT/ MPH	$/ CT-YR	INDUSTRY ACHIEVABLE PERFORMANCE: CMIN/ TREE	CUNITS/ YEAR	CT/ PMH	CT/ SMH	COST/ PMH	COST/ CT	CT/ MPH	$/ CT-YR
SHORTWOOD HARVESTERS																			
1010 RT	SW harvester-forwarder	230	6.2	98	7,800	2.6	1.9	58.00	22.60	1.0	29.50	98	18,900	3.1	2.5	45.00	14.40	1.4	12.20
1011 RT	SW harvester-forwarder	173	5.1	172	4,500	1.5	1.1	47.40	32.30	0.7	38.90	172	10,800	1.8	1.4	37.40	21.00	0.9	16.10
TREE LENGTH HARVESTERS																			
1200 --	Power Saw, fell. limp, top (Single sh.)	3.5	0.5	130	2,900	1.9	1.5	14.70	7.60	1.4	1.20	130	5,300	2.4	1.9	13.60	5.80	1.9	0.70
1020 RT	Small TL harvester, bunches	91	2.3	81	9,500	3.1	2.3	30.80	9.90	1.7	9.60	81	22,800	3.8	3.0	25.20	6.70	2.3	4.00
1021 TR	TL harvester, head on boom, no bunch	120	2.8	81	9,500	3.1	2.3	36.20	11.60	1.6	12.70	81	22,800	3.8	3.0	29.00	7.70	2.2	5.30
1022 RT	TL harvester, head, bunching	104	3.2	83	9,200	3.0	2.3	33.90	11.20	1.6	11.30	83	22,300	3.7	3.0	27.60	7.50	2.2	4.70
1023 TR	TL harvester, head on boom, no bunch	120	3.4	79	9,700	3.2	2.4	36.80	11.50	1.7	12.40	79	23,400	3.9	3.1	29.60	7.70	2.2	5.10
1024 RT	TL harvester, semi-auto, bunching	199	5.6	60	12,800	4.2	3.2	52.30	12.50	1.8	15.70	60	30,800	5.1	4.1	41.00	8.00	2.5	6.50
1025 TR	TL harvester, bunching	200	5.4	68	11,300	3.7	2.8	52.20	14.10	1.6	17.80	68	27,200	4.5	3.6	40.80	9.00	2.2	7.40
1026 TR	TL harvester, head on boom, bunching	120	3.4	95	8,100	2.7	2.0	36.80	13.90	1.4	14.90	95	19,500	3.2	2.6	26.60	9.20	1.9	6.20
1027 TR	TL harvester, assembles	120	3.1	112	6,800	2.3	1.7	36.60	16.30	1.2	17.70	112	16,[illegible]	2.7	2.2	29.40	10.80	1.6	7.30
FULL TREE FELLING																			
1030 RT	Feller - assembler - forwarder	180	6.4	58	13,200	4.3	3.3	49.90	11.50	2.0	13.60	58	31,900	5.3	4.2	39.60	7.50	2.7	5.60
1400 --	Power Saw, fell only (single shift)	3.5	0.5	75	5,100	3.4	2.5	14.70	4.40	2.5	0.70	75	9,300	4.1	3.3	13.60	3.30	3.2	0.40
1040 TR	Feller-buncher	89	2.8	36	21,300	7.0	5.2	31.00	4.40	3.9	4.20	36	51,400	8.5	6.8	25.50	3.00	5.3	1.70
1041 RT	Feller-buncher	113	3.0	36	21,300	7.0	5.2	35.10	5.00	3.7	5.30	36	51,400	8.5	6.8	28.30	3.30	5.0	2.20
1042 RT	Feller buncher	143	3.4	38	20,100	6.6	5.0	40.60	6.10	3.2	7.10	38	48,700	8.0	6.4	32.20	4.00	4.4	2.90
1043 TR	Large Feller-buncher	97	2.8	62	12,300	4.1	3.0	32.30	7.90	2.2	7.80	62	29,900	4.9	3.9	26.30	5.30	3.0	3.20
PROCESSORS (Limb, Top, Buck, Pile)																			
1050 TR	Processor, Roadside	220	7.1	29	26,400	8.7	6.5	57.30	6.60	3.6	8.30	29	63,800	10.5	8.4	44.80	4.30	5.0	3.50
1051 RT	Processor, Stump	185	4.4	46	16,600	5.5	4.1	48.60	8.90	2.4	11.10	46	40,200	6.6	5.3	38.00	5.70	3.3	4.60
LIMBING MACHINES																			
1100 RT	Flail limbing machine	55	3.0	18	42,500	14.0	10.5	25.60	1.80	8.7	1.30	18	102,800	17.0	13.6	21.90	1.30	11.6	0.50
1060 RT	Bunch limbing machine	66	1.8	25	30,300	10.0	7.5	26.20	2.60	6.0	2.20	25	73,200	12.1	9.7	21.90	1.80	8.0	0.90
1101 --	Power Saw limb and top (single shift)	3.5	0.5	82	4,700	3.1	2.3	14.70	4.80	2.3	0.80	82	8,500	3.7	3.0	13.60	3.70	3.0	0.40
1061 RT	Single stem limber, roadside	145	3.6	37	20,700	6.8	5.1	41.20	6.00	3.3	7.00	37	50,000	8.3	6.6	32.70	4.00	4.5	2.90
1062 RT	Single stem limber, stump	145	3.6	60	12,800	4.2	3.1	41.20	9.80	2.0	11.40	60	30,800	5.1	4.1	32.70	6.40	2.8	4.70
SKIDDERS																			
1070 RT	Choker skidder (single shift)	40	2.3	126	3,000	2.0	1.5	25.00	12.50	1.3	13.20	126	5,500	2.4	1.9	21.60	8.90	1.7	7.30
1071 RT	Grapple skidder (tree length)	59	2.6	67	11,400	3.8	2.8	25.90	6.90	2.3	5.20	67	27,600	4.6	3.6	21.90	4.80	3.1	2.10
1072 RT	Grapple skidder (full tree)	59	2.6	60	12,800	4.2	3.1	25.90	6.20	2.6	4.60	60	30,800	5.1	4.1	21.90	4.30	3.4	1.90
1073 TR	Bunk grapple skidder	94	4.1	52	14,700	4.9	3.6	33.00	6.80	2.7	6.40	52	35,600	5.9	4.7	27.40	4.70	3.6	2.60
1074 RT	Bunk grapple skidder	79	2.2	43	17,800	5.9	4.4	28.70	4.90	3.4	4.40	43	43,000	7.1	5.7	23.70	3.30	4.5	1.80
FORWARDERS																			
1080 RT	Large forwarder	180	5.5	19	40,300	13.3	10.0	49.00	3.70	5.9	4.50	19	97,400	16.1	12.9	38.60	2.40	8.2	1.90
SLASHERS																			
1090 RT	Mobile slasher	250	7.0	12	63,800	21.0	15.7	88.80	4.20	8.1	3.90	12	154,200	25.5	20.4	73.10	2.90	11.33	1.60
PROTOTYPES AND PROPOSALS																			
2001 RT	Automated TL Harvester, bunching	170	8.7	44	17,400	5.7	4.3	50.70	8.90	2.6	9.80	44	42,000	7.0	5.6	40.90	5.90	3.6	4.00
2002 RT	Automated TL Harvester, bunching	180	6.6	46	16,600	5.5	4.1	50.10	9.20	2.5	10.80	46	40,200	6.6	5.3	39.80	6.00	3.4	4.50
2006 RT	TL harvester-assemble, forward	230	6.4	79	9,700	3.2	2.4	58.20	18.20	1.3	23.70	79	23,400	3.9	3.1	45.20	11.70	1.8	9.80
2007 RT	Large Forwarder	150	13.6	17	45,000	14.8	11.1	52.50	3.50	7.1	3.30	17	108,900	18.0	14.4	43,70	2.40	9.7	1.40

TR - TRACKED CHASSIS RT - RUBBER TIRED CHASSIS SW - SHORT-WOOD TL - TREE-LENGTH

MACHINE NUMBER & CHASSIS TYPE	MACHINE NAME AND DESCRIPTION	PURCHASE PRICE 1000's	FUEL GAL/ PMH	INDUSTRY ULTIMATE PERFORMANCE								INDUSTRY MINIMUM PERFORMANCE							
				CMIN/ TREE	CUNITS/ YEAR	CT/ PMH	CT/ SMH	COST/ PMH	COST/ CT	CT/ MPH	$/ CT-YR	CMIN/ TREE	CUNITS/ YEAR	CT/ PMH	CT/ SMH	COST/ PMH	COST/ CT	CT/ MPH	$/ CT-YR
SHORTWOOD HARVESTERS																			
1010 RT	SW harvester-forwarder	230	6.2	98	32,200	3.7	3.7	33.30	9.10	2.3	7.20	98	3,700	2.2	1.3	85.00	38.60	0.7	62.10
1011 RT	SW harvester-forwarder	173	5.1	172	18,300	2.1	2.1	28.00	13.40	1.5	9.40	172	2,100	1.3	0.8	68.60	54.60	0.4	82.00
TREE LENGTH HARVESTERS																			
1200 --	Power Saw, fell. limp, top (Single sh.)	3.5	0.5	130	9,100	2.8	2.8	10.90	3.90	2.3	0.40	130	1,600	1.7	1.0	18.60	11.10	1.0	2.20
1020 RT	Small TL harvester, bunches	91	2.3	81	38,900	4.4	4.4	19.00	4.30	3.6	2.30	81	4,500	2.7	1.6	23.60	16.30	1.1	20.30
1021 TR	TL harvester, head on boom, no bunch	120	2.8	81	38,900	4.4	4.4	21.70	4.90	3.4	3.00	81	4,500	2.7	1.6	26.30	19.50	1.0	26.80
1022 RT	TL harvester, head, bunching	104	3.2	83	38,000	4.3	4.3	20.90	4.80	3.4	2.70	83	4,400	2.6	1.6	48.00	18.50	1.1	23.80
1023 TR	TL harvester, head on boom, no bunch	120	3.4	79	39,900	4.6	4.6	22.30	4.90	3.5	3.00	79	4,600	2.7	1.6	52.50	19.20	1.1	26.10
1024 RT	TL harvester, semi-auto, bunching	199	5.6	60	52,600	6.0	6.0	30.40	5.10	4.0	3.80	60	6,000	3.6	2.2	76.30	21.20	1.1	33.00
1025 TR	TL harvester, bunching	200	5.4	68	46,400	5.3	5.3	30.20	5.70	3.5	4.30	68	5,300	3.2	1.9	76.20	24.00	1.0	37.50
1026 TR	TL harvester, head on boom, bunching	120	3.4	95	33,200	3.8	3.8	22.30	5.90	2.9	3.60	95	3,800	2.3	1.4	52.50	23.10	0.9	31.40
1027 TR	TL harvester, assembles	120	3.1	112	28,200	3.2	3.2	22.10	6.90	2.5	4.30	112	3.200	1.9	1.2	52.40	27.20	0.8	37.30
FULL TREE FELLING																			
1030 RT	Feller - assembler - forwarder	180	6.4	58	54,400	6.2	6.2	29.80	4.80	4.3	3.30	58	6,300	3.7	2.2	71.80	19.30	1.2	28.80
1400 --	Power Saw, fell only (single shift)	3.5	0.5	75	15,800	4.8	4.8	10.90	2.30	4.8	0.20	75	2,700	2.9	1.7	18.50	6.40	1.7	1.30
1040 TR	Feller-buncher	89	2.8	36	87,600	10.0	10.0	19.40	1.90	8.2	1.00	36	10,100	6.0	3.6	43.40	7.20	2.6	8.80
1041 RT	Feller-buncher	113	3.0	36	87,600	10.0	10.0	21.30	2.10	7.8	1.30	36	10,100	6.0	3.6	50.10	8.40	2.4	11.20
1042 RT	Feller buncher	143	3.4	38	83,000	9.5	9.5	24.00	2.50	7.0	1.70	38	9,500	4.7	3.4	58.78	10.30	2.1	15.00
1043 TR	Large Feller-buncher	97	2.8	62	50.900	5.8	5.8	20.00	3.40	4.7	1.90	62	5,900	3.5	2.1	45.60	13.10	1.5	16.50
PROCESSORS (Limb, Top, Buck, Pile)																			
1050 TR	Processor, Roadside	220	7.1	29	108,700	12.4	12.4	33.50	2.70	8.0	2.00	29	12,500	7.5	4.5	83.30	11.20	2.3	17.60
1051 RT	Processor, Stump	185	4.4	46	68,600	7.8	7.8	28.10	3.60	5.4	2.70	46	7,900	4.7	2.8	71.00	15.10	1.5	23.50
LIMBING MACHINES																			
1100 RT	Flail limbing machine	55	3.0	18	175,200	20.0	20.0	17.20	0.90	17.6	0.30	18	20,200	12.0	7.2	34.60	2.90	5.8	2.70
1060 RT	Bunch limbing machine	66	1.8	25	124,600	14.2	14.2	16.70	1.20	12.2	0.50	25	14,300	8.5	5.1	36.30	4.30	4.0	4.60
1101 --	Power Saw limb and top (single shift)	3.5	0.5	82	14,400	4.4	4.4	10.90	2.50	4.4	0.20	82	2,500	2.6	1.6	18.50	7.00	1.6	1.40
1061 RT	Single stem limber, roadside	145	3.6	37	85,200	9.7	9.7	24.30	2.50	7.1	1.70	37	9,800	5.8	3.5	59.50	10.20	2.1	14.80
1062 RT	Single stem limber, stump	145	3.6	60	52,600	6.0	6.0	24.30	4.10	4.4	2.80	60	6,000	3.6	2.2	59.50	16.50	1.3	24.00
SKIDDERS																			
1070 RT	Choker skidder (single shift)	40	2.3	126	25,000	2.9	2.9	15.30	5.40	2.6	1.60	126	1,600	1.7	1.0	33.60	19.60	0.9	24.70
1071 RT	Grapple skidder (tree length)	59	2.6	67	47,100	5.4	5.4	17.00	3.20	4.7	1.30	67	5,400	3.2	1.9	35.30	10.90	1.5	10.90
1072 RT	Grapple skidder (full tree)	59	2.6	60	52,600	6.0	6.0	17.00	2.80	5.2	1.10	60	6,000	3.6	2.2	35.30	9.80	1.7	9.80
1073 TR	Bunk grapple skidder	94	4.1	52	60,600	6.9	6.9	21.10	3.10	5.6	1.50	52	7,000	4.2	2.5	46.10	11.10	1.8	13.40
1074 RT	Bunk Grapple skidder	79	2.2	43	73,300	8.4	8.4	18.10	2.20	7.0	1.10	43	8,400	5.0	3.0	40.20	8.00	2.2	9.40
FORWARDERS																			
1080 RT	Large forwarder	180	5.5	19	166,000	18.9	18.9	28.90	1.50	13.1	1.10	19	19,100	11.4	6.8	70.90	6.20	3.8	9.40
SLASHERS																			
1090 RT	Mobile slasher	250	7.0	12	262,800	30.0	30.0	55.60	1.90	18.5	1.00	12	30,200	18.0	10.8	124.60	6.90	5.1	8.30
PROTOTYPES AND PROPOSALS																			
2001 RT	Automated TL Harvester, bunching	170	8.7	44	71,700	8.2	8.2	31.50	3.90	5.7	2.40	44	8,200	4.9	3.0	71.50	14.60	1.7	20.60
2002 RT	Automated TL Harvester, bunching	180	6.6	46	68,600	7.8	7.8	30.00	3.80	5.4	2.60	46	7,900	4.7	2.8	72.00	15.30	1.6	22.80
2006 RT	TL harvester-assemble, forward	230	6.4	79	39,900	4.6	4.6	33.50	7.40	2.9	5.80	79	4,600	2.7	1.6	85.30	31.20	0.8	50.10
2007 RT	Large Forwarder	150	13.6	17	185,500	21.2	21.2	35.20	1.70	15.4	0.80	17	21,300	12.7	7.6	71.30	5.60	4.6	7.00

TR - TRACKED CHASSIS   RT - RUBBER TIRED CHASSIS   SW - SHORT-WOOD   TL - TREE-LENGTH achieved within the concept is achieved wood cost, read from the vertical axis.

The reported average wood cost for 1975-76 for conventional power saw fell, limb, top, choker skidding and slashing operations ($19.85 per cunit), is indicated by the horizontal line.

These systems include almost all combinations of machine types currently in use in eastern Canada, as well as several systems tried and discontinued, and several systems in prototype stages or at proposal stages only. Twenty-five of the thirty-five machines have been studied under FERIC machine evaluations, providing the concept factors for estimates. Manual operations and the remaining machines have been estimated from available information.

System estimates

Tree-length, full-tree, and shortwood systems appear scattered throughout the list (and the chart), and there is no apparent conceptual advantage of importance for any one of these major system types.

Conventional manual tree-length with slashing is reported at an industry average cost of $19.85 in 1975-76. Only six mechanized systems would fail to better this cost level, if the industry achievable assumptions of performance were achieved (24 hours per day 315 days per year, 80% utilization, 85% operator efficiency, maintenance costs of $.08 per $1000 price per productive machine hour). However, at industry average performance (18 hours per day for 225 days per year, 75% utilization, 70% operator efficiency and maintenance of $.10 per $1000 price per productive machine hour), only 21 systems would better the average cost of conventional tree-length operations. At minimum achievement performance, the best mechanized system would cost $7.00 more than conventional tree-length.

While the total range of wood cost

Wayne Novak assesses damage to sawlogs resulting from the use of hydraulic shears, by using a chain saw to remove discs at pre-measured intervals.

Appendix C: Table III, system performance.

SYSTEM NUMBER	SYSTEM TYPE	MACHINE COMBINATIONS	INDUSTRY AVERAGE	INDUSTRY ACHIEVABLE	RANGE
9041	FT	TR feller-buncher/grapple skidder/flail/slasher	16.60	11.40	7.50-26.80
9910	TL	RT automated TLH/large RT forwarder/slasher	16.60	11.20	7.40-27.10
9901	TL	RT automated TLH/large RT forwarder/slasher	16.80	11.10	7.20-27.70
9915	TL	RT automated TLH/large RT forwarder/slasher	16.90	11.30	7.40-27.90
9914	TL	RT automated TLH/large RT forwarder/slahser	17.10	11.30	7.20-28.50
9042	FT	RT feller-buncher/grapple skidder/flail/slasher	17.20	11.80	7.70-28.00
9046	FT	TR feller-buncher/grapple skidder/bunch limber/slasher	17.40	12.00	7.80-28.20
9030	FT	TR fell-assemble-forwarder/flail/slash	17.60	11.70	7.50-29.10
9001	TL	RT small TLH/large RT forwarder/slasher	17.80	11.90	7.70-29.50
9035	FT	TR feller-buncher/grapple skidder/roadside processor	17.90	12.00	7.80-29.40
9907	TL	RT automated TLH/bunk-grapple skidder/slasher	18.00	12.10	7.90-29.50
9047	FT	RT feller-buncher/grapple skidder/bunch limber/slasher	18.00	12.30	8.00-29.30
9033	FT	RT fell-assemble-forward/roadside processor	18.10	11.80	7.50-30.50
9043	FT	RT feller-buncher/grapple skidder/flail/slasher	18.30	12.50	8.10-29.90
9912	TL	Rt automated TLH/bunk-grapple-skidder/slasher	18.30	12.20	7.90-30.30
9036	FT	RT feller-buncher/grapple skidder/roadside processor	18.50	12.40	8.00-30.50
9002	TL	RT small TLH/bunk-grapple skidder/slasher	19.00	12.90	8.30-31.30
9048	FT	RT feller-buncher/grapple skidder/bunch limber/slasher	19.10	13.00	8.40-31.30
9037	FT	RT feller-buncher/grapple skidder/roadside processor	19.60	13.00	8.40-32.50
8806	FT	TR feller-buncher/bunk-grapple skidder/single stem limber/slasher	19.60	13.20	8.50-32.40
9908	TL	RT automated TLH/TR grapple skidder/slasher	19.90	13.40	8.80-32.60
9906	TL	RT automated TLH/grapple skidder/slasher	20.00	13.50	8.90-32.40
9044	FT	TR large feller-buncher/grapple skidder/flail/slasher	20.20	13.80	9.00-32.70
9913	TL	RT automated TLH/TR grapple skidder/slasher	20.20	13.50	8.70-33.40
9911	TL	RT automated TLH/grapple skidder/slasher	20.30	13.70	8.90-33.20
9006	TL	RT harvester head on chassis/large RT forwarder/slasher	20.30	13.70	8.20-33.40
9007	TL	RT harvester head on chassis/bunk-grapple skidder/slasher	20.30	13.70	8.80-33.40
9011	TL	RT semi-auto TLH/large RT forwarder/slasher	20.40	13.30	8.40-34.30
9051	FT	TR feller-buncher/grapple skidder/single stem limber/slasher	20.80	14.10	9.10-34.20
9003	TL	RT small RT TLH/TR grapple skidder/slasher	21.00	14.20	9.20-34.40
9004	TL	RT small RT TLH/grapple skidder/slasher	21.00	14.30	9.30-34.20
9049	FT	TR large feller-buncher/grapple skidder/bunch limber/slasher	21.00	14.30	9.30-34.10
9038	FT	TR large feller-buncher/grapple & skidder/roadside processor	21.40	14.40	9.30-35.20
9052	FT	RT feller-buncher/grapple skidder/single-stem limber/slasher	21.40	14.50	9.30-35.90
9012	TL	RT semi-auto TLH/bunk-grapple skidder/slasher	21.60	14.20	9.10-36.10
9019	TL	TR harvester head on boom, bunching/large RT forwarder/slasher	21.80	14.50	9.30-36.30
9032	FT	RT fell-assemble-forwarder/single-stem limber/slasher	21.80	14.30	9.20-36.40
9015	TL	TR TLH/large RT forwarder/slasher	22.00	14.30	9.10-37.10
9060	TL	Power saw felling/single-stem limber, stump/large RT forwarder/slasher	22.00	15.00	9.70-36.00
9061	TL	TR feller buncher/single stem limber, stump/large RT forwarder/slasher	22.10	14.70	9.40-36.90
9008	TL	RT TL harvester, head, bunching/TR bunk grapple skidder/slasher	22.30	15.00	9.70-36.50
9009	TL	RT TL harvester, head, bunching/grapple skidder/slasher	22.30	15.20	9.90-36.30
9916	TL	RT TL harvester, assemble, forward/slasher	22.50	14.60	9.20-38.10

from the system with apparent best conceptual potential to that with apparently lowest potential is reasonably high ($11.40 to $23.50 per cunit at the industry achievable level), the estimated range of wood cost due to variation of performance within the concept is even higher ($11.40 at achievable level to $26.80 at the minimum achievement level). The system with weakest concept, if operated at maximum performance achievement and if particularly well-designed and engineered, appears able to produce wood at lower cost than the conceptually-best system operated with all performance factors at the minimum achievement level.

Several of the systems rated highest in conceptual potential are relatively new systems which continue to encounter both machine design problems and problems of application, which makes the higher levels of performance achievement uncertain. For example, many of the systems with best potential utilize the efficient chain flail for limbing, but in practice, it has proven difficult to find sufficient accumulations of suitable stands to keep flails operating productively. Also, planning and layout problems have restricted the number of places that flails can be used. Other systems high on the list are still in experimental stages, and long-term performance remains uncertain.

Many of the best machine combinations include the large rubber-tired forwarder, a machine not currently in production in Canada and largely unproven in operations. Systems combining large forwarders and flail limbing may prove impossible, since the large bundles of full trees are not easily broken down for flail limbing.

Many of the systems ranked lowest on the list are suitable for integrated operations and sawtimber-size trees. The potentially higher wood cost of these concepts is likely to be more than offset by the higher value of the log product obtained.

A few of the systems listed are most notable for their failure to achieve even the industry average level of performance. An analysis of reported costs is likely to confirm unusually high maintenance costs and low utilization, reflecting the design immaturity or startup problems of the user.

Estimated productivity range

Similar procedures have been used to estimate productivity per paid man-hour of operators and mechanics in various systems, and the results are shown schematically in Fig. 2. Almost all mechanical systems have good potential to show higher man-hour output than conventional tree length operations, and best concepts appear capable of about three times the productivity of manual operations.

Appendix C: Table III, system performance.

SYSTEM NUMBER	SYSTEM TYPE	MACHINE COMBINATIONS	INDUSTRY AVERAGE	INDUSTRY ACHIEVABLE	RANGE
9090	SW	RT shortwood harvester, forwarder	22.60	14.40	9.10-38.60
9053	FT	RT feller buncher/grapple skidder/single-stem limber, roadside/slasher	22.60	15.10	9.70-37.20
9062	TL	RT feller buncher/single-stem limber, stump/large RT forwarder/slasher	22.70	15.00	9.60-38.00
9020	TL	TL harvester, head on boom, bunching/bunk-grapple skidder/slasher	22.90	15.40	9.90-38.00
8811	FT	power saw felling/choker skidder/flail/slasher	22.90	16.40	10.30-35.70
9016	TL	TR TL harvester, bunching/bunk grapple skidder/slasher	23.20	15.30	9.70-38.90
9065	TL	power saw felling/single-stem limber, stump/bunk-grapple skidder/slasher	23.20	15.90	10.30-37.80
9066	TL	TR feller buncher/single-stem limber, stump/bunk-grapple skidder/slasher	23.40	15.60	10.00-38.70
9013	TL	RT semi-auto TLH/bunk-grapple skidder/slasher	23.50	15.60	10.00-39.20
9014	TL	RT semi-auto TLH/grapple skidder/slasher	23.60	15.70	10.10-39.00
9063	TL	RT feller buncher/single-stem limber, stump/large RT forwarder/slasher	23.90	15.70	10.00-40.00
9067	TL	RT feller buncher/single-stem limber, stump/bunk grapple skidder/slasher	24.00	14.90	10.20-39.80
9023	TL	TL harvester, assembles/large RT forwarder/slasher	24.20	16.00	10.20-40.30
9039	TL	power saw, fell, limb, top/choker skidder/slasher	24.20	17.50	11.10-37.40
9054	FT	TR large feller buncher/grapple skidder/single-stem limber, roadside/slasher	24.40	16.50	10.60-40.00
9021	TL	TR TL harvester, head on boom, bunching/TR bunk-grapple skidder/slasher	24.90	16.70	10.90-41.10
9022	TL	TR TL harvester, head on boom, bunching/grapple skidder/slasher	25.00	16.90	10.90-38.30
9017	TL	TR TL harvester, bunching/TR bunk-grapple skidder/slasher	25.10	16.60	10.60-42.00
9068	TL	RT feller buncher/single-stem limber, stump/bunk-grapple skidder/slasher	25.10	16.60	10.60-41.80
9018	TL	TR TL harvester, bunching/grapple skidder/slasher	25.20	16.70	10.70-42.00
9070	TL	power saw felling/single-stem limber, stump/TR bunk-grapple skidder/slasher	25.20	17.20	11.20-40.80
9075	TL	power saw felling/single-stem limber, stump/grapple skidder/slasher	25.23	17.40	11.30-40.70
9076	TL	TR feller buncher/single-stem limber, stump/grapple skidder/slasher	25.30	17.10	11.00-41.60
9071	TL	TR feller buncher/single-stem limber, stump/TR bunk-grapple skidder/slasher	25.30	16.90	10.90-41.80
9024	TL	TL harvester, assembles/bunk-grapple skidder/slasher	25.40	16.50	10.90-42.10
9064	TL	TR large feller buncher/single-stem limber, stump/large RT forwarder/slasher	25.70	17.00	10.90-42.80
9077	TL	RT feller buncher/single-stem limber, stump/grapple skidder/slasher	25.90	17.40	11.20-42.70
9072	TL	RT feller buncher/single-stem limber, stump/TR bunk-grapple skidder/slasher	25.90	17.30	11.10-42.90
9069	TL	TR large feller buncher/single-stem limber, stump/bunk-grapple skidder/slasher	26.90	18.00	11.50-44.50
9073	TL	RT feller buncher/single-stem limber, stump/TR bunk-grapple skidder/slasher	27.00	17.90	11.50-44.90
9078	TL	RT feller buncher/single-stem limber, stump/grapple skidder/slasher	27.00	18.10	11.60-44.70
9025	TL	RT TL harvester, assembles/TR bunk-grapple skidder/slasher	27.30	18.30	11.80-45.20
9026	TL	RT TL harvester, assembles/grapple skidder/slasher	27.40	18.40	11.90-45.00
9010	TL	RT harvester, head on boom, TLH/choker skidder/slasher	28.30	19.40	12.10-45.70
9005	TL	RT harvester, head on boom, TLH/choker skidder/slasher	28.40	19.50	12.10-46.00
9079	TL	TR large feller buncher/single-stem limber, stump/grapple skidder/slasher	28.80	19.40	12.50-47.50
9074	TL	TR large feller buncher/single-stem limber, stump/TR bunk-grapple skidder/slasher	28.80	19.30	12.40-47.60
9080	TL	power saw felling/single-stem limber, stump/choker skidder/slasher	30.80	21.50	13.50-49.30
9081	TL	TR feller buncher/single-stem limber, stump/choker skidder/slasher	31.00	21.20	13.20-50.30
9082	TL	Rt feller buncher/single-stem limber, stump/choker skidder/slasher	31.60	21.50	13.40-51.40
9091	SW	RT shortwood harvester, forwarder	32.30	21.00	13.40-54.60
9083	TL	RT feller buncher/single-stem limber, stump/choker skidder/slasher	32.70	22.20	13.80-53.30
9084	TL	large feller buncher/single-stem limber, stump/choker skidder/slasher	34.50	23.50	14.70-56.10

Estimated investment range

Total investment in machines for each cunit per year of production has been calculated for each of the systems at each performance level, and results are shown schematically in Fig. 3. All mechanized systems appear to have the potential for higher output per invested dollar than the 1975-76 estimated average investment in power saws, choker skidders and slashers for conventional operations. Failure to achieve high utilization and good operator efficiency can result in a large increase in investment, reaching more than four times current averages for conceptually weak systems with poor performance achieved. Mechanized systems which include manual (power saw) felling or limbing are somewhat less sensitive to changes in performance level. This is shown by the short lines adjacent to the lines defining the limits of performance of fully mechanized systems.

Remarks and conclusions

The method of logging machine and system concept analysis proposed by this report is believed to provide a useful tool for separating the ideas for logging systems from the achievement problems of manufacturer and user.

While the method suggests that there are important differences in potential between various system concepts, it must be concluded from the estimated effects of performance variation that concept cannot, by itself, provide a guarantee of high productivity and low wood cost. Concept cannot provide a guarantee of superiority of any currently available systems over any other available system.

When all factors of engineering, design, operator, mechanic, and supervisor achievement are at near-ideal levels, any of the presently available concepts of logging systems appears to have the potential to produce wood at costs equal to or better than conventional manual systems. With poor achievements in hardware or operation, any concept currently available can result in wood costs higher than conventional systems.

No logging system currently available can miraculously reduce wood cost. Good concepts, combined with effective application, superior design, low maintenance costs and effective operation by trained and skilled operators and mechanics working with top quality tools in best facilities, can achieve significant savings in wood cost, higher productivity and less investment per cunit produced than conventional systems.

No important difference between the potential of full tree systems and tree-length systems is indicated by the analysis, and system selection is likely to depend primarily upon a detailed analysis of the performance achieved by specific machines, rather than upon the type of system or on system concept. While short-wood systems do not appear high on the list for concept potential, the conceptual differences are small, and are balanced by potential performance advantages of a single-machine system and advanced levels of development.

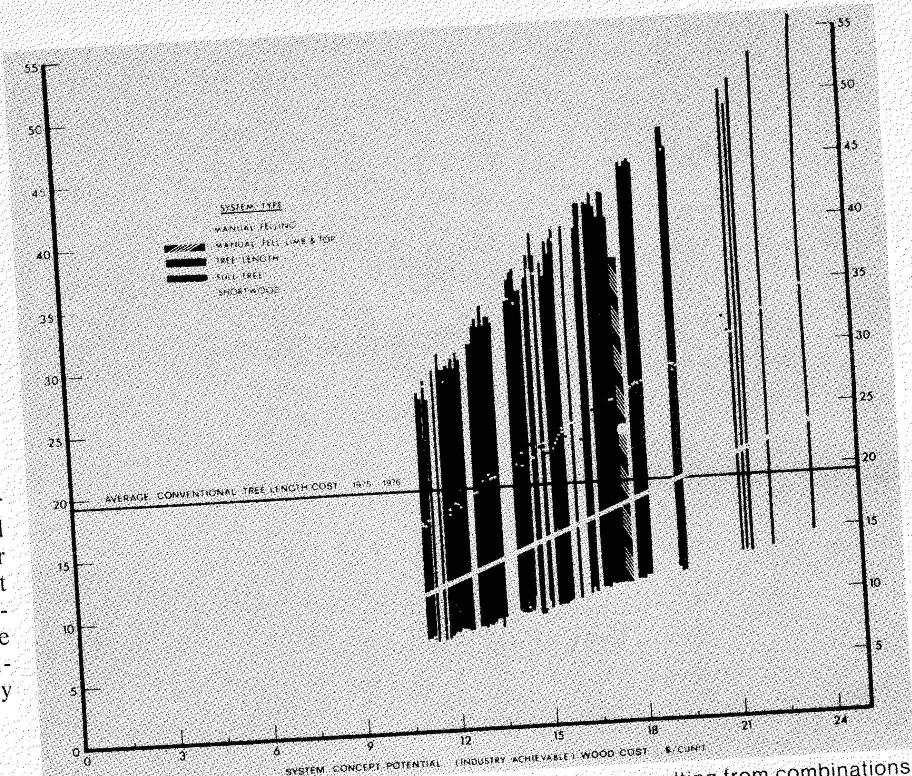


Fig. 1. Pictorial representation of the range of wood cost, resulting from combinations of concept and performance within concept for 84 logging systems. Each vertical line represents a logging system analyzed.

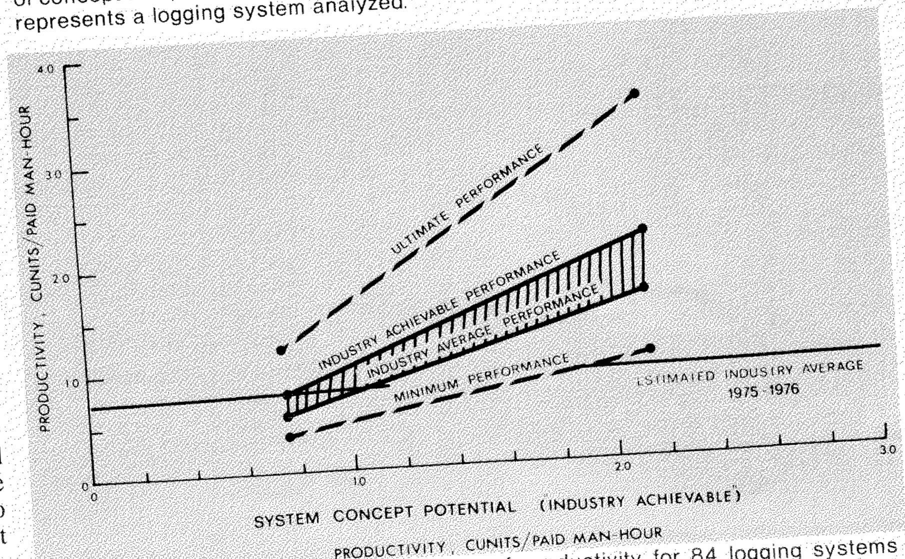


Fig. 2. Schematic illustration of the range of productivity for 84 logging systems analyzed, showing productivity estimated from various combinations of concept performance.

Future work in systems analysis

The method of logging system comparison proposed in this report provides a basic tool required for system analysis and comparison. Unfortunately, the conclusion of the application of the concept analysis must be interpreted as meaning that it is not, by itself, adequate to select most effective systems for an operation, or even to select those concepts most deserving of development effort.

Concept analysis sets reasonable top and bottom limits on our expectations of achievement from systems. Performance analysis is required to determine whether a system concept can actually achieve reasonably high levels of productivity and wood cost reduction.

Fortunately, there is a growing bank of performance data and indications of a growing ability to isolate the effects on performance of many of the important problems of mechanized system operation. Through FERIC machine evaluation studies, the effects of many of the stand and terrain variables on machine productivity can be measured. It is known which components are responsible for mechanical downtime and cost, and it is known why these components fail and why they are not always repaired efficiently. It can be predicted with reasonable accuracy, the effect on productivity and wood cost of a failure which tends to occur on one machine but not on another. Collected data reveals something about how much difference in efficiency occurs from one operator to another, and work on human factors has provided some indications of why operators perform differently.

Concept analysis by itself provides no miracle solutions to the problem of system development and selection. Concept analysis combined with performance analysis can lead to superior results with present systems and superior systems for the future.

Future systems

The charts of estimated range of achieved wood cost, productivity and investment for present and contemplated systems, reveal that all mechanized systems have relatively consistent response to changes in utilization, operator efficiency, and other performance factor changes. A straight line drawn through the achievable estimates for the ranked systems, and another through the minimum achievement estimates, describes these limits for all systems with relatively small error.

This line can be projected to demonstrate the range of performance which is likely to occur for systems with concepts that could achieve much lower wood cost and higher productivity than any presently available.

Fig. 4 shows the area where greatly improved future system concepts fall into. By accepting the same standard levels of industry performance in operator efficiency, utilization, and maintenance cost, for machines of a given price, the operating cycle time required to achieve this performance range can be calculated. For example, to create a system that produces wood at one-half of the cost of the best present concepts, a tree-length harvester/forwarder capable of producing 6 trees per minute would be required if the machine cost $250,000 and was combined with a slasher at roadside. A feller-forwarder costing $175,000 combined with flail and slasher would have to produce 9 trees per minute to produce this estimate of performance.

This method of system concept comparison permits new ideas to be evaluated under the same conditions, and permits a specification to be set for future systems that are capable of producing much better wood cost and productivity.

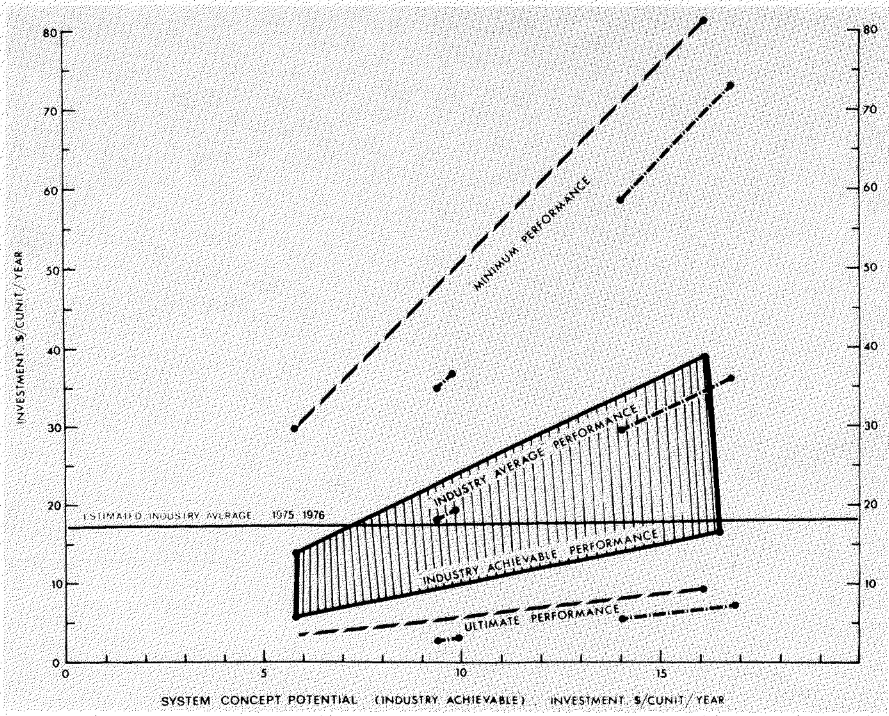


Fig. 3. Schematic illustration of the range of investment in machines required to produce one cunit per year using 84 system concepts at various levels of performance.

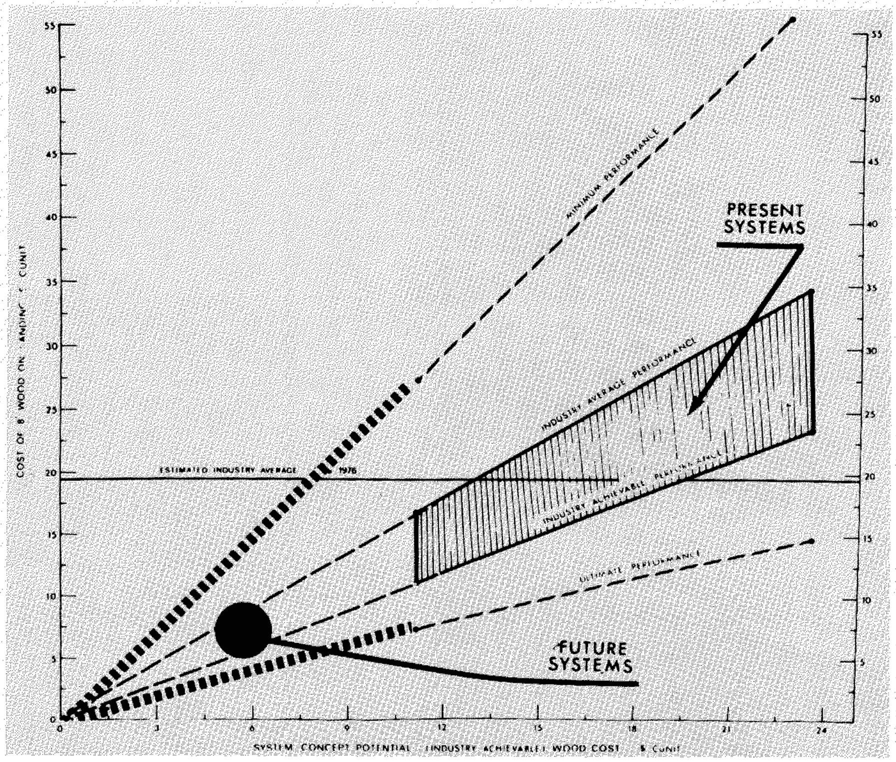


Fig. 4. Requirements for future systems can be projected from present system estimates.

RÉSUMÉ: Ce document propose une méthode permettant d'évaluer le prix du bois, la productivité et les sommes à investir pour des abatteuses et des systèmes, en s'appuyant sur des facteurs inhérents ou "conceptuels" ainsi que sur quatre présumés niveaux de rendement à l'intérieur des possibilités des concepts. Cette méthode s'applique à 35 machines dans 84 systèmes d'abattage utilisés au Canada.

Original title: A method of comparing logging system and machine concepts. This paper — W.S. 1 No. 2723 (B-4-e): ODC 311 — was presented at the 58th Annual Meeting of the Woodlands Section, CPPA, held March 28-30, 1977 in Montreal, Que.