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TRACKING FOR SKIDDER EXTRACTION — ON FLAT COUNTRY

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INTRODUCTION

The basic concept of rubber tyred skidders is that they are capable of short cycle times through their ability to travel to and from the felling face at relatively high speed. It is well recognised that average haul distance plays an important part in the productivity of skidders (Liley, 1986). In discussing target setting, Higgins and Buse (1986) noted that: "The extraction machine will be the factor that limits production in most situations."

The two main factors that limit a skidder's "travel empty" speed are slope and ground roughness, through their effect on operator comfort. On easy terrain, it is the ground roughness that has the greatest effect on travel speed. Mechanically, the skidder is capable of operating at maximum speed. However, the operator has difficulty maintaining control of the machine when travelling across stumps, slash, etc.

Figure 1 - Machine returning to felling face in tracked area. Travel speed restricted by ground roughness; in this case, stumps and slash.

In 1985, Tasman Forestry Limited, Murupara, began experimenting with the concept of forming tracks for the extraction machine in their "old crop" clearfelling operations. Early indications were; tracking increased skidder productivity, and repairs and maintenance were reduced. The benefits were not quantified to assess whether the cost of tracking was offset by increases in production.

In 1986, LIRA set up a comparative trial in Kaingaroa Forest to evaluate the effect of formed tracks on skidder productivity. The trial had two objectives :

- to determine if there was a significant increase in productivity by operating rubber tyred skidders off formed tracks versus the cutover.
- to measure the levels of whole body vibration the operator was subjected to, as a means of determining operator comfort levels for each treatment.

This Report discusses the results of the trial in two separate parts; production studies and whole body vibration studies.

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LIRA is grateful for the assistance given by Tasman Forestry Limited, Murupara staff and the co-operation of contractor, Pat Cox and his gang. LIRA also thanks David Reid Electronics for supplying the whole body vibration instrument.

THE TRIAL AREA

The stand of 1931 radiata pine was located in the Matea region of Kaingaroa Forest. Live stocking was 800 stems/ha, with 150 dead stems/ha. Average extracted stem volume was 1.98 m^3.

The two trial areas were 2.2. hectares for the tracked area and 2.3 hectares for the untracked area. Both areas were similar in terms of; terrain, piece size, haul distance, and the amount of windthrow.

The extraction machine used for the trial was a three month old Clark 668D rubber tyred skidder. It was powered by a Cummins (turbocharged) VT-555, 8 cylinder diesel rated at 152 kW. The machine was fitted with a Weldco parallelogram grapple. It was also fitted with a fully enclosed cab for the operator.

The contractor operated an out-of-phase logging system. The machine extracted wood to a landing until it was full. He then moved to another landing while the skiddies processed the extracted wood. The loader would then fleet and/or load out the wood. At any given time there were four skids being worked. This operating system presented some problems in data collection, since the skidder extracted on to the skid adjacent to the trial area for only approximately two hours per day. The data collected takes no account of smokos, downtime etc.

Tracking was carried out using a Caterpillar D8 supplied by Tasman Forestry Limited, Murupara. The tracks were formed prior to felling and the few trees in the way were uprooted and pushed into the stand.

For the 2.2 hectares of the tracked area, a total of 543 metres of tracks were formed (10% of the total area). The time taken was 1.8 hours plus a further 0.6 hours cleaning up heads from the untracked area which had been felled across the tracks. The cost of this tracking (based on Tasman Forestry Limited information) was $159 per hectare or, over the 906 tonnes extracted per hectare, $0.18 per tonne.

PRODUCTION STUDY

A production study was undertaken from November, 1986 to February, 1987. From the untracked area, 134 cycles were observed and 117 cycles from the tracked area. In addition to work cycle measurements, extracted drag volumes were measured during the trial. Distances were marked out along the extraction path prior to extraction, to enable calculation of haul distances.

Data was collected using a Husky Hunter data logger which was downloaded on to a personal computer for subsequent analysis using Statistix (Version 1.1) (Heisey and Nimis).

Table 1 presents the results of the production study for the two areas.

Table 1 - Production Study Results

	TRACKED		UNTRACKED	
Element	No. of Observations	Mean Per Cycle	No. of Observations	Mean Per Cycle
Travel empty	117	0.81	134	1.17
Position	117	0.91	134	0.90
Pick up drag	117	0.95	134	1.02
Travel loaded	117	1.58	134	1.72
Drop at landing	116	0.54	130	0.55
Blade skid	18	0.06	22	0.07
Blade haul path	30	0.16	21	0.10
Blade for breakout	31	0.23	35	0.19
Delay	13	0.16	73	0.23
Total cycle time (min)	117	5.40 ± 0.33*	134	5.95 ± 0.37*
Average measured haul distance		195 m		158 m

(* 95% confidence limits)

Due to the operating technique, the average measured haul distance for each area was quite different (158 m for untracked vs 195 m for the tracked area). Average volume per drag, however, was similar (4.9 m^3, untracked, and 4.8 m^3 tracked).

Using the relationship between haul distance and cycle time,[1] the haul distance was standardised to 195 m. The predicted average cycle time for the untracked area with an average haul distance of 195 metres was 6.47 minutes. Based on a 6.5 productive machine hour day and an average volume per drag of 4.85 m^3, the comparison between productivity of the tracked and untracked areas is given in Table 2.

In this study the establishment of formed tracks showed an increase in productivity of 20%.

Table 2 - Productivity of the Two Treatments

TRACKED	UNTRACKED
6.5 productive machine hours per day Standardised haul distance = 195 m Average cycle time = 5.40 min Daily productivity = $(60/5.40) \times 6.5 \times 4.85$ m^3	6.5 productive machine hours per day Standardised haul distance = 195 m Average cycle time = 6.47 min Daily productivity = $(60/6.47) \times 6.5 \times 4.85$ m^3
= 350 m^3/day	= 292 m^3/day

Figure 2 - Skidder extracting log on formed track

DISCUSSION

Detailed analysis of travel speeds, both loaded and empty, revealed significant increases in speed when the machine was operated off the formed tracks. Travel empty speed increased from 2.3 m/sec, untracked, to 4.2 m/sec, tracked, (8.1 km/hr to 15.0 km/hr). This equates to an 85% speed increase travelling on formed tracks. Travel loaded speeds increased from 1.5 m/sec, untracked, to 2.5 m/sec, tracked. This is a 64% increase in speed (from 5.5 km/hr to 9.0 km/hr).

Results from this study suggest that in easy terrain, such as Kaingaroa forest, average haul distance could be increased without adversely affecting machine productivity through the adoption of tracking as a routine procedure.

Although not measured during the study, it is possible that the levels of soil disturbance, in terms of area, could be reduced through tracking. The formation of tracks con-

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[1] Equation : $Y = 1.92 + 0.023x$

$r^2 = 0.53$

centrates the path taken by the machine both to and from the felling face. During the extraction from the tracked area, it was noticed that once the machine had picked up a drag, the operator made as direct a line as possible to get back on the track. It is proposed to examine this more closely in subsequent trials.

The effect on repair and maintenance costs of skidders operating from formed tracks is difficult to quantify from such a relatively short study. The measurement of operator whole body vibration, as discussed in the next section, could be used as an indicator of the longer term effects of tracking, on the machine.

WHOLE BODY VIBRATION

The objective of this second part of the trial was to determine the effect of tracking on operator comfort levels, as measured by whole body vibration. Since this study was the first time such measurement had been attempted in the New Zealand logging industry, a brief description of whole body vibration follows.

There are two points at which vibration enters the body that are significant; feet/buttocks (skidder operator), and hands (chainsaw operator). Vibration is measured in units of acceleration (m/s^2). For analysis, the logarithmic measure dB was converted to the arithmetical measure of m/s^2. There are five variables which are important when evaluating whole body vibration (Kjellberg and Wikstrom, 1985). The five variables are :

- Intensity - the level of vibration, i.e. 154 dB is more dangerous than 120 dB
- Variation in vibration over time
- Frequency - different parts of the body are susceptible to different frequencies, i.e. 3-4 Hz in the spine or 60-90 Hz in the eyeballs. The frequency range of interest when measuring whole body vibration is 0-80 Hz.
- Direction - vibration is measured in three directions; head to toe (Z axis), back to front (X axis), and side to side (Y axis).
- Duration

The effect of whole body vibration on operator's health has been well summarised by Griffin (1982) in a paper presented to the Swedish National Board of Occupational Safety and Health. A list of health problems was reported as being associated with people subjected to whole body vibration. Some of these problems include; back problems, abdmoninal pain, digestive problems and urinary frequency.

VIBRATION MEASURING EQUIPMENT

A Bruel and Kjaer 2512 Human-Response Vibration Meter in conjunction with Bruel and Kjaer 4322 Triaxial seat accelerometer was used to collect whole body vibration data. The instrument allows collection of; equivalent exposure expressed as a percentage of the allowed daily exposure dose (based on ISO 2631), the equivalent RMS vibration level over the period of one cycle (this is a measurement of the time-weighted vibration levels, the troughs and peaks are levelled), the peak level that has occurred during the cycle, and the time of the cycle. Each axis is measured separately. Typically the recording sequence started on the X axis and progressed through Y to Z and then back to X.

The triaxial seat accelerometer was correctly oriented on the seat of the machine and periodically checked during data collection. The instrument was mounted on the floor of the cab between the operator's feet, securely held by two flexible fasteners.

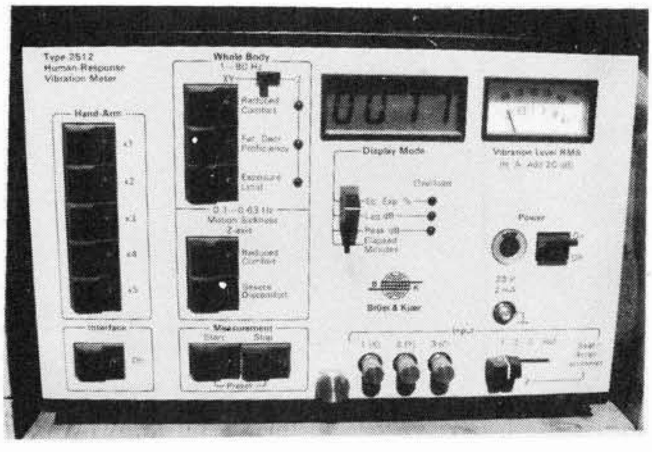

Figure 3 - The Whole Body Vibration recording equipment. The seat accelerometer connects to the back of this unit.

RESULTS OF VIBRATION MEASUREMENT

Nineteen samples for each of the three axes were obtained from both the tracked and untracked areas. These measurements were related to the volume and haul distance data collected in the skidder production study. Significant reductions in the percent exposure levels and RMS levels were noted. The following figures illustrate the reduction.

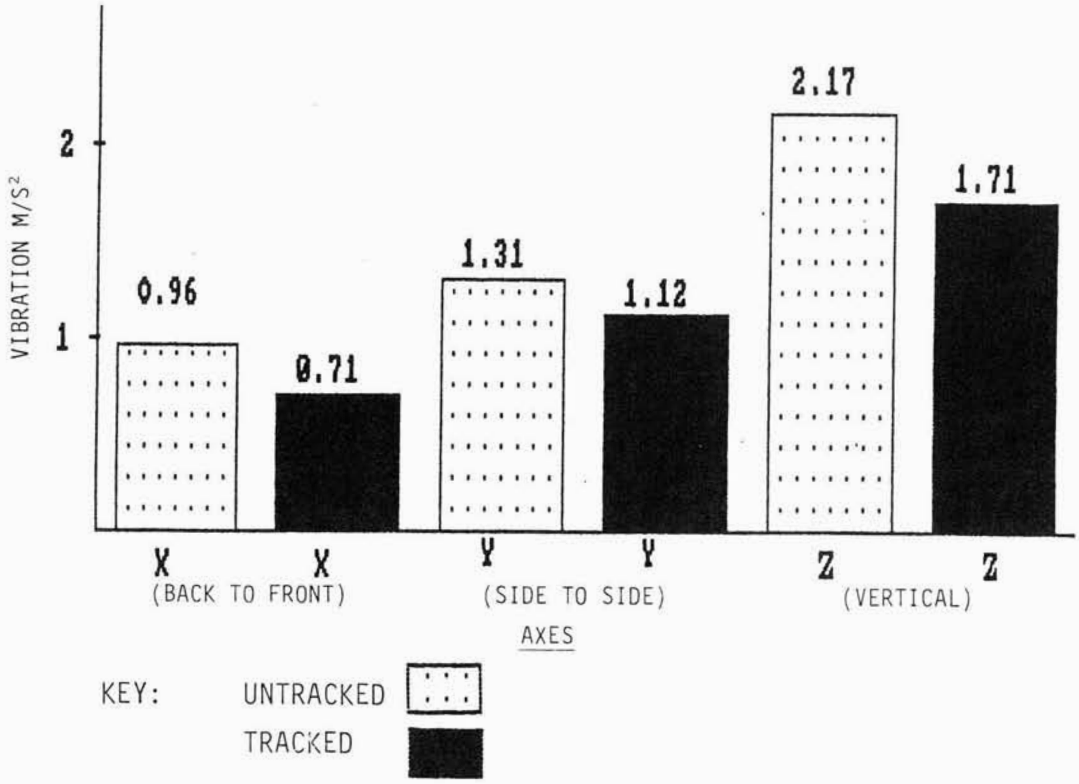

Figure 4 - RMS Vibration Levels

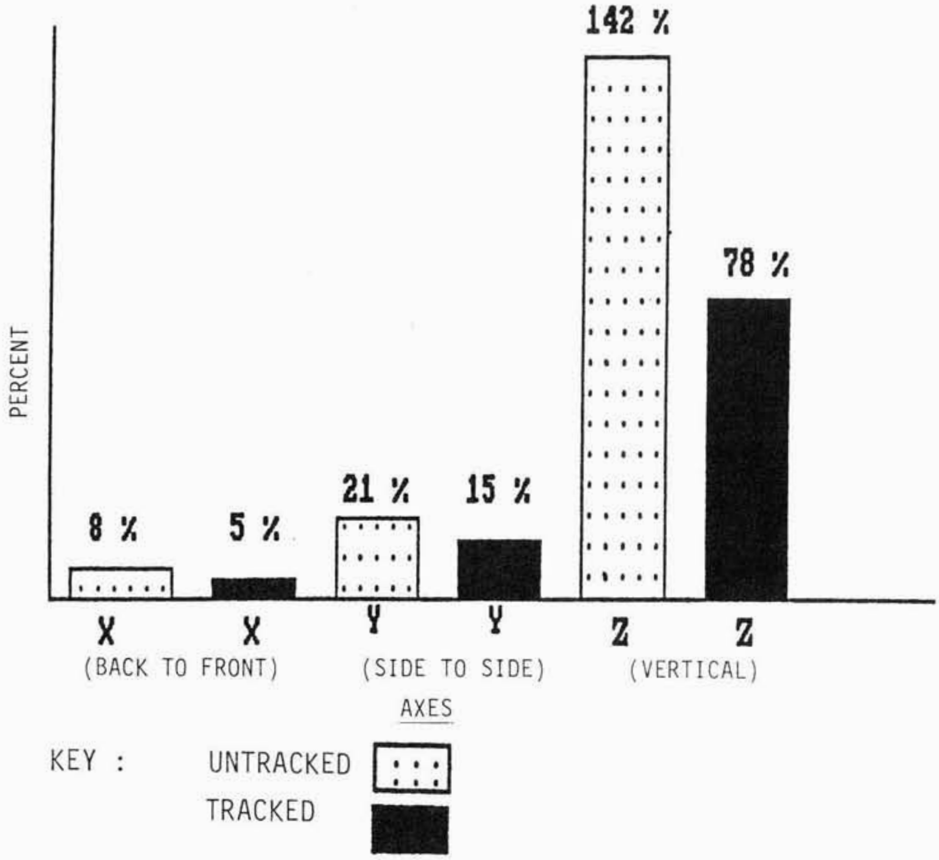

Figure 5 - Whole Body vibration - Dose per Cycle as percent of ISO Standard

Reductions in RMS vibration levels recorded were significant at the 95% level for Y and Z axes and the 99% level for the X axis. The percent dose per cycle, based on the International Standards Organisation general standard for whole body vibration (ISO 2631, 1978), was dramatic - 45% reduction in the Z axis and over 30% reduction for the other two. Such reductions are most encouraging and certainly point to better levels of comfort for the operator.

Figure 6 - Measurements being taken at the landing at completion of the full cycle

DISCUSSION

Although the study was of only short duration, results achieved show potential for considerable improvements to operator comfort through operation on formed tracks. Such improvements will undoubtedly result in reduced fatigue levels and vibration-induced occupational illnesses. It is anticipated that frequency recordings will be carried out during a longer term study later this year, thus enabling the identification of those frequencies that are reduced by operating on formed tracks.

The long term effect of this vibration reduction on machine repairs and maintenance is a matter for conjecture. Given the degree of reduction it would be reasonable to expect repair and maintenance costs to reduce significantly.

CONCLUSION

The formation of tracks from which skidders operate has resulted in a 20% increase in productivity. The cost of that tracking was insignificant in terms of the benefits gained.

Levels of whole body vibration are greatly reduced through the use of formed tracks. That reduction will have benefits for both the operator's long term health and the machine's life.

Ergonomics, as a science to improve the safety, productivity, and profitability of logging operations, need not incur large costs.

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