Backhoe Loaders as Base Machines in Logging Operations

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Time studies and an ergonomic assessment were carried out in logging operations for three logging machines based on backhoe loader chassis. The time studies were completed with a follow-up study of one backhoe loader-based single-grip harvester. The studies indicated a productivity at the same level as that of specialized Nordic logging machines. Ergonomics also proved to be good. Mean ground pressure exerted by the backhoe loader-based logging machines was a little higher than for some of the conventional Nordic single-grip harvesters, to which it was compared. The ability of the machines to operate in the terrain was also good, even in rough terrain.

These machines can also be used for other jobs, such as ditch digging, road building, and road maintenance. The machines then function more as carriers for attachments rather than custom-built backhoe loaders. By more careful planning of operations, the machines can be used to a higher degree and more effectively. The relatively low investment cost compared to many custom-built Nordic logging machines also contributes to a reduction in operating costs.

Keywords attachments, backhoe loaders, base machines, forest machines, harvesting, logging.
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1 Introduction

Conventional Nordic logging machines are specialized and can normally do only one type of work, and investment level is often high. However, in Canada, USA, Australia, New Zealand, and Great Britain standardized excavator chassis are common as base machines in forestry with attachments such as feller/bunchers (MacDonald 1990), processors (Richardson et al. 1991), or harvesters (Spencer 1990, Evanson and Riddle 1994). They are also used in shovel-logging (Hemphill 1986) and as log loaders (Langsford 1985). The productivity of these machines is good. There are various booms and attachments available for excavators for these purposes. Excavators may be equipped with tracked or wheel undercarriages depending on their use. They range in size from small machines (8 tons) to large machines (40 tons).

In the early 1980's some backhoe loaders with attachments were introduced in Nordic forest operations. Most of the machines tested only worked for a short period because the results were not satisfactory, mostly due to the base machine. Backhoe loaders with attachments were again introduced in logging operations in the later 1980's, and with greater success because of the improved base machines and the development of the single-grip harvester head. The backhoe loaders introduced in Nordic forest operations in the late 1980's can be described as follows:

- wheel-mounted loader originally with a digging device (crane and bucket) on the rear end
- all wheels of the same size
- four-wheel drive
- articulated frame steering
- mass 8–13 tons

The logging attachments used were identical to those used by conventional Nordic logging machines. The main difference between backhoe loader-based logging machines and conventional Nordic logging machines was the base machine undercarriage. The backhoe loader-based logging machines in Sweden are used in thinning as well as in clear cutting, with the most common application in thinning. The attachments are placed at the rear end of the machines, while the machines move and operate facing backwards. Approximately ten backhoe loaders are equipped for logging purposes in Sweden, in Finland the number of these machines is larger.

2 Objectives

Studies were conducted with the aim of obtaining an indication of suitability of backhoe loader-based logging machines operating in Sweden. The studies included:

- fitness for use in logging operations
- productivity
- ergonomics

3 Material and methods

3.1 Machines

Time studies and ergonomic assessments were carried out for three backhoe loader-based logging machines (Table 1). In addition, a follow-up study for one of the machines was conducted (Table 1, machine no. 2). Damage to remaining trees in thinning was measured. Size of damage was measured in the following three classes: less than 15 cm^2, 15–100 cm^2, and larger than 100 cm^2. Location of damage was also measured in three classes, namely: stump or roots within 70 cm from stem, from stump up to 0.5 m over stump, and the rest of the stem.

Table 1. Backhoe loader-based logging machines studied.

Base machine	Attachment	Mass, kg	Wheel base, cm	Tyres	Reach, m	Ground clearance, cm	Mean ground pressure, kPa
1. Volvo 6300	Processor, Skogserik RC 380 P[1)], strokedelimbing	appr. 11000	251	Twin 600	10.0	50.5	60
2. Huddig 960	Harvesting head, Tufab GS 301, rollers, extra dipper[2)]	13100	252	Twin 600	7.1	49	66
3. Huddig 760 M4	Harvesting head, Tufab GS 302, rollers, forest crane[3)]	8500	242.5	16.9/30	7.2	50	68

1) Original crane removed.
2) Extra dipper = extension rod on the crane to increase reach.
3) The forest crane was a Mowi 465 parallellogram crane.

Fig. 1. Volvo 6300 backhoe loader with Skogserik RC 380 P stroke delimbing processor (machine no. 1). Original crane removed.

Fig. 2. Huddig 960 backhoe loader with Tufab GS 301 harvester head and an extra dipper attached to the original crane (machine no. 2).

Fig. 3. Huddig 760 M4 backhoe loader with Tufab GS 302 harvester head (machine no. 3). The original crane is replaced by a Mowi 465 parallellogram crane.

Mean ground pressure was calculated. Data for Volvo 6300/Skogserik RC 380 P (machine no. 1, Fig. 1) was used according to manufacturers' specifications. Two machines were weighed, one machine identical to the Huddig 960/Tufab GS 301 (machine no. 2, Fig. 2), and the Huddig 760 M4/Tufab GS 302 (machine no. 3, Fig. 3). Weighing equipment used was Telub 8023, consisting of one central unit and four scale units. All machines were studied when working in normal production.

Standard definitions of elements used in Swedish time studies often differ from those used in other countries. One commonly used term is "Technical degree of utilization", defined as basic time divided by operating time. The following elements used in this study are defined in the Forestry Vocabulary (1994):

Basic time – effective time plus delays of a certain maximum length (here less than 15 minutes).
Delay time – sum of disturbance time, maintenance time, and repair time.
Effective time – productive time with no delays.
Operating time – basic time plus delay time.

Other terms used in this report are defined as follows:

Crane zone – part of the thinning area that can be reached by crane from the strip roads.
Middle zone – the rest of the thinning area that can not be reached from the strip roads. The trees in the middle zone are felled manually towards the strip roads from where they are processed.
Work place – place from where the trees are processed/harvested within crane reach.
Work cycle – included reaching out crane - positioning - processing - release top in clear cutting.
Work cycle – included reaching out crane - positioning - felling - processing - release top in thinning.

Volume shown in this report (m^3) means solid volume over bark, and diameter (cm) is over bark. Diameter was measured according to the lower limit of each size-class.

Table 2. Data of the stands studied.

Machine	No. of trees per ha	Species mix. Pine, spruce, decideous, in tenths	Mean tree diameter, cm	Mean tree volume, m^3
Machine 1	1500	0,10,0[2)]	21.3 ± 8.1 (SD)[2)]	0.406 ± 0.355 (SD)[2)]
Machine 2	2720[1)]	7,2,1[1)]		
	1620[2)]	9,1,0[2)]	11.4 ± 3.8 (SD)[2)]	0.088 ± 0.073 (SD)[2)]
Machine 3	1500[1)]	2,7,1[1)]		
	800[2)]	1,8,1[2)]	12.2 ± 4.8 (SD)[2)]	0.099 ± 0.113 (SD)[2)]

1) Total
2) Harvested

Table 3. Terrain classification result in the studies. Assessed according to a scale of five levels from very good to very poor (Terrain Classification System ... 1992). The levels are coded (by the author) where 1 = very good and 5 = very poor.

Machine	Season	Terrain factors Ground condition	Surface structure	Slope
Machine 1	Autumn, no snow	1	1	1
Machine 2	Autumn, no snow	1	1	1
Machine 3	Winter, 20 cm snow. Frozen crust	1	3	2

3.2 The Stands

Machine no. 1 was studied processing in a clear cut spruce stand. The stand was located in the south of Sweden. Machine no. 2 was studied thinning a 50-year old pine dominated mixed stand. The stand was located in the middle of Sweden. Machine no. 3 was studied thinning an 80-year old spruce dominated mixed stand. The stand was located in the middle of Sweden. Stand data are presented in Table 2.

Terrain conditions in the studied stands (Table 3) were assessed according to Terrain Classification System for Forestry Work (1992).

3.3 Harvesting Methods

Machine no. 1 was studied processing a clear cut stand (cut-to-length). The trees studied were chosen in the stand according to a criteria that diameter deviation of sampled trees should be wide. After felling (manual), the trees were mixed with the trees not studied. The operator had about one year of experiance with this machine, but he had earlier operated a Rottne Snoken forest machine for some years.

The machines no. 2 and no. 3 were studied harvesting in thinning stands (cut-to-length). The machines were working on a net of strip roads. The machines were moving along strip roads and harvested trees in the crane zone within reach from where they were standing (work place), then they moved to a new work place. The operator on machine no. 2 had operated this machine in harvesting for a little more than one year, which was the only experiance he had from forestry. The operator on machine no. 3 had only a few weeks of experiance with this machine, but he had operated other single-grip harvesters for many years.

After harvesting the crane zone trees, the middle zone trees were felled (manually) towards the strip roads (machine no. 2). Thus the operator could process the trees from the strip roads. The trees were processed from the top, toward the butt, just the opposite of the trees in the crane zone. The machine was moving along the strip roads from work place to work place in the same way as in the crane zone. By driving into natural gaps in the stand beside the strip roads (machine no. 3), the operator could extend the crane reach. Thus the middle zones could be eliminated.

3.4 Time Studies

The diameters at breast height and lengths of the trees to be processed were measured and the diameters were marked on the trees before the studies in clear cutting (machine no. 1). The field work (time recording) in clear cutting was carried out with a video camera with time measuring equipment attached. The entire work cycle was recorded. The time studies and the regression analyses then were carried out indoors.

The diameters of all trees were measured and marked on the trees in thinning, and the heights of sample trees in each stand were measured (machines no. 2 and no. 3). The time study was carried out during harvesting operation using a Husky Hunter data collector. The entire work cycle was studied. Only regression analyses were carried out indoors.

3.5 Study of Ergonomics

Ergonomics were assessed using An Ergonomic Checklist for Forestry Machinery (1990). The assessments were carried out (by the author) by measuring and/or judging the machines and interviewing the operators. The checklist contains 13 factors (Table 8) to be measured and/or judged. Each factor can be measured/judged according to a scale of five levels, from very poor to very good. Some of the factors had to be judged subjectively since the checklist is to some extent not a precise instrument. In order to get a better overview, the scale was coded from 1 to 5, where 1 is very poor and 5 is very good. Note that the numbers are not measured values.

Vibrations were measured with a Brüel & Kjær 2512 vibration meter and a Brüel & Kjær 4322 tri-axial accelerometer and analyzed (whole body) using SS-ISO 2631 (1982). Vibrations were measured in three directions: x (forwards/backwards), y (sidewards), and z (up/down). Because of a technical failure the z-direction for machine no. 3 could not be measured. Noise level was measured with Brüel & Kjær 4428 S sound level meter (machine no. 1) and Brüel & Kjær 2221 sound level meter (machines no. 2 and no. 3). The lighting factor was not measured for any of the machines because two of the machines were only operated during day light hours (machines no. 1 and no. 2), and the third machine was new and the lighting had not yet been tested.

3.6 Follow-up Study

A follow-up study was conducted on machine no. 2. The machine had been used 9 900 hours basic time when the study started. The harvesting head had been used approximately 1 000 hours basic time. The study period was a little more than two years, and the entire "harvesting period" was studied. Data was sent to author from the operator. Some data was according to the operator, rest of the data was according to productivity reports from the forest company. Factors of special interest were productivity, repair time, maintenance time, and fuel consumption. Repair time (excl. repairs < 15 min) was divided into two groups depending on what caused the delays, base machine or attachments. The follow-up of time usage and productivity took place in clear cutting and thinning. The harvesting methods in clear cutting were cut-to-length and tree sections respectively, and in thinning cut-to-length. The study of fuel consumption took place in thinning and clear cutting, with small trees, using the cut-to-length method.

3.7 Analysis

Time usage was analysed using regression analysis. A significance test for intercepts and regression coefficients was carried out. Intercepts and regression coefficients were tested to see if they differed from zero. Time is shown as effective time, commonly used in Swedish time studies, and productivity per effective time unit.

Tested variables for a regression model (processor, clear cutting) were diameter at breast height (Dbh), diameter squared, tree length, tree volume, delimbing difficulty, and number of logs per tree. Delimbing difficulty was subjectively measured by using two classes, "very difficult" and "not so difficult". This variable was in the analysis a dummy variable. The variables were tested individually or combined.

Tested variables in thinning (harvesters) were tree species, diameter at breast height (Dbh), diameter squared, tree length, tree volume, and number of logs per tree. The variables were tested individually or combined.

The follow-up study shows productivity per time unit including delays less than 15 minutes, which is commonly used in day-to-day operations.

4 Results

4.1 Time per Work Cycle

Processor: The following model describes effective time for an entire work cycle (moving forward excluded) for machine no. 1 in clear cutting:

$$T = a + b \times Vol + c \times NL$$

T = time per work cycle, cmin per tree
Vol = volume per tree, m^3
NL = number of logs per tree

The intercept and the regression coefficients are significantly different from zero. The number of logs per tree is of great significance for time consumption. The model is presented in Table 5. Mean time appear in Table 6.

Productivity was 48 trees per effective hour for machine no. 1. Productivity in three studies of Volvo BM Tvigg roller feeding processor on three SMV chassis and with three different forest cranes (Sondell 1975) varied from 91 to 169 trees per hour effective time (Table 4). The number of stems per hectare in the studies by Sondell was smaller, and so were the diameters. The stands were spruce dominated and the terrain conditions were rather good.

Harvesters: No significant difference (time consumption) was found between tree species. Time is described according to the following

Table 4. Productivity for machine no. 1 compared with Volvo BM Tvigg processor (rollers).

Machine	No. of trees per hectare	Mean diameter, cm	Productivity, trees per effective hour
Machine 1	1500	21.3	48
Volvo BM Tvigg[1]			
– study 1	1280	18.3	111
– study 2	643	17.0	91
– study 3	1420	16.6	169

[1] According to Sondell (1975).

Table 5. Time per work cycle, cmin per tree. Intercepts, regression coefficients, and R-square in the regression analyses ($T = a + b \times Vol + c \times NL$[1]).

Machine	Intercept in regression a	Regression coefficient b	c	R^2	Interval diam., cm	vol., m^3	No. of trees in regr.
Machine 1	24.4	38.3	7.2	0.54	9–38	0.030–1.446	62
Machine 2							
– crane zone	36.6	134.9	–	0.37	5–24	0.011–0.395	231
– middle zone	44.5	162.4	–	0.25	6–25	0.011–0.435	208
Machine 3	34.5	138.1	–	0.60	6–34	0.015–0.980	434

[1] NL = number of logs per tree, only in clear cutting.

model for the machines no. 2 and no. 3 (moving forward excluded):

$$T = a + b \times Vol$$

T = time per work cycle, cmin per tree
Vol = volume per stem, m^3

Intercepts and regression coefficients in the models are significantly different from zero. Regression coefficients for both machines were at about the same size (Table 5, Fig. 4). Mean time appear in Table 6.

Productivity for the two studied backhoe loader-based single grip harvesters was 91 to 105 trees per effective hour. Productivity for three medium-sized single-grip harvesters in thinning (Hellström 1987) varied in one study from approximately 85 to 115 trees per effective hour (Table 7). The mean diameter cut was smaller in the study by Hellström, but the terrain conditions were a little worse than for the backhoe loader-based machines studied.

Table 6. Mean time (effective) in clear cutting and thinning.

Machine	Time per tree by element, cmin Processing/harvesting	Moving	No. of trees per work place
Machine 1	113.3±49.5 (SD)	12.7	7.1
Machine 2			
– crane zone	57.3±20.1 (SD)	6.7	4.6
– middle zone	59.7±22.4 (SD)	6.3	4.8
Machine 3	48.4±20.2 (SD)	9.2	3.3

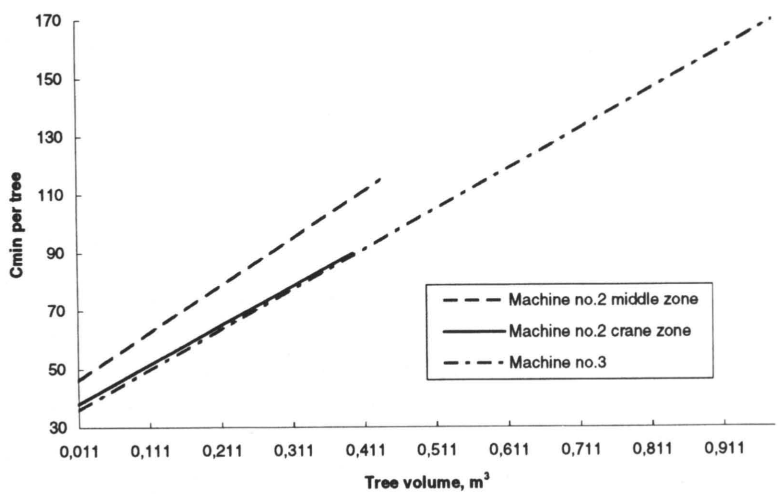

Fig 4. Time per tree (cmin) at varying tree volume for machines no. 2 and no. 3 (moving time excluded).

4.2 Ergonomics

The worst appraisal was for the operator's seat on machine no. 3 (Table 8). The seat was intended for use in earth moving work and had not been exchanged for a seat suitable for harvesting.

Entering/exiting, work position, cabin, levers, cabin climate, view, and maintenance were factors which had considerably higher grades. However, one machine received the highest mark for levers. The most serious remark for entering/exiting the machines was that the ladders were not acceptable according to the check list. The operators considered work position to be good but the cabins could not be levelled. To some degree this could be compensated by the outriggers on machines no. 1 and no. 2. The outriggers had been removed on machine no. 3. According

Table 7. Productivity for the backhoe loader-based single-grip harvesters compared with three Nordic single-grip harvesters in thinning.

Machine	Reach, m	No. of trees per hectare	Mean diam., cm	Productivity, trees per eff. hour
Machine 2	7,1	2720		
– crane zone and middle zone			11.4	93
Machine 3	7,2	1500		
– also working off strip road			12.2	105
Valmet 901[1]	9,5	2700		
– crane zone and middle zone			10.1	105
– no middle zone			10.1	115
Rottne Rapid[1]	10	2700		
– crane zone and middle zone			10.1	85
Bruun Two[1]	5,1	2700		
– also working off strip road			10.1	110

1) According to Hellström (1987).

Table 8. Ergonomic check list results. Assessed according to a scale of five levels, from very poor to very good (An Ergonomic Checklist ... 1990). The levels are coded (by the author) where 1 = very poor and 5 = very good).

Ergonomic factor	Base machine Machine 1	Machine 2	Machine 3
1. Entering/exiting	4	4	4
2. Work position	4	4	4
3. Cabin	4	4	4
4. Operators seat	5	5	3
5. Levers	5	4	4
6. Instruments	5	5	5
7. Climate in cabin	3	4	–
8. View	4	4	4
9. Lighting	–	–	–
10. Noise	5	5	5
11. Exhaust gas and dust	5	5	5
12. Vibrations	5	5	(5)[1]
13. Maintenance	4	4	4

1) Z-direction not measured.

to the checklist, the cabins had slightly narrow widths. The operators did not consider this to be a problem, since they seldom needed to turn their seats. The machines were operated by a two-lever system, which was considered to be good except for some remarks for two of the machines. For example, one operator found that some functions could be mixed up with each other, and another operator felt there were too many buttons on each lever making them difficult to learn. Cabin climate was judged to be rather good, except for some minor remarks. For example, two of the machines could not be preheated, and strong sunshine could be annoying in one of the machines. The cabin climate for machine no. 3 was not appraised, since it was a new machine. The view out of the cabins was considered to be rather good, except that the harvester cranes and the processor boom could sometimes obscure the view. Maintenance was also considered to be good, with the exception that there was too little room for tools and it could sometimes be difficult to reach places to be serviced.

All other factors were considered to be very good. Especially high ratings were given for the factors noise and vibrations. These factors are considered to be very important. The risk for hearing impairment is high if the equivalent level of noise during a typical work day exceeds 85 dB(A). The highest level of noise inside the cabin (windows closed) when operating was 74 dB(A) and the lowest level was 62 dB(A). These levels are far below the level at which hearing impairment may occur. These levels are also below the maximum level of 75 dB(A) recommended in the checklist.

Measured vibration levels (machines no. 1 and no. 2) show that the operators can be exposed to vibrations for at least one 8 hour-shift without exceeding the limit for fatigue and lowering work capacity because of vibrations. Measured vibrations for machine no. 3 (x-, and y-directions) also indicated a low level of vibrations. The overall impression was that the ergonomics were rather good.

4.3 Damage

The frequency of remaining trees damaged by harvesting in thinning was 5.5 % with machine no. 2 and less than 1 % when harvesting with machine no. 3. Most damage on remaining trees in the thinned stands was located above stump up to a height of 2 m, and was mostly less than 15 cm². The size of damage and location on the trees appear in Table 9. The machines moved almost entirely on harvesting residues and hence no visible ground damage was observed.

Fröding (1992) found that the damage to remaining trees in thinning was mainly situated between the stump and up to 1.5 m height on the stems when harvesting with single-grip harvesters. Of remaining trees 5.9 % were damaged when harvesting with single-grip harvester (trees damaged when forwarding was included). Of the remaining trees 0.2 % were damaged when loading, and 2.2 % were damaged when driving (harvesting and forwarding). Cause of damage was not identified for 0.2 %.

Table 9. Remaining trees damaged in thinning. Distribution (in percent) by location and size.

Location of damage	Size of damage < 15 cm²	15–100 cm²	> 100 cm²
Root or stump	–	–	–
From stump – 0.5 m			
over stump	30	21	2
Stem	26	11	10

4.4 Follow-up Study

Total time in harvesting during the period studied was 4 361 hours operating time. Productivity during the study period for machine no. 2 was 98 trees per hour basic time in clear cutting of tree sections, and 96 trees per hour basic time when cut-to-length. Productivity in thinning was 68 trees per hour basic time. Mean stem volume was 0.071 m³ (clear cutting, tree sections), 0.070 m³ (clear cutting, cut-to-length), and 0.084 m³ (thinning, cut-to-length), respectively.

Service time was 6.6 %, and repair time was 12.3 % of operating time. About one third of repair time was on the base machine. Technical degree of utilization was 0.811. Fuel consumption was 10.8 litres per hour basic time in thinning. According to productivity fuel consumption was 1.86 litres per m³. Fuel consumption in clear cutting was 11.1 litres per hour basic time. According to productivity fuel consumption was 1.88 litres per m³.

Productivity for single-grip harvesters in large scale forestry in Sweden 1990 (Hellström and Westerberg 1991) was approximately 30–40 m³ total volume over bark (incl. top) per 8-hour shift in thinning. If the technical degree of utilization was 0.85 and the volume of tops was 5 %, productivity was 4.2–5.6 m³ per hour basic time, which was about the same as for the backhoe loader-based harvester in the follow-up study. The follow-up cited does not tell anything about size of trees and machines. Fuel consumption for three types of two-grip harvesters in clear cutting (Bengtsson 1985) was, in a study of 9 machines, 20.9., 16.1, and 15.3 litres per hour effective time, respectively. Fuel consumption can also be expressed as 0.26, 0.23, and 0.18 litres per tree, compared to 0.16 litres per tree in thinning and 0.11 litres per tree in clear cutting (small trees) for the backhoe loader based harvester.

5 Discussion

All test variables for time per work cycle were tested in the regression analyses, individually or combined. Tree volume and in one study (clear cutting) the number of logs per tree proved to be the best descriptors of time. The models shown are simple and easy to use. R-square is sometimes low, but can probably be raised with the help of other variables than those measured in this study, such as distance of tree from machine and/or strip road, and operator. The "operator factor" has proved to vary widely in forestry and is of great importance (Gjedtjernet 1989, Pettersson 1968). R-square is especially low for machine no. 2 where the operator was less experienced. "Operator no. 2" also had to process some trees from the top (middle zone) which probably contributed to a low R-square. It is likely that more training will increase R-square, especially for machine no. 2. When comparing different harvesting machines one must keep in mind that manual felling of middle zone trees accounts for extra cost. In this case manual felling of middle zone trees is done for machine no. 2. Manual felling of middle zone trees is also done for the machines Valmet 901 and Rottne Rapid (Table 7).

However, it is rather common in time studies of harvesting operations that disturbance during some part of the work cycle leads to a large deviation from the time expected when production is not disturbed. One example is that time for delimbing a small tree could be high if one or more of the branches bend between the stem and the delimbing knives and is difficult to get cut off. Therefore, in future studies it could be of interest to pay extra attention to extreme values. Studies in the future should also examine more carefully the effects of different stand conditions.

The number of trees in the time studies is rather small, but together they give a good indication about productivity. Productivity in the time studies was at about the same level as that of Nordic custom-built forest machines. High productivity was also confirmed in the follow-up study. In addition, the technical degree of utilization was at a rather high level.

Ergonomic factors for the backhoe loader-based forest machines were, in total, judged to be equivalent to ergonomic factors for the two wheeled Nordic machines FMG 250 E and Skogsjan/LL 487 which were studied by Gellerstedt (1989, 1990). Some factors are a little better, some factors are a little poorer and some factors are at the same level. Especially high ratings were given important factors such as levels of noise and of vibrations.

Mean ground pressure for the studied backhoe loader-based harvesters was rather low, but higher than for FMG 0470 (Myhrman et al. 1990) and Ponsse HS 15e (Granlund et al. 1992). Mean ground pressures are calculated for ideal conditions. That means that the machines are standing still and all wheels are in total contact with the ground. It should also be noted that ground pressure is dependent on several factors. These factors can vary between machines of the same make e.g. length of crane, mass of attachments, extra mass due to modification, and wheels. Ground pressures shown for the studied machines are valid for those, and for machines with identical attachments and modifications. Wästerlund (1992) considers that machines with a mass of 30 tons should be avoided on many sites in order to reduce soil compaction in depth. And he continues: *'A 5–10 tonnes machine with good tyres and rather low inflation pressure could come down to a real ground pressure of 60–70 kPa which may be an acceptable level of soil disturbance'*. Ground pressure during work also varies by dynamic effects.

Terrain mobility was good, primarily due to the articulated frame steering and a relatively short wheel base for all machines (Table 1). Furthermore, the possibilities for better adaptation between the ground and the wheels of the machines no. 2 and no. 3 by having the cabin section and the engine section pivot against each other contributes to good terrain mobility. Ground clearance of the machines could be better.

A standardized base machine which can function as carrier for attachments for different types of work increases machine utilization which leads to a reduced cost. Machine flexibility also increases. One disadvantage is the increased demands for operators to be skilled in the different types of work.

The transportation cost, to the next logging site, for backhoe loader-based logging machines is the same as for purpose-built logging machines if they are used only for one operation. If they are also used for other operations at the same time the over-all transportation cost is reduced. These base machines then function as attachment carriers instead of specialized machines.

The level of investment is also quite low. The price for Huddig 760 M4/Tufab GS 302 is approximately 1.2 million SEK. The price for a purpose built wheeled single grip harvester of the same size is approximately 1.5 million SEK.

Thus, the conclusion is that the machines studied had good productivity and reliability, rather good ergonomics and a low cost level. Over the long term a forest company can, with the right planning, obtain a high yearly machine use and reduce costs.

References

An ergonomic checklist for forestry machinery. 1990. The National Institute of Occupational Health, The Forest Operations Institute of Sweden & Swedish University of Agricultural Sciences, Kista, Sweden. Manual. 43 p. ISBN 91-7614-072-5.

Bengtsson, P. 1985. Bränsleförbrukning vid avverkning med skördare. Forskningsstiftelsen Skogsarbeten, Spånga, Sweden, Resultat 10. 4 p. ISSN 0280-1884.

Evanson, T. & Riddle, A. 1994. Evaluation of a Waratah hydraulic tree harvester model HTH 234. LIRO, New Zealand, Report 19(3). 9 p. ISSN 1171-6932.

Forestry vocabulary. TNC 96. 1994. Sveriges skogsvårdsförbund & Tekniska Nomenklaturcentralen, Solna, Sweden. ISBN 91-7196-096-1. ISSN 0081-573X.

Furuberg Gjedtjernet, A.M. 1989. Timbertransport with tractor in Norwegian forest terrain. Agricultural University of Norway, Department of Forest Operations, Ås, Norway. Doctor Scientiarum Theses 1989:11. (In Norwegian with English summary). ISSN 0802-3220. ISBN 82-575-0086-0.

Fröding, A. 1992. Thinning damage to coniferous stands in Sweden. Swedish University of Agricultural Sciences, Department of Operational Efficiency, Garpenberg, Sweden. Thesis (unpublished). 71 p. (In Swedish with English summary.)

Gellerstedt, S. 1989. Operating conditions in forestry machines. An examination of the single grip harvester FMG 250 E. Swedish University of Agricultural Sciences, Department of Operational Efficiency, Garpenberg, Sweden, Uppsatser och Resultat 158. 45 p. (In Swedish with English summary.) ISSN 0282-2377, ISBN 91-576-3840-3.

— 1990. Operating conditions in forestry machines. The single grip harvester Skogsjan/LL 487. Swedish University of Agricultural Sciences, Department of Operational Efficiency, Garpenberg, Sweden, Research Notes 189. 22 p. (In Swedish with English summary.) ISSN 0282-2377, ISBN 91-576-4229-X.

Granlund, P., Karlsson, L., Landström, M. & Myhrman, D. 1992. Skogsarbeten testar engreppsskördaren Ponsse HS 15e. Forskningsstiftelsen Skogsarbeten, Kista, Sweden, Resultat 3. 4 p. ISSN 0280-1884.

Hellström, C. 1987. Beståndsgående eller stickvägsgående engreppsskördare i förstagallring. Forskningsstiftelsen Skogsarbeten, Spånga, Sweden, Resultat 16. 4 p. ISSN 0280-1884.

— & Westerberg, D. 1991. Prestationer och kostnader 1990 i det storskaliga skogsbruket. Forskningsstiftelsen Skogsarbeten, Kista, Sweden. Resultat 3, 4 pp. ISSN 0280-1884.

Hemphill, D. C. 1986. Shovel-logging. LIRA, New Zealand, Technical Release 8(1). 4 p. ISSN 0111-6711.

Langsford, J. F. 1985. Hydraulic excavators as log loaders. LIRA, New Zealand, Project Report 25. 40 p.

MacDonald, A. J. 1990. A case study of roadside logging in the northern interior of British Columbia. FERIC, Canada, Technical Report 97. 20 p. ISSN 0318-7063.

Myhrman, D., Granlund, P. & Gårdh, R. 1990. Skogsarbeten testar, FMG 0470. Forskningsstiftelsen Skogsarbeten, Kista, Sweden, Resultat 10. 4 p. ISSN 0280-1884.

Pettersson, B. 1968. Extraction of pulpwood by grapple equipped forwarder. Logging Research Foundation, Stockholm, Sweden, Report 1. 21 p. (In Swedish with English summary).

Richardson, R., Swift. E. & Gingras, J.-F. 1991. Comparison of roadside and in-stand delimbing: a case study of two harvesting systems. FERIC, Canada, Special Report 76. 30 p. ISSN 0381-7733.

Sondell, J. 1975. Volvo BM Kvistare-kapare Tvigg. Forskningsstiftelsen Skogsarbeten, Stockholm, Sweden, Teknik 11. 6 p.

Spencer, J.B. 1990. Trial of JCB 814S/OSA 746 grapple harvester. Work Study Branch, Forestry Commission, Great Britain, Report 25. 32 p.

SS-ISO 2631. 1982. Vibration and shock-guide for the evaluation of human exposure to whole-body vibration. Svenska Elektriska Kommissionen, Kista, Sweden. 16 p.

Terrain classification system for forestry work. 1992. Forest Operations Institute of Sweden, Kista, Sweden. Manual. 28 p. ISBN 91-7614-078-4.

Wästerlund, I. 1992. Extent and causes of site damage due to forestry traffic. Scandinavian Journal of Forest Research 7: 135–142. ISSN 0282-7581.

Total of 22 references

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