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PROJECT REPORT

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FACTORS AFFECTING LOGMAKING FROM THE CAB
A Study of Mechanised Logmakers

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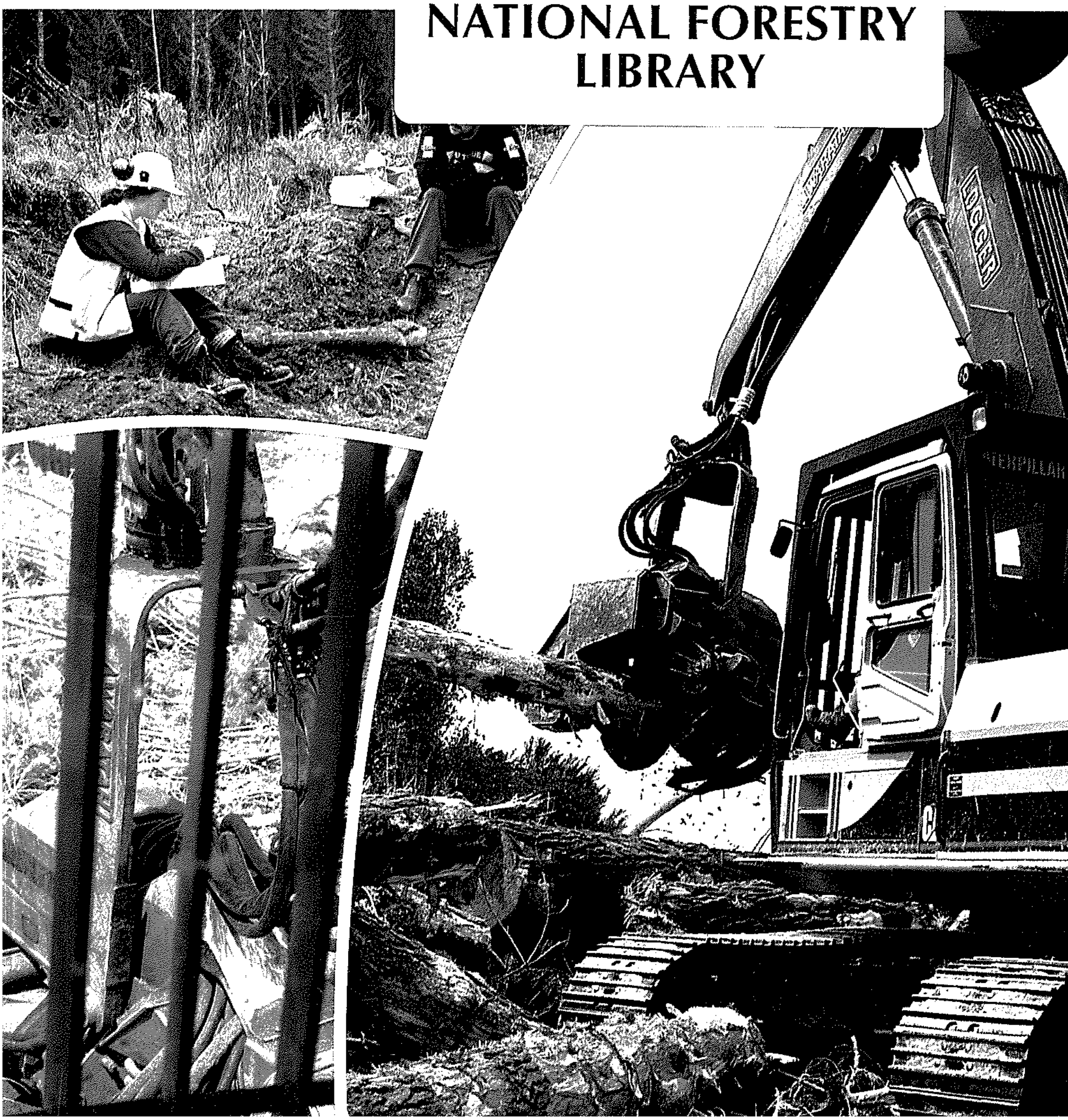

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

A survey was carried out with 23 operators of excavator-based mechanised single-grip processors who were cutting to length (logmaking) in New Zealand clearfell harvesting operations. The study aimed to identify which features of the cab environment, operator controls, and work organisation, may be reducing operator performance through the inability of the logmaker to effectively process stems into logs. Past research has shown that poor operator performance results in reduced vigilance, decreased concentration, increased rate of error and reduced productivity. All these are factors are essential to the role of the logmaker, who plays a crucial role in recovering maximum value from the stem when processing. By identifying those features which may be contributing to reduced levels of efficiency, improvements can be made to both the machine and the work environment. The result being a more favourable work environment for the mechanised operator, which in turn improves operator sustainability, productivity and profitability.

RECOMMENDATIONS

Results from the study show the following need to be addressed to improve the working environment of the operator, leading to improved and efficient logmaking performance.

MACHINE

-Development of stem feature recognition aids
-Improved visibility through the front cab guarding
-Improved windscreen cleaning facility
-Improved sunshading of cab
-Brighter computer displays with larger screens and numbers
-Altered joysticks and keypads
-Seat adjustment to each specific operator

WORK ENVIRONMENT

-Limit shift length to less than four hours continuous
-Use of frequent short breaks
-Better training and follow-up
-Improve communication between processor operator and rest of crew operations
-Education of operator about Occupational Overuse Syndrome (OOS)
-Adopt a system which minimises machine interference on the skid

FACTORS AFFECTING LOGMAKING FROM THE CAB

INTRODUCTION

Forest harvesting in New Zealand is increasingly being carried out by mechanised processors. Operating a mechanised processor is a sustained complex task which requires continual and rapid decision making. The critical stage in value recovery has always been at logmaking, and with mechanisation this task is now carried out from the confines of a cab.

Operators are often expected to concentrate for extended periods (nine to 10 hours), yet the average attention span of most humans is approximately 40 minutes. Increased demands on perception, concentration and motor control of the hands, have been shown to increase overall physical fatigue, resulting in reduced levels of concentration and vigilance. The effect is a reduced ability to detect log features and process information, reducing the ability of the logmaker to make optimal logmaking decisions.

By identifying features which are hindering the mechanised logmaker's performance, improvements can be made to mitigate problems and improve the environment and performance of the mechanised logmaker, who is a critical component in a complex technical system.

BACKGROUND

Much has been documented on the importance of correct ergonomic cab design to optimise the performance of the operator (Scherman, 1988, Pierrot, 1988, Hansson, 1990), leading to substantial improvements to cab design to better fit the cab to the operator. Tyson (1994) observed that poor ergonomic design of the operator's cab has contributed to back, neck and shoulder injuries, slips and falls, cumulative trauma disorders of the hand and wrist, and even tragic accidents due to poor visibility. He concluded that to reduce operator injury from mechanised equipment, and maximise machine productivity, there must be an optimal match between the operator and the operator compartment. David (1979) also reported that an imbalance between work place, equipment and work comfort was responsible for developing fatigue in operators. Tyson (1996) went further and listed fatigue, boredom, job dissatisfaction, negative stress, absence/sickness, reduced productivity, reduced quality, increased errors, and equipment replacement, as symptoms of poor ergonomic design. These comments supported previous findings that poor cab adaptation increased physical and mental loads on the operator, thereby reducing operational efficiency (Souza et al, 1981; Toyokawa et al, 1981). The consequences of poor ergonomic design are summarised in Figure 1.

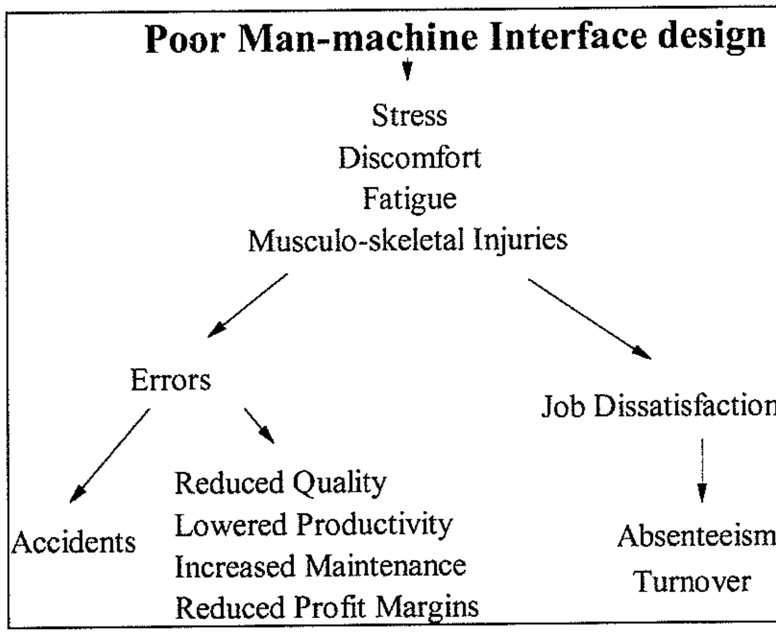

Figure 1 - The human consequences of poor interface design

Physical fatigue reduces the ability to concentrate or focus on mental tasks, and tired workers have shown to have a higher error potential, leading to lost production, equipment damage, less effective work output and increased rate of injury (Anon, 1994). Grandjean (1988) commented on the increased level of physical fatigue likely to be experienced with any job requiring rapid and precise eye movements, as heavier demands are placed on perception, concentration, and motor-control of the hands. This supported Ring's (1984) finding that prolonged mental effort causes mental fatigue. Both Grandjean and Ring list symptoms of visual and mental fatigue as burning and reddened eyes, double vision, headaches, reduced visual acuity, sensitivity to contrast and speed of perception, reduced intellectual capacity, diminished power of concentration, and reduced alertness.

Mental fatigue can impact on work through lowered productivity, reduced quality, and an increased rate of accidents (Ring, 1984), absenteeism and turnover (Gellerstedt, 1997). In a health survey of feller-buncher operators (Byers, 1997), many operators indicated they were exhibiting symptoms of mental fatigue by the end of their shift.

Mechanisation has reduced the physical demands on workers and improved the safety of harvesting operations, by removing the operator from many of the hazards of the work face. Past research has shown machine operators to have less than 15 % of the accidents suffered by chainsaw operators in harvesting the same amount of timber (Poschen, 1993). However, there is concern that a new type of injury is being substituted for the traditional harvesting injuries, resulting from the long, repetitive and often monotonous hours of manipulating the controls (Poschen, 1993).

Static work conditions keep bloodflow at a minimum, depriving the brain of oxygen. This creates fatigue levels five times higher than dynamic work, and muscular stiffness from lactic acid build-up (David, 1979; Holmes, 1996). In Scandinavia, despite years of substantial ergonomic improvements to machines, a significant number of harvesting machine operators continued to exhibit subjective musculoskeletal complaints (Erikson, 1995, Hansson, 1990). Medical research into repetitive strain-type injuries (RSI) has shown often highly complex underlying causal factors, requiring a variety of technological, personal and organisational measures to safeguard operators (Erikson, 1995). Technical improvements designed to reduce the intensity of work involved in operating controls, physical exercises to promote circulation, a relaxed working technique, and job rotation, are all measures which form a comprehensive RSI prevention program (Erikson, 1995; Johanssen et al., 1996). These same measures also have the capacity to improve operator performance and prevent turnover and absenteeism (Gellerstedt, 1997). Occupational Overuse Syndrome (OOS) is a term commonly applied to injuries which have developed from an ongoing exposure to fatigue and strain that exceed the capacity of the individual's recovery process. It incorporates the mechanical, repetitive motion which is characteristic of RSI, with a complexity of psychosocial and personal factors such as stress and personality type (Wilson, 1998).

Operating forest equipment places new demands on the forest worker. Repetition, short work cycles, and a high demand for sustained concentration can increase job monotony and lead to worker overload and lack of job satisfaction. High production targets coupled with a high proportion of static work make the job mentally strenuous. This combination of risk factors has been shown to be linked to musculoskeletal problems like OOS (Wilson, 1998). Human beings are inherently adaptable, but according to Webb (1982), that adaptation has some cost, such as reduced productivity, increased error or job dissatisfaction. Although productivity levels may apparently remain at a consistent level, quality has been shown to decrease (Grandjean, 1988). The ability to adapt means a machine operator may have become so used to an environment that they are eventually unaware of factors which make their job harder to carry out. The new operator may have the highest awareness of any ergonomic problems, but they soon adapt to the environment until it becomes accepted as normal. While experienced operators may not even be aware of excessive demands placed upon them, improvements in equipment design, work environment or operational procedures might leave them significantly less stressed, more productive and less accident prone (Webb, 1982).

The benefit of correct cab design is shown through increased levels of quality, stemming from an improvement in the performance of the operator.

ACKNOWLEDGMENTS

Liro Limited would like to thank all those machine operators who provided their time and experience to assist with the study, and the harvesting contractors who allowed us onto their operations. Thanks also to Jules Larsen of Waratah Forestry Equipment Limited for assisting with the study.

OBJECTIVE OF STUDY

To identify those factors which have the capacity to affect the operator's ability to logmake, so that improvements can be made to operating equipment and the work environment.

Figure 2 - Processing stems into logs

METHOD

A questionnaire was presented as a structured interview, to operators of excavator-based processors, who were cutting to length (logmaking) in mechanised operations. The questionnaire covered such things as logmaking experience in both motor-manual and mechanised operations, what training operators had received for their job, and their usual work shift patterns. The operators were also asked to comment on features of the cab, instruments and skid organisation, which they thought had an impact on the job of processing.

The questionnaire (Appendix 1) was completed by 23 processor operators working in 12 mechanised harvesting operations throughout the Auckland, central North Island, Hawke's Bay and Nelson regions of New Zealand. This represents 86% (12/14) of all harvesting crews who were using an excavator-based processor to cut to length at the time of the study. Those not interviewed were either not working at the time of the survey (due to changes in the forest company contract structure) or had been shifted into another crop where they were not logmaking.

.RESULTS AND DISCUSSION

OPERATIONAL

MAKE OF BASE MACHINE

Caterpillar excavators were the most commonly used base machine to which a processor head had been retro-fitted (Figure 3). Each of the machines had been fitted with Roll-Over Protection Structures and Falling-Object Protection Structures (ROPS and FOPS).

OPERATIONAL SYSTEM

Most (70%) of the operators were cutting to length in a ground-based system rather than cable. Hot-deck truck loadout systems were used in 70% of the crews visited. Unlike cold-deck truck loadouts, operators in hot-deck systems had to contend with logging trucks in addition to other machinery and crew movements on the skid. Discussion with the operators following the survey indicated a cold-deck system was better to work in, as full concentration could be applied to the job without the distraction of having to watch or wait for other machinery.

DEFINITION: Mechanised logmaking includes the tasks of delimbing the stem and cutting to length according to a set of pre-determined log types and stem features.

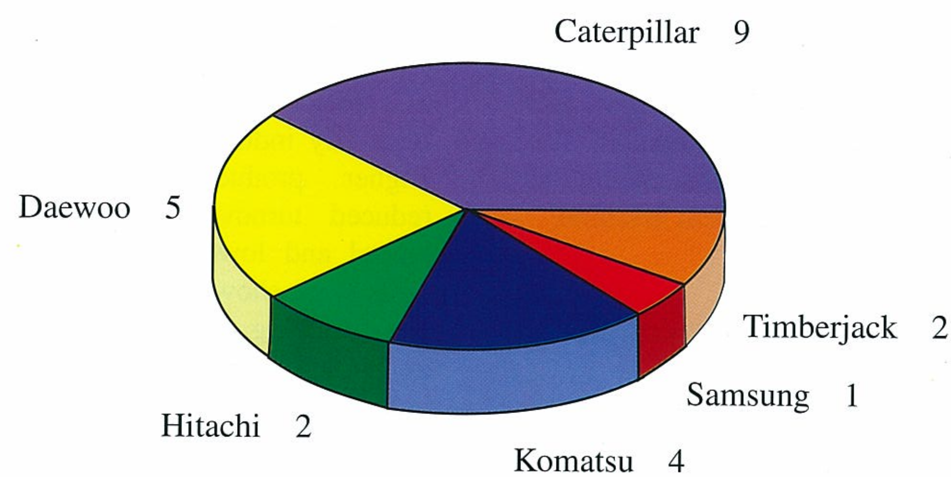

Figure 3 - Make of carrier base machines (n=23)

FREQUENCY OF MACHINE RECALIBRATION

Recalibration of the length and diameter measurements on the processor head was commonly carried out on a fortnightly or monthly basis, although two operators said their machine had never been recalibrated. Recalibration was usually carried out by the operator or contractor (20%). Monthly recalibration of the length and diameter measurements is recommended by the manufacturing company.

Recalibration took 21 minutes on average to carry out. The most common reply was 10 to 15 minutes (10 responses).

TRAINING

LOGGING EXPERIENCE

The operators had spent from one to 21 years working in motor-manual logging operations, and from three months to six years in a mechanised operation. Although the average for motor-manual was nine years (± 6.9), the variation in years reported and number of responses make the median of seven years a better indication of the average time spent logging in a motor-manual operation. This can be compared with the average of three years (± 1.4) (median three years) that the operators had spent working in a mechanised crew. On average, the operators had spent more time in a motor-manual operation than in a mechanised crew. This suggests that operators are transferring from motor-manual operations to mechanised, rather than being sourced from other industries or polytechnic training courses. In a previous study of the forest workforce, the median time spent working in a logging operation was six years (Gibson, 1994).

Figure 4 - Interviewing mechanised logmaker during meal break

LOGMAKING EXPERIENCE

Most of the operators (78%) said they had been a logmaker prior to operating their machine. Logging experience was four years average in a motor-manual crew, and two years in a mechanised operation. The operators had spent from three months to six years operating their current machine.

PREVIOUS TRAINING FOR MECHANISED LOGMAKING

The operators were asked whether they had received any training for mechanised logmaking. A significant number (78%) said they had. In 47% of cases this had been from the supplier of the processor head (Figure 5).

Currently there is little formal training available in New Zealand for operators of mechanised processing equipment. In 1988, the Forest Industry Training and Educational Council (FITEC) was in the process of registering units of learning toward a National Mechanisation Certificate. This contrasts with Scandinavia, where specialised courses exist for training mechanised operators, and there is greater emphasis on operator selection. In Australia, potential employees are screened through a dexterity assessment on a simulator, and attend a three day induction course (Anon, 1990). Higher productivity, less downtime, reduced turnover, an improved safety record and lower owning and operating costs were shown to be the benefits from this training. Additional benefits of machine operator training have been identified as a faster rate of productivity in a shorter time frame than from an untrained operator, less machine damage, lower site damage, less machine overturning and reduced operator injuries including OOS (Parker et al., 1996; Sullman and Evanson, 1998). In Scandinavia, training machine operators is seen as an indispensable additional investment because repairs and downtime are very expensive (Johansson et al., 1996). While ergonomic principles are designed to fit the machine to the man, Webb (1982) identified correct selection and training as a complementary approach (i.e. fitting the man to the machine).

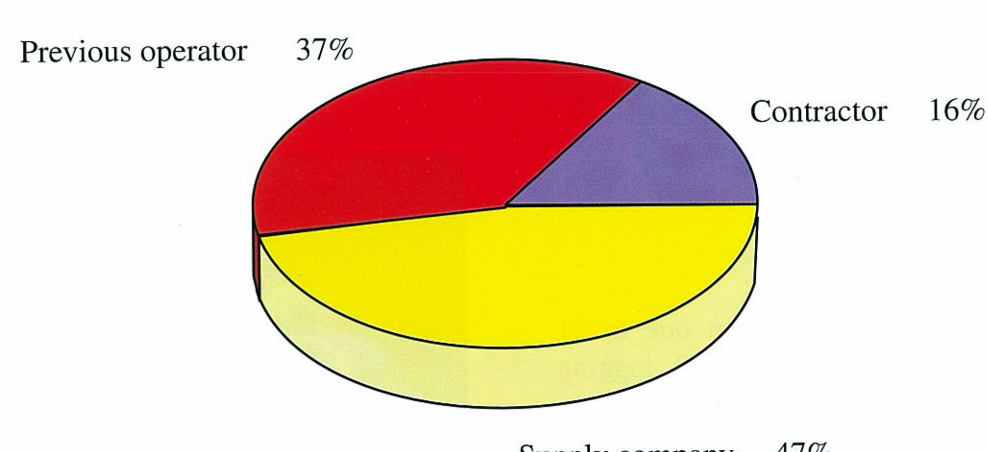

Figure 5 - Sources of training for mechanised logmakers

Table 1 - What was covered in your training?

What did the training cover?	n	%
Use of controls in cab	17	36
Use and interpretation of logmaking software	13	28
Recognition of stem defects from a distance	8	17
Recognition of knot size from a distance	7	15
Motor manual logmaking course	2	4

WHAT DID THE TRAINING COVER?

A range of options were provided to the operators to identify what the training had covered. All except two indicated a range of options, which have been summarised in Table 1.

The most common combination of training reported was in the use of the controls and the interpretation and use of the processor software (64%). While this training is suited to an operator with previous logmaking experience, it would not be suitable to a newcomer, as it fails to address logmaking in terms of stem feature recognition. Only 36% of the training (shaded) was actually related to logmaking. In most cases (60%), the training had been a one-off training session lasting up to a week.

PREFERRED TYPE OF TRAINING

A number of operators (64%) thought their job would have been easier to carry out if they had received more training prior to starting the job.

A selection of options for training was offered to the operators for comment. A specialised logmaking course for machine operators, and one-to-one training were the preferred choices for training (both 39% of replies). Working with an auditor was seen as a useful option by 13% of the operators, and training workshops were least preferred at 9%. As there are currently no specialised logmaking courses for machine operators, there is an opportunity for a training organisation to develop this option.

The operators verbatim comments on training are ranked in order of preference (Table 2).

Table 2 - Operator's comments on training

(1) Should be a motor-manual logmaker before logmaking on machine
(1) Use audits to help operator
(1) Training provided as needed, eg advances in machines, updates by factory staff
(2) Daily training for 2 weeks, then weekly update
(2) Training on how to read sweep
(2) Simulator for hand-eye coordination, joysticks and head operation
(2) In first month of starting, training on hydraulics and break down fault finding
(2) Off job logmaker course initially, on-job to follow. Outside of production situation

MECHANISED LOGMAKING

NUMBER OF LOG GRADES

The number of different log grades cut ranged from three to 14; most were cutting six to 10 different grades (Figure 6).

In a previous study on a motor-manual operation, cutting more than 10 log grades increased log-maker error and the number of out-of-spec logs (Parker et al., 1995). The error margin expected from higher numbers of log grades may be compounded by increased error associated with poor work environment, and the associated loss in quality.

Eleven of the surveyed operators said they were audited on their logmaking, but only four of this group said they had worked with the auditor to find out where any problems lay. Working with the auditor would provide the operator with the opportunity to improve their skills, from learning where wrong decisions have been made. In many mechanised harvesting operations there is already a requirement by the company for a quality check to be carried out on all logs cut from mechanised operations. However, audits can only assist the operator when they are carried out on processed logs prior to any additional crew quality check being made.

MECHANISED LOGMAKING SKILLS

The operators were asked which stem features they needed to see from the cab to make a log. Features identified included: Knots, stem diameters, roundness, splits, sweep, damage, rot, and sapstain. Most of the operators said they needed to see a number of different stem features to logmake, several of which were currently not easy to see from the cab (Figure 7).

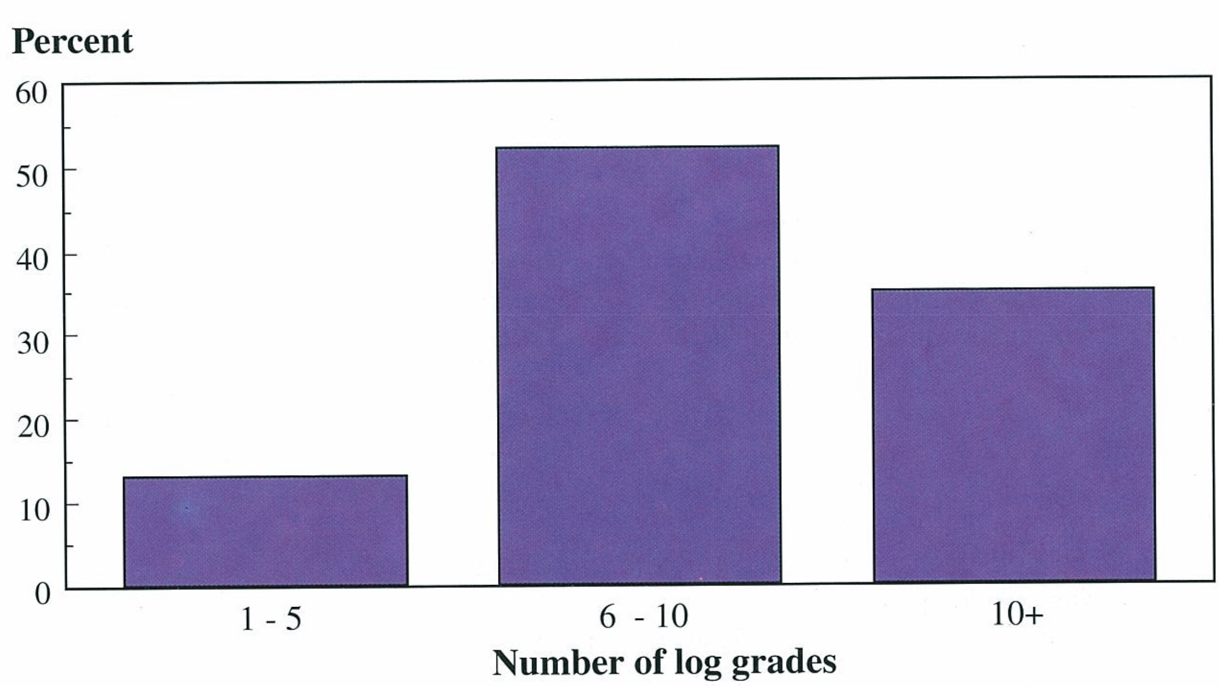

Figure 6 - Number of log grades cut

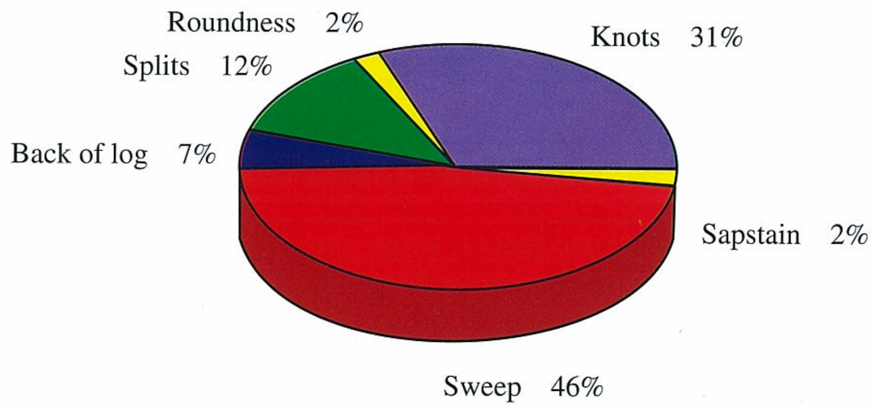

Figure 7 - Which stem features are not easy to see?

Sweep

Sweep was identified as the most difficult feature to see. In motor-manual operations, sweep is measured by placing a tape between the two log ends, and taking the distance that the centre of the log deviates from the line of tape (LFITB, 1994). The flexible nature of radiata pine makes sweep a difficult feature to identify for single-grip processor operators. When a full stem is picked up in the processor by the head, the subsequent flexing of the stem hides the sweep feature. Comments from some operators indicate that they circumvent this problem by cutting shorter length logs. Other types of processor (Flat Deck and Stroke) have long, straight features (the flat bed and the boom) which can be used by the operator as a reference point to ascertain sweep. Single-grip processors observed in this study differ from the flat bed and stroke designs, as they locate the operator at right angles to the stem, and provide no straight feature to use as a reference point for measuring sweep.

Knot Size

Another stem feature difficult to see from the cab was knot size. Mechanised logmaking differs from motor-manual, where the logmaker works close to the stem and can clearly see knot size. With mechanised logmaking, distance from the stem is a hindrance to stem feature recognition.

Length

Slippage of the measuring wheel, especially when measuring over knots and stubs, was reported as a problem by all operators who took the opportunity to comment.

Stem Features

A range of stem features caused a problem when processing, which operators commented on (Table 3 - in order of ranking).

Table 3 - Which stem features cause a problem when mechanised logmaking?

Bark	Measuring wheel jumps on nodes and thick bark
	Thick bark clogs measuring wheel, causes slippage
	Diameter measure is from over bark (log specification taken from inside)
	Measuring wheel slides on slippery log where bark has come off
Forking	Double handling forked trees slows operation
	Wheel slips
	Have to drop stem and process twice - two lengths to process
	Wheel stops on swelling giving false idea of diameter
	Need to make more cuts with forks
Spike Knots	Measuring wheel jumps/slips on swellings and knots
	In rough blocks, so many spikes you only see 50% of them
	Size of spike knot
	Miss spikes if on rear of stem
	Spikes don't trim well
Nodal swelling	Measuring wheel jumps on nodal swellings
	Hard to minimise cut face size with nodal swelling
	Can't trim big nodal swelling properly
	Nodal swelling makes diameter measurement inaccurate
	Size of swelling
	Wheel rides over swelling giving longer length than actual, same for coathangers
	Knives sometimes dig into swelling
Other	Insufficient diameters in machine to cover whole field
	Can't get head to move properly around bark encased knots

THE HUMAN FACTOR

LENGTH OF WORK DAY

Nine or ten hour shifts on the machine were common (45%). However, there were a wide range of shift lengths, from two hours to 13 hours, including breaks (Figure 8). Many (81%) were the sole operator, processing the entire work day. Due to the potential for increased fatigue levels associated with long periods of mentally demanding and repetitive but sedentary work, it is important for the operator to get off the machine during the work shift to introduce movement into the muscles and assist the body in removing fatigue-inducing waste build-up (Byers, 1996). Getting off the machine also stimulates the mind, and reduces the cumulative effect of mental fatigue (inattention, reduced concentration and vigilance), which is a critical factor in lost revenue due to increased rate of error and sub-optimal logmaking.

Seventy-eight percent worked eight hours or longer. Operators working shifts of five hours or less were often filling in for the main operator. When not operating the machine they carried out another job, often operating the loader. The operators commonly began their shift at 6 am or 7 am. One operator started his shift at 4 am and worked through until 1 pm, at which time another operator took over and the first operator went home. The longest time worked continuously was 13 hours. The level of mental fatigue experienced by this operator would be considerable. This operator started at 6.30 am and worked through until 7.30 pm. Gellerstedt (1997) stated that working at an early or late hour of the day is more fatiguing and requires more rest breaks to remain healthy.

OCCUPATIONAL OVERUSE SYNDROME

The term "Occupational Overuse Syndrome" (OOS) is often confused with "Repetitive Strain Injury" (RSI). A repetitive strain injury (RSI) is a mechanical injury or condition that generally develops over time in response to repeated exposure to three major risk factors: awkward posture, excessive force and high rates of repetition. OOS is a collective term for a range of conditions characterised by pain or discomfort in the muscles, tendons and other tissues, which is thought to be brought on by the cumulative effect of static or repetitive workload on the body (Macfie, 1995). OOS encompasses the mechanical factor of RSI, with psychosocial and personal factors (stress, job dissatisfaction, personality type) (Wilson, 1998). Most of the operators (78%) had heard of either RSI or OOS, and half (55%) of this group said they were aware of prevention techniques. Micropauses can be effective in reducing the cumulative build-up of waste in the muscles caused by repetitive tasks. It is of concern that only 17% (four) of the operators had heard about micropauses, as this is a technique commonly promoted in other industries to reduce the risk of OOS occurring (Byers, 1996). Of even more concern, is that only two of the four operators who knew about micropauses actually used them. The potential for musculoskeletal injury in mechanised operators is high, as they are exposed to a high number of risk factors in their work (David, 1979; Hansson, 1990; Wilson, 1994; Erikson, 1995; Holmes, 1996; Wilson, 1998).

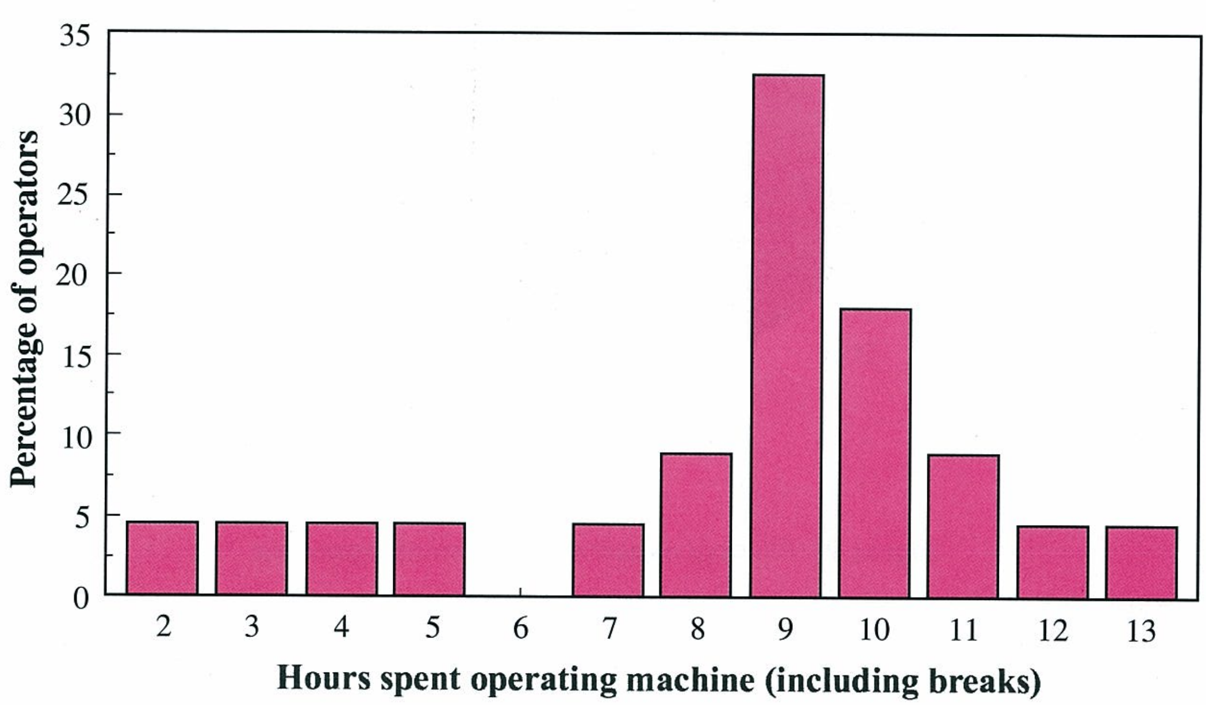

Figure 8 - Shift lengths of operators

SYMPTOMS OF FATIGUE

All of the operators experienced some form of physical discomfort when logmaking from the cab. Drowsiness, sore eyes and various body aches were commonly reported (Figure 9). The types of body aches reported included the thumb joint, sore elbows, the last two digits of the hand, the hands and neck, top of the back, tightness between the thumb and forefinger, sore wrists, and numb posterior.

Considering the length of time operators were spending on the machine, and the characteristic nature of the job (high repetition, sedentary, requiring constant attention), these symptoms are to be expected and predictable. Rest breaks are important to reduce the cumulative effects of physical and mental fatigue (Kopardekar et al., 1994); Boucsein, 1996; Henning et al., 1997).

Sore eyes and headaches

Sore eyes were attributed to eyestrain (two operators) and glare from the sun (two operators). Airconditioning and cigarette smoke were also mentioned. Four operators who experienced headaches said they were caused from the amount of concentration required to process. While this is the operator's personal opinion, these findings are supported by Byers (1997) study which found machine operators were reporting signs of visual strain.

Drowsiness

Shift length was one of the main reasons operators were feeling drowsy (Figure 10). Shorter shifts would reduce this problem and result in a more alert and productive operator.

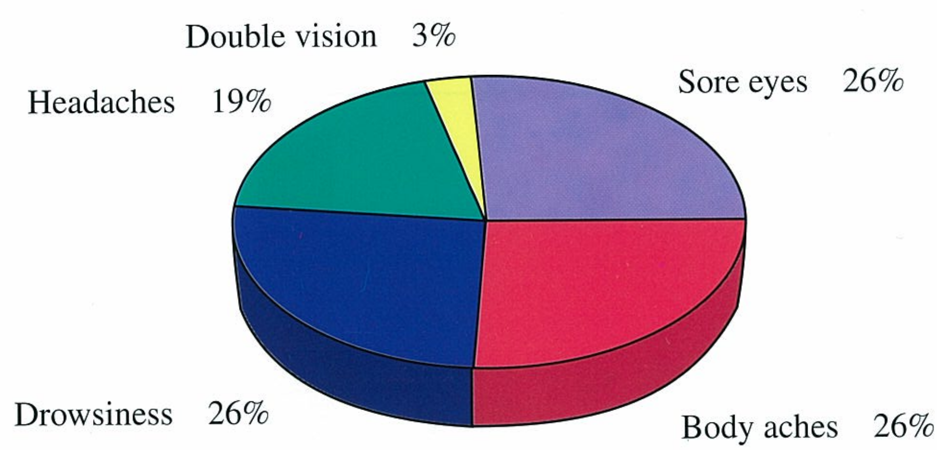

Figure 9 - Physical impact of mechanised logmaking

A *micropause* is a brief break for relaxation (e.g, 5 to 10 seconds complete relaxation every 3 minutes.

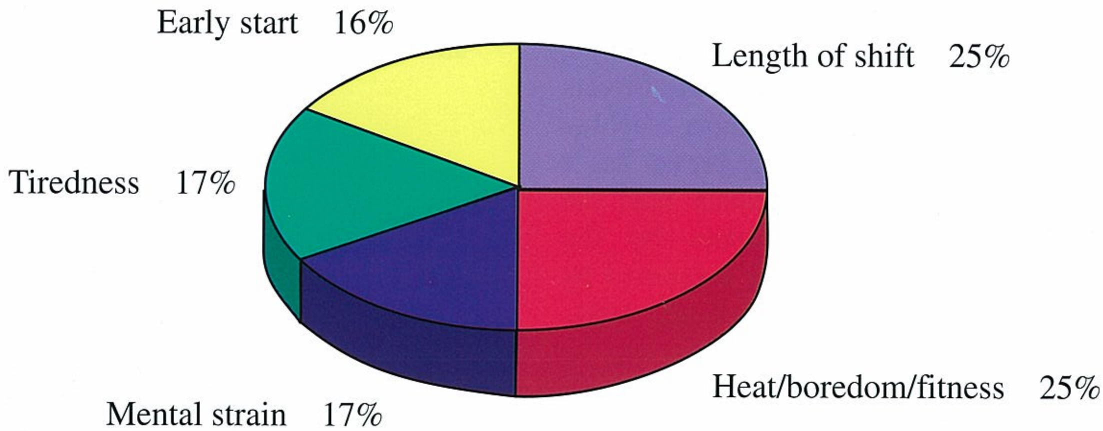

Figure 10 - What contributed to your drowsiness?

Body part discomfort

Sitting for extended periods in one position and using the controls caused body part discomfort (Figure 11), which the operators attributed to a variety of factors (Table 4). Regular breaks where the operator gets off the machine and undertakes some form of physical activity would reduce aches. Introducing micropauses into the shift is another way to reduce the severity of these problems (Darby, 1998).

Table 4 - Operator comments on causes of body aches

Bodyaches
angle the machine sitting on
numb buttocks from no rest breaks
top of back sore from seat
wrists sore from using joysticks
not fit for job
using the controls
not moving head around
sitting all day in one position
tiredness
using top of joystick

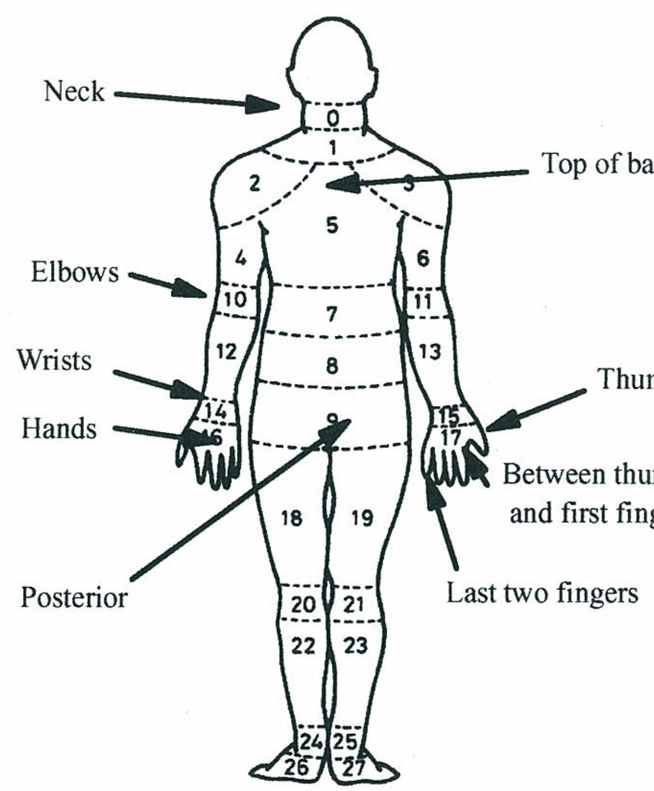

Figure 11 - Body part discomfort experienced by operators

These results support previous research which showed that repetitive tasks, machine-based work pace, long hours, and a stressful environment, were all contributors to fatigue (Wilson, 1994; Grandjean, 1988; Ring, 1984). These findings are also consistent with those from a study of feller-buncher operators (Byers, 1997). Although Byers (1997) subjects were operating feller-bunchers, the similarity in symptoms of fatigue between the current study and that of Byers (1997) suggests that operating a machine for extended hours with few breaks has a greater impact on performance than the actual task being undertaken by the operator. These findings are supported by international literature (Grandjean, 1988; Ring, 1984)

OPERATOR'S SEAT

Some of the physical symptoms reported by the operators may have been related to the seat in the machine they were operating. The operator's seat can play a large part in determining the level of fatigue experienced by the operator. A seat which absorbs shock loadings, machine vibration, and fits the operator's body comfortably, will place less stress on the body and reduce fatigue levels over the day. Gaskin et al. (1988), identified a significant number of logging machine operators in New Zealand who were experiencing back problems. To isolate possible causes, Gaskin and Smith (1989) subsequently evaluated skidders commonly used in New Zealand, and found most had poor seating. In a study of seat adjustments of Finnish machine operators, a high percentage said they experienced neck-shoulder pains and low back pain, even though most considered their seats good for condition, comfort and seat adjustment (Perkiö-Mäkelä and Riihimäki, 1995). Subsequent developments have improved machine seating (Figure 12). However, information needs to be disseminated about how to adjust the seat to fit the operator. While Hansson (1990) found no significant difference in muscular activity between work with and without an armrest, Attebrant (1998) reported numerous studies which demonstrated the load-reducing effect of an arm rest. While recognising that a well-fitting seat can dramatically improve the working environment of the operator, it appears that this is only part of the solution in reducing operator fatigue. Getting off the machine is still a critical factor in reducing fatigue.

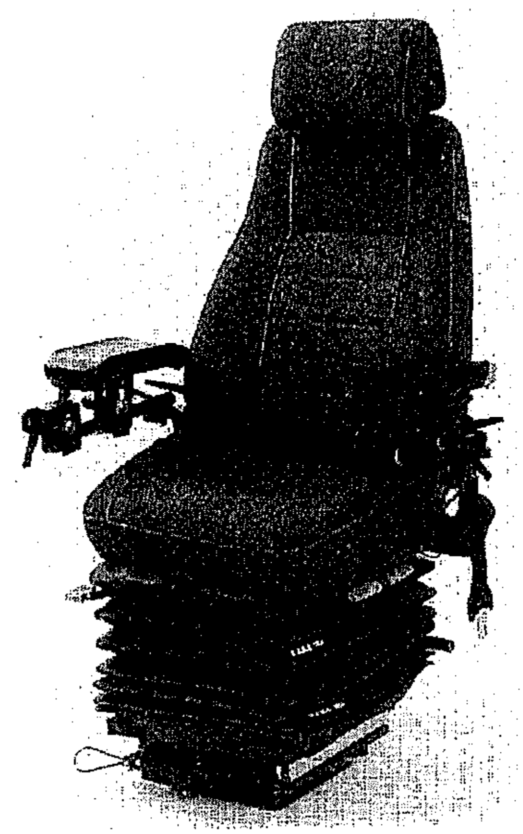

Figure 12 - Operator seat design - 1997

WORK BREAKS

Information was collected on the frequency and duration of any work breaks taken by the operators. Meal breaks included the standard 2 x 30 minute breaks per day, one 30 minute break, one 60 minute break, and 2 x 15 minute breaks (Table 5). Two operators did not stop at all for a meal, but ate either as they worked or at the end of their shift. All but two got off the machine to have their meal break. Getting off the machine is an easy way to introduce movement into the muscle groups, allowing them to remove any damaging waste products from the muscles and reducing the cumulative effects of fatigue. It also provides a break in routine from the job, stimulating the mind and aiding mental recovery.

Meal Break Time and Frequency	Number of Operators
30 minutes x 2	13
30 minutes x 1	4
1 Hour x 1	2
No meal break	2
15 minutes x 2	1
No reply	1

Table 5 - Meal break patterns of mechanised logmakers

Many of these meal break patterns suit manual tasks such as felling. The working heart rate is lowered, and body energy reserves are refuelled, allowing the body a suitable period to recover from physical fatigue. However, operating a processor is different to hard physical work in that is a mentally demanding job which exposes the operator to high levels of mental fatigue (Sullman and Gellerstedt, 1997), but requires low levels of physical effort. As a result, more frequent breaks need to be taken in conjunction with organisational measures such as job rotation to reduce mental strain (Gellerstedt, 1997) and physical workload (Johansson et al., 1996). It is more important to have frequent breaks of a shorter duration in jobs with a high mental workload.

Average time taken over the work day for maintenance was 29 minutes, consisting of three to five minute breaks taken four to seven times a day (usually to tighten the chain), to a full 30 or 60 minute maintenance once a day (usually at the end of the shift). As expected, all operators got out of their machine for this. In addition to meal and maintenance breaks, many of the operators took spontaneous rest breaks consisting of either a five second stop to light a cigarette, two to five minute breaks taken frequently throughout the day, or two 10 minute breaks which the operator used to get off the machine.

Figure 13 - Limitation of vision from protective bars

Table 6 - Operator comments about joysticks

- Could be a better shape
- Shape of joystick doesn't fit hand right
- Metal plate on LHS sticks into hand
- Top button digs into thumbs
- Right hand stick too square to fit in hand comfortably
- Toggles on joysticks would be better angled rather than flat
- Bottom buttons hard to reach
- Joysticks would be better located higher up
- Could be improved
- Likes ones on machine

CARRIER

The operators were asked a range of questions about the operating environment, including the instruments, controls and skid organisation. They were also provided the opportunity to make additional comments on any factors they thought were affecting their job.

MACHINE CONTROLS

The machine controls are the interface between the operator's decisions and the machine responses, which have the potential to influence production levels and the level of operator efficiency and fatigue (Golsse, 1990). In Sweden, modified machine controls have been associated with reduced levels of tension in muscles (Scherman, 1988). The operators were asked whether there was anything about the controls (joysticks) on their machine that could be improved (Table 6). Most of the operators had used no controls other than those currently on their machine. One operator had used mushroom (flat) controls and thought they were better than the joysticks he was using on the current machine. From the operators' comments, it appears that there is room to improve the fit of the joysticks to the hands of the operators.

A Swedish study of logging machine operators found that work with hand operated controls was intense, accounting for up to 90 to 95% of hand-arm movement during work time (Hansson, 1990). The same study measured finger activity, and found the thumb of the right hand active 50% of work time. Hansson recommended implementing measures to reduce work intensity, including a reduction in the proportion of machine hours worked to reduce muscle loading. This can be achieved through job rotation, shorter work sessions, and more micropauses (Axelsson and Ponten, 1990; Hansson, 1990). In a previous ergonomic evaluation of four common New Zealand excavator bases fitted with a processor head, the controls required large hand and wrist movements (Parker and Gellerstedt, 1998).

Figure 14 -Logmaking buttons and joystick

Figure 15 - Operator field of vision past boom

VISUAL HINDRANCE

In New Zealand, processing heads are usually mounted on a modified excavator base. The hydraulic boom which directs the processing head is to the right of the cab, blocking the operator's vision.

Six operators commented that the boom reduced visibility on the right side of the cab (Figure 15), including one comment that the external light of the cab was blocked out by the boom when working at night. Reduced vision due to the ROPS and FOPS structures was reported by seven operators (Figure 13). One commented that the reduced vision made it hard on his eyes. Scherman (1988) observed that machines with a limited field of view from the cab cause higher levels of (muscular) tension than machines with a good view. New Zealand and Canadian Standards for operator protective structures do not specify the distance between protective bars, but state that the fitting should not restrict the degree of clear all-round view obtainable from the operator's normal position (SANZ, 1978; WCB, 1990).

Glare was a problem for 10 operators, a factor identified in a previous study (Byers, 1997). Mounting a sun shading strip across the top of the windscreen may alleviate some of the problems of glare. Dirty windows, and the lack of a proper facility for cleaning the screen, was reported by seven operators as a problem. It appears that the standard issue machine windscreen wipers need improving to successfully clean the window, and the current water reservoir needs a greater water storage capacity do the job well.

INSTRUMENTS

Operators were asked what they thought of the logmaking instrumentation installed in the cab, including the computer location (Figure 16), computer screen (Figure 17), and selection buttons (Figure 14). This feedback is valuable for developers making informed decisions on ergonomic improvements of the cab environment.

Location of computer

The operators were divided equally on where they thought the computer screen should be located (Figure 16). Sunlight reflecting off the screen was identified as a problem which created problems when trying to read the displayed information.

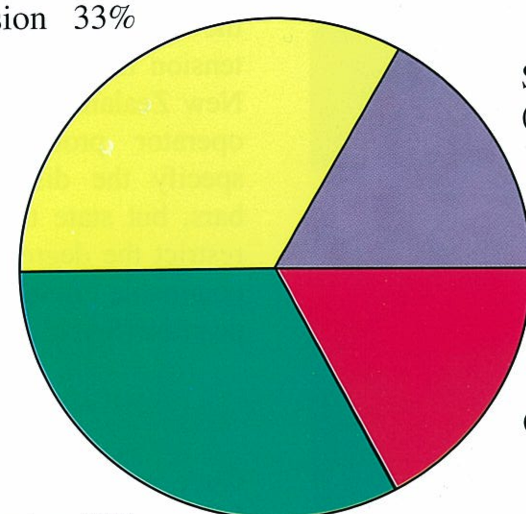

Figure 16 - Computer location

*Other included:

- Display information on window - "Heads Up Display", commonly employed by the airforce with fighter pilots

Computer operating screen

While 42% of the operators were satisfied with the computer operating screen they were using, 58% indicated some dissatisfaction (Figure 17). Larger and brighter numbers were most commonly requested.

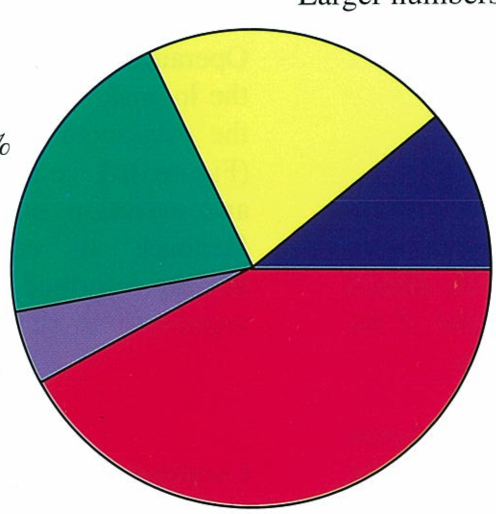

Figure 17 - Suggested improvements for computer operating screen
Other: Only need length and diameter on screen, access into other areas.*

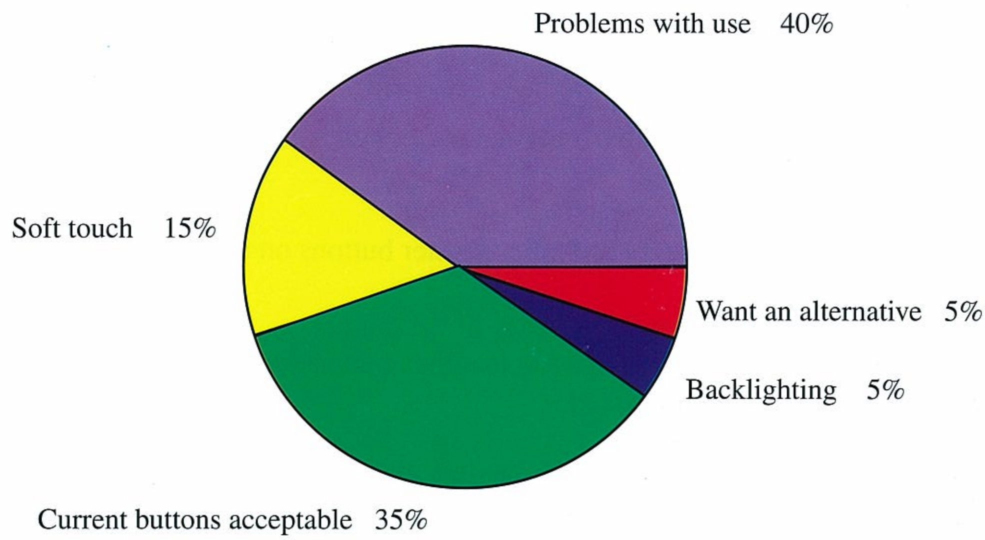

Figure 16 - Comments on selection buttons

Selection buttons

A significant number of operating problems were reported with button use, with 65% reporting dissatisfaction with the current buttons (Figure 18). Table 7 lists the operator comments on problems they encountered when using the current buttons. Suggestions for improving the operating buttons included a soft-touch pad, and backlighting for illumination when working at night. One operator had used a flat mushroom control, which he thought had better buttons.

OPERATOR COMMENTS ON IMPROVEMENTS TO LOGMAKING CONTROLS

The operators were asked to provide general comments and suggestions for improvement of the logmaking controls (Table 8). The number of responses to this set of questions indicates dissatisfaction with the current designs, and highlights areas which operators perceived as those most likely to be beneficial to their job.

Table 7 - Operator comments on problems with use of selection buttons

- If working fast, sometimes hit species button and throw computer out.
- Too small, hard to tell exactly where hitting without looking down.
- Have to hit 4 buttons to assign log lengths.
- Unnatural position.
- Don't push in far enough, not enough travel.
- One button for each grade rather than having to double up (more buttons).
- Problems keeping fingers on buttons, keeps swapping them around.

Table 8 - Operator recommendations on improvement of controls

1. More streamlined hand controls.
2. More basic computer system.
3. Optimiser to assess various faults then cut the logs, operator just uses saw and excavator controls.
4. Something to scan for sweep.
5. Better screen illumination.
6. More pressure on drive arms, voice activation, better buttons on remote keypad.
7. Log optimiser in controls.
8. Angle the top toggle on the joysticks to better fit the thumb.
9. Currently have to hit 4 buttons to assign log lengths , button for each grade would be better.
10. Location of controls could be improved.
11. Brighter cab light for night work.
12. See measuring wheel from LHS, can't see whether slipping or not when working from other side.
13. Illuminated buttons on selection keys, buttons 5 and 6 a problem in dark, faster software.

ADDITIONAL FEATURES BENEFICIAL TO OPERATORS

A range of machine modifications were suggested in the survey for the operators to comment on. Some way of reducing visual hindrance from ROPS bars was selected as being the most beneficial modification. Another suggestion was the creation of some form of measuring scale mounted on the processor head, to assist in judgement of knot size at a distance. In some cases, operators have already retro-fitted a measuring scale to the processor head, with varying degrees of success.

SKID ORGANISATION

A critical component to efficient processing was said to be the placement of stems ready for processing (Figure 19). Presenting stems in an open manner, rather than crossed-up, made the job of processing the stems easier to carry out. In a ground-based system, the skidder operator can play an integral role when dragging wood to the skid for processing, by presenting wood butt first, stems open and uncrossed, and preferably in a position where the jaws of the processor can grab the wood in a downhill direction. This may not be such a problem in cable operations, as the processor frequently clears the chute in addition to processing, controlling the formation of the processing stack. Another critical factor was machine interference. Processing on a skid separate to where other machinery is working, such as in two-staging operations and cold-deck truck loadouts, reduces the amount of machinery and people present and allows the processor operator to focus on the job. The use of smaller, alternating stem piles can minimise machine interference, allowing the operator to work on one stack while the skidder created a second stack out of the way of the wood being processed. Comments from both processor operators and crew members stated that clear and effective lines of communication between crew members was essential in developing a well-run system. Verbatim comments from operators are presented as Appendix 2.

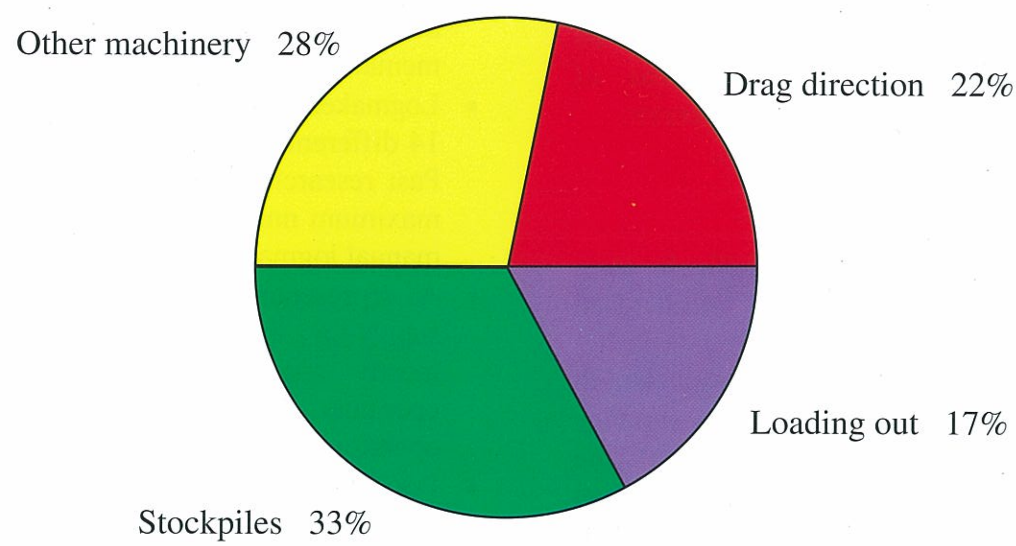

Figure 19 - Skid organisational factors affecting processing

GENERAL COMMENTS ABOUT MECHANISED LOGMAKING

The operators were provided with the opportunity to make additional comments about their job. One operator thought processing was better carried out at night, as there were fewer distractions from machine interference and other crew and he could focus totally on the job. For night processing to be most effective, the lights on the cab need to give good 360° vision. Another operator would have liked to be able to get off the machine to do another job for a break. Yet another thought there should be a training package for two operators when a new machine is purchased.

In many of the discussions following the survey, operators said they had become used to using the current machine controls as they had used no other type. Therefore, it was hard for them to make comment on any improvement when little is known of other options.

CONCLUSIONS

The findings from this study can be categorised into three broad areas of concern: Machine, system and operator.

MACHINE

- Sweep was the most difficult stem feature to identify with mechanised logmaking.
- The key issue in log length measurement was identified as slippage of the measuring wheel in the processing head. Measuring wheel slippage was identified as a problem when processing stems with thick bark, forking, spike knots and nodal swellings.
- Recalibration of the length and diameter measurements in the processor head were commonly carried fortnightly or monthly.
- Visual hindrance from the ROPS and FOPS bar protection, and the boom, was commonly reported.
- Glare was another common problem, made worse by the lack of good windscreen washing facility on the machine (poor wipers, water reservoir). Glare also created problems with reading the computer screen.

SYSTEM

- The operators had spent more time in motor-manual operations (median seven years) than in a mechanised operation (median three years).
- Most (78%) of the operators said they had been a logmaker prior to operating their machine, having spent an average four years logmaking in a motor-manual crew and two years in a mechanised operation.
- Operators had worked as a mechanised logmaker three months to six years.
- Most of the operations visited employed a hot-deck (active skid) load-out system, which meant the operators had to watch for other machinery movements while trying to concentrate on the job of logmaking, adding to their mental workload.
- Logmakers were cutting from three to 14 different log grades on the machine. Past research suggests 10 to 12 as the maximum number of grades for motor-manual logmaking.
- A representative from the company supplying the processor head was mostly responsible for training the operators, followed by a previous operator of the machine (37%).
- Prior training was usually on a one-off basis for up to a week in duration, and covered use of the controls and the logmaking software.
- A significant number of operators (64%) said their job would have been easier to carry out if they had received more training prior to logmaking from the cab. Preferred training options were one-to-one training, and a specialised logmaking course for machine operators.
- Shift lengths ranged from two hours to 13 hours. Nine and 10 hour shifts were most common.
- The skidder operator can have a large impact on the job of the processor operator in the way wood is presented for processing. Proper communication between the two operators should ensure wood for processing is presented in a manner which does not create additional time delays for the processor operator.

OPERATOR

- Most (78%) of the operators had heard of OOS or RSI, but only half of this group were aware of prevention measures.
- All of the operators experienced some form of physical discomfort when logmaking, commonly sore eyes and body aches. Drowsiness was also an issue. Several operators thought that the

length of their shift and the amount of concentration needed to carry out the job were responsible for their symptoms.

- The most common meal break pattern of the operators was to take two, thirty minute breaks. Additional breaks were taken for maintenance, shifting skids, and for personal reasons.
- Most operators commented that they had no experience with using machine operating controls other than those they were currently using.
- Operators made sufficient comments about the logmaking buttons to indicate dissatisfaction with the current design.

SUMMARY

The job of logmaking from a cab is mentally demanding. While the ergonomic design of the cab environment has a large part to play in the optimum performance of the operator, there are additional factors which can also have an impact on the operator, and which need to be addressed. A range of factors including rest break patterns, job rotation, length of shift, and job enlargement falls within the boundary of work organisation. It is important to develop a work system which allows the operator a period away from the mentally intensive task of logmaking, to reduce the cumulative and fatiguing effect of a high mental workload. Current research is investigating the effect of different rest break patterns on operator fatigue levels (both physical and mental) (Kirk, *pers comm.*). An operational system which encourages mental stimulation and reduces fatigue will benefit both the contractor and operator, through sustainable levels of operation and improved levels of productivity and quality.

Ring (1984) identified several important ergonomic cab design considerations:

- Placing controls within easy reach of the operator, especially those most often used.
- Making display screens legible and of proper size, and located within reading distance when the operator is in the normal position.
- The force required to operate the machine controls should be related to speed and length of time of operation. An example is a light force and minimum motion for fast action and long operating periods.
- The size and shape of controls should be comfortable. Direction of operation should be compatible with natural motion of the working limbs.
- Characters on the visual display should have a high contrast with the background. Ends of pointers or levers should not cover numbers or letters.
- Controls and displays should be positioned to avoid reflected light.

RECOMMENDATIONS

Changes to mechanised processors and the operating environment which will improve the ability of the operator to perform effectively, and therefore improve the logmaking ability, include:

✓ Improved visibility through the front cab guarding
✓ Improved windscreen cleaning facility
✓ Improved sunshading of cab
✓ Brighter computer displays with larger screens and numbers
✓ Altered joysticks and keypads
✓ Regular rest breaks and a maximum shift length of four hours continuous
✓ Better training and follow-up

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FACTORS AFFECTING LOGMAKING FROM THE CAB

Please complete the following questions using your own experience of logmaking from the cab of your current machine

Make of Base:... Size of base:.................................
Felling Head/processor type:.........................Harvester Size:.......................

---

1 **How long have you been working in logging operations?**
Motor-manual:....................years..........................months
Mechanised: :....................years..........................months

2 **Were you a logmaker before using this machine? yes/no**
If yes, how long have you been a logmaker?
Motor-manual:....................years..........................months
Mechanised: :....................years..........................months

3 **Is your operation: cable ground based**
hot deck cold deck

4 **How long have you been operating this machine?**
..................years.....................months

5 **How often is your machine re-calibrated for length and diameter?**
....

Who does this?
self serviceman contractor other (who?)........................

How long does re-calibration take?..

6 **How many different log grades do you normally cut?**..................
7 **How many different lengths?** ....

TRAINING

8
Have you had any training for mechanised logmaking from the cab? Y/N

If yes, who trained you?..

What did the training cover?
☐Use of controls in cab
☐Use and interpretation of logmaking software
☐Recognition of stem defects from a distance
☐Recognition of knot size from a distance (ie. a chance to get your eye in)
☐Motor manual logmaking course
☐Other:(specify)...

9 How long was the training for?..
Was it : (a) once only (b) on-going
If on-going, is this (a)hourly (b)daily (c) weekly (d) monthly

10 Are you audited on this machine? Yes/no
Did you receive any additional training as a result of this audit? Yes/no

11 Would the job of logmaking from the cab have been easier if you had received more training prior to starting the job? Yes/no

12 What type of training would you like to see?
(a) workshops
(b) off job training
(c) one on one training
(d) working with an auditor
(e) logmaking course for machine operators
(f) Any other comments?

....
....
....
....

13 How often would you like this training?
....

LOGMAKING SKILLS

14 What aspects of a stem do you need to see from the cab to make a log?
knots diameters roundness splits sweep other

15 What aspects of a stem do you think you currently can't easily see?
knots diameter roundness splits sweep other

16 What is the hardest thing to see?

17 Do any of the following stem features cause you a problem when logmaking? (tick where applicable)

Feature	***Why?***
Bark Thickness	
Forking	
Spike knots	
Tree flexibility	
Nodal Swelling	
Other:	

18 What is the hardest thing about length measurement?
....

THE HUMAN FACTOR

19
How long do you normally operate the processor? ....hours
Shift Time start:...................... Time finish...................................

20
Do you work a full day on the processor yes/no
If no, what other job(s) do you do?...
For how long do you do the other job(s)?...

21
Do you know what a micropause is? Yes/no
Do you currently use micropauses? Yes/no
What would you think of compulsory micropauses? good/bad

22 Do you ever experience any of the following when logmaking from the cab?

Symptoms	**How often?**	**What time of day (end of shift, am, pm, anytime)**	**What do you think causes this? (heater, A/C etc)**
Painful, burning eyes			
Double vision			
Headaches			
Drowsiness			
Body aches (where?)			

23 Have you heard of **OOS or RSI**? (circle if yes) OOS/RSI
Are you aware of OOS prevention techniques? Yes/No

24 Work Breaks: ***Please complete the following table***

Break Type	**Length of Break (minutes/break)**	**Number of Breaks/Day**	**You get off the machine to take this break**
Meal			**Yes/No**
Rest/smoke (micropause)			**Yes/No**
Maintenance			**Yes/No**
Other			

CARRIER

25 Is there anything on the carrier (base) that could be improved?

-excavator controls (joysticks)..

-boom location..

-cab mounted structures..

-cab noise..

-visibility from cab (glass,glare etc)..

SKID ORGANISATION

26 Is there anything about the skid organisation which could hinder your logmaking? (e.g. loadouts, log stacking, drag direction, other machinery)..........

....

....

INSTRUMENTS

27 What do you think of the following machine logmaking controls you currently use? (for readability, illumination, location, size, placement etc)

1-location of computer..........

....

2-machine operating screen,numbers..........

....

3-selection buttons ....

....

4-printer and relay board location..........

....

28 Do you have any other ideas on how the machine logmaking controls could be improved?

....

....

29 Do you think any of the following features would help your logmaking?

☐scale painted on felling head to gauge branch size
☐mirror mounted on boom
☐magnification of the log being processed
☐Reduced visual hindrance from bars
☐Better placement of computer display
☐Better design of computer display or software

30 Any other comments on ways you think your job of logmaking from the cab could be improved?

....

....

....

Appendix 2 -
Operator Comments on Skid Organisational Factors Affecting Log Processing

- Has to be a balance between hauler, processor and loader
- Hot deck a problem when area small
- Machines pulling up to same skid as working on, crossed up stockpiles
- Where the wood is pulled to
- Log stacks for processing need to be open and level or ready for a downhill pull
- Having to watch for other machinery x 2
- Extraction direction, angle of pull affects ease of job
- Concentrating on other machine movements disrupts the flow of work, a dephased operation is best as you can concentrate on the job
- Sometimes have to shift skids when loading out at night
- Landing should be set up so trees come in on angle to processor, can see logs
- Loadouts and drag direction
- Crossed up wood-puts loading on machine, lack of room around machine
- Wood has to come in butt first, try to avoid tail-lock, skidder needs to be careful not to break trees when pushing up
- Moving wood already cut