

so be it!

A mad focusing on the bottom line of a spreadsheet doesn't always allow such considerations. Most often the value of the

options are not quantified (some probably can't be), and many may not even be identified during the analysis. But that is another story.

Time to throw the line back into the water; I'll add a bit of berley this time.
Ed.

CONFERENCE PAPERS

Mechanisation of logging operations in New Zealand

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Introduction

There has recently been a flurry of activity in New Zealand forests as contractors and forest owners look to mechanising parts of their logging operations. The 1994 Forest Industries expo at Rotorua provided some of the impetus for this push, as many of the machines imported for this show were subsequently trialed in forest operations. The Health and Safety in Employment Act (1992) has also provided motivation for the industry to seek safer alternatives to people with chainsaws. By the end of the decade it is possible that a large proportion of the delimiting operations in our forests will be undertaken by machines, with a smaller proportion (because of slope limitations) of the harvest being mechanically felled. It is likely that most logmaking decisions will be made by machine/computer as the cost of poor decision making climbs with increasing log values. There is also a renewed interest in undertaking this logmaking at processing yards rather than on skids. For mechanisation to be achieved at acceptable economic levels however, both contractor and forest owners' operations must be run efficiently. Any poor tactical or operational planning pushes the unit rates of a mechanised operation to unacceptable levels.

Background

Mechanisation of logging is not a new trend, but has been a spasmodic process over the last 15 to 20 years. In the late 70s and early 80s there were several tractor, rubber-tyred loader and excavator-based feller bunchers being used in minor species. Chain flail delimiters, both static and mobile, had also been used with vary-

ing degrees of success. Waratah Engineering had three machines working in radiata thinning operations. Gleason at the 1982 NZ Logging Industry Research Association's (LIRA) Logging Machinery Seminar reported that of all the different machines and approaches that had been tried, just four felling machines and no delimiting machines were being used. At the 1986 LIRA 'Ground Based Logging' seminar Gordon reported the lull continuing, with a few feller bunchers and a locally built delimitter, the Hunt processor, being the only machines replacing men with chainsaws falling and delimiting in our forests. In contrast, an Australian speaker, O.H. Raymond, reported the widespread mechanisation of falling and processing in their pine forests by a range of systems. The New Zealand speakers put the slow rate of change down to our extensive use of small contractors, controls on the volumes produced, conservative forest owners and the high cost of imported machinery, although in hindsight it is obvious that low-priced and

readily available labour gives forest owners little incentive to change.

LIRO has kept a watching brief on the new machines and systems and has been able to help the industry with evaluating these. A large number of different machines and systems have been tried and reported and these are summarised in a review of mechanisation in New Zealand which will soon be published by LIRO. This will contain summaries of 220 published and unpublished reports and papers on mechanisation in our forests.

Analysis of these reports shows a gradual increase in the mechanisation of thinning and minor species operations, although by LIRO's 1991 'Machinery Developments in Logging' seminar only seven of the 78 Waratah units sold were being used in New Zealand. Just 15 mechanical harvesting machines had been introduced in the five years since the 1986 seminar (Cochrane 1991). In the last three years to February 1995 there has been a considerable change, as can be seen in Table 1.

Machine Type	Thinning	Clearfell
Feller Director	1	2
Feller buncher	1	7
Delimitter/feller/buncher	3	
Harvester - shear		2
Harvester - saw	4	6
Grapple processor	2	6
Stroke delimitter		3
Hahn harvester		5
Static delimitter	1	38
Forwarder	13	1

Table 1. Logging machines for felling or delimiting in use in New Zealand - Feb. 1995 (LIRO, unpublished)

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Many of the operations in the clearfell column are working in small radiata clearfell or high-stocked minor species (*Pinus ponderosa*, *P. nigra*, *P. contorta*) stands with small average piece size. Only now are the machines capable of handling large radiata becoming available. In 1991 the Bell static delimber was introduced and now has a wide following in small (under 1 m³ average piece size) radiata and minor species clearfell. The range of modifications to this machine is a tribute to 'kiwi' ingenuity.

Reasons for Renewed Interest in Mechanisation

- Health and Safety in Employment and employment contracts legislation is perceived to be making employing and training staff more complicated and expensive. One machine and operator may seem easier to manage than several men.
- Safety – Most of the accidents to workers in forest operations occur during felling and delimiting (Parker, 1993). Replacing men with machines will reduce accidents. The physical stresses on an operator are less than if they were using a chainsaw, and life-threatening accidents are reduced. Machine operators are at risk from new types of injuries, however. With increasing numbers of haulers producing higher volumes of wood there are more skid workers trying to work on these small landings. Processing machines under haulers are becoming a popular method of reducing the number of workers exposed to hazards on these skids. It is not certain whether mechanisation is being driven by the desire to improve safety or the fear of the legal consequences of an accident.
- Two machines have now shown themselves to be capable of processing large clearfell radiata reliably and economically over the long haul. These are the Waratah HTH234 harvester and the Denis DM3000 and DM3500 stroke boom delimiters. In a slightly smaller piece size 'off the shelf' static delimiters are working well and several large purpose-built static delimiters are being used to delimit large trees.
- In both clearfell operations and thinning operations where trees are smaller and there is a heavy delimiting workload, skilled labour is becoming harder to attract.
- As with the first forays into mechanisation, forest owners are encouraging and supporting the move. However enthusiastic contractors may be, mechanisation only happens with company support. Mechanisation is perceived to offer flexibility to a forest owner in that

a machine may increase production if a boat needs filling or in the case of wind throw. Flexibility is reduced, however, if production should need to be decreased, as a contractor with higher capital commitments is less able to survive a stand down.

Mechanisation in Thinnings

Machines that are working successfully in radiata thinnings are the Waratah HTH230 felling and processing at stump, with forwarders moving wood to roadside stockpiles. The variation in form and branch size, and the large size of radiata thinnings, if left just one or two years later than planned, will prevent the reliable use of lighter grapple harvesters. The base carriers to date are mainly 20 tonne excavators, but a move to level swing machines such as the Timbco T445 and Timberjack TJ2518 will see more forests on steeper country able to be production-thinned economically. Combinations which use feller bunchers, Waratah delimber-feller, bunchers, Bell static delimiters and line or grapple skidders will persist.

Douglas fir and *Eucalyptus* species

The minor species forests of *P. ponderosa*, *P. nigra* and *P. contorta* are giving way to Douglas fir and *Eucalyptus* species. Douglas fir thinning operations can be undertaken by smaller processors, such as those from Scandinavia, and clearfell will use similar machinery as the radiata clearfell operations. There is an increasing area of *Eucalyptus* species being planted for short-rotation pulp crops. Carter Holt Harvey Forests contractors at Kinleith have adopted (from Australian practice) successful mechanised debarking and processing systems based on the Waratah 240 (Gadd and Sowerby, 1995).

Radiata Clearfell

Small radiata pine clearfell (under 1 m³) operations are using static delimiters, Hahn harvesters, stroke boom delimiters and in some cases Waratah 230s. In larger piece sizes a Rotosaw feller buncher and a Hultins F850 feller director have been used and two Timbco T445s have recently moved into Carter Holt Harvey Forests Kinleith region. Timberjack base carriers will move into thinning and clearfell operations in the coming year. To delimit and process, the Waratah 234 and the Denis 3500 and 3000 are being used mounted on 30 and 40 tonne excavators. The Waratah 234 is also used to fell, delimit and bunch full-tree lengths. The Timberline stroke delimiting and Trinder static delimiting have been trialed and appear to suit trees under two tonnes.

Issues

A noticeable trend in the industry has been the shift away from an early preoccupation with productivity towards a wider range of issues when looking at logging systems. A large number of these issues are as yet unresolved and are challenges for the industry. Some of the key issues facing us are as follows:

Capital Costs and Continuity of Work

Logging machines are extremely expensive. A costing (Riddle, 1994) of an example mechanised operation is shown in Table 3. The system comprises nine men, a Waratah HTH234 on a Caterpillar 330 excavator base felling and delimiting, a large grapple skidder, and on the skid following manual log-making and bucking, a small excavator and a wheeled loader.

Total capital cost of this system is \$1,570,000.

Dividing this daily cost of \$4939 by a target of 500 tonnes gives a unit rate of \$9.87 per tonne. If only 400 tonnes are logged in a day then: 400 x \$9.87 = \$3948. This is a reduction in income of \$990 per day or \$230,000 per year from the income originally planned for. Operations such as this are very sensitive to a drop in average production, and the further from the 'mainstream' logging operations of large forest owners, the more likely is interference to an operation by such things as wet weather causing access problems, the need for frequent shifts, availability of transporters, bridge weight restrictions, etc.

If an operation like this works in smaller forests and has more shifts during the year, and fewer days worked because of wet weather, the costing will be different. Based on 200 working days and 10 shifts requiring transporters at \$1200 per shift, the total daily cost is estimated to be \$5330. With a 500 tonne target the logging rate becomes \$10.65; 400 tonnes and the rate is \$13.32. A four-hectare woodlot might only take five days of work, but take two part days to shift to and from the block. Lower capital cost operations may be able to do this type of work more economically, so an increasing percentage of the national cut in small forests works against mechanisation.

From this example it is evident that contractor profit is so sensitive to production rate and the number of days worked during a year that efficient operations and particularly mechanised operations will only develop if guarantees of continuity of work are offered. Small forest or woodlot owners cannot provide this guarantee. It must come from those professionals who are amalgamating these stands for marketing.

We at LIRO are concerned about the

Machine	Species	Operation	Piece size (m ³)	Productivity (m ³ /hr)	Reference
Trinder and Bell	Radiata	Clearfell	1.88	64	Hill, 1995
Trinder and grapple	Radiata	Clearfell	2.5	115	McConchie, 1994
Bell Static and Bell	Radiata	Clearfell	1.0	53	Jones, Evanson, 1992
Modified Bell static + 40t excavator	Radiata	Clearfell	2.3	103	McConchie, Evanson, 1995
Timberline ST3530	Radiata	Clearfell	2.6	Too big	Hall, 1994
Timberline ST3530	Radiata	Delimb and logmaking	2.2	59	Evanson, Riddle, Fraser 1994
Denis DM3000	Radiata	Delimb and logmaking	1.53	43	Robinson, Evanson, 1992
Hahn Harvester	Radiata	Clearfell	1.3	39	Evanson, 1995
Hultins F850 FD	Radiata	Clearfell	2.6	122	Raymond, Evanson, 1994
Timbco T445FB	Radiata	Clearfell	1.8	110-145	McConchie, 1994
Timbco T445 FB	Radiata	Clearfell	2.4	170	Evanson, 1994
Timbco T445 FB	P. nigra	Clearfell	1.11	120-160	Evanson, 1994
Timbco T445 FB	Radiata	Thinnings	0.19	15	Evanson, 1994
Timbco T430	Radiata	Clearfell	2.2	120	Evanson, Riddle, Fraser
Bell tracked FB	P. nigra	Clearfell	0.18	19	Evanson, 1993
Waratah 234HTH	Radiata	Clearfell, fell and delimb	1.95	100	McConchie, Evanson, 1994
Waratah 234HTH	Radiata	Clearfell, delimb	1.95	140	McConchie, Evanson, 1994
Waratah 234HTH	Radiata	Clearfell, delimb	2.9	75	Evanson, Riddle, Fraser 1994
Waratah 234HTH	Radiata	Clearfell, delimb	1.5	82	Evanson, Riddle, 1994
Waratah 240HTH	Eucalypts	Debark + logmaking	0.8	25	Gadd, Sowerby, 1995
Waratah 230HTH	Radiata	Thinning	0.48	29	Evanson, McConchie, 1992

Table 2. Some examples of machine performance.

Element	Capital cost	Estimated daily cost (235 days)
Labour - 9 men		\$1,555
Overheads/operating supplies	\$15,000	\$285
Two trucks for crew transport	\$75,000	\$165
Caterpillar 330L with Waratah 234	\$660,000	\$1,030
Caterpillar 936 wheeled loader	\$230,000	\$365
Caterpillar 530 Grapple skidder	\$370,000	\$670
Caterpillar 320 excavator (20t)	\$220,000	\$420
Profit @ 10%		\$449
Total daily cost		\$4,939

Table 3. Estimated daily costs for a logging operation.

growing gap between contractors in large forests and those in the small forest and woodlot area, in terms of efficiency, safety, business skills, environmental management and quality of output. Mechanisation will not happen in these forests without improvements. Those employing contractors need to improve their knowledge, there needs to be better continuity of work offered to contractors, and contractors should be expected to improve their skills.

Logging System Balance

When introducing a machine or machines to an operation there is a desire to use them to their full capacity to reduce unit costs. If each machine is capable of different levels of production this can create problems. In motor manual systems this can often be overcome by moving a worker to another task. This is not so easy in mechanised systems. One LIRO study of an Australian system found a feller buncher capable of 119 m³ per hour followed by a stroke boom delimeter processing trees at a rate of 59 m³ per hour

and then a forwarder extracting the resultant product at 33 m³ per hour (Evanson, Riddle and Fraser, 1994). Balance involved short hours for the feller buncher and falling for two operations, extended hours for the other machines and bringing in old machines to use at times. Planning a balanced operation is much harder when using machines.

Quality Issues

In falling, the stump heights, breakage functions and butt damage caused through motor manual falling is currently being remeasured by a LIRO study. Indicative studies show a lower effective stump and less breakage leading to a longer log to the first break with mechanised falling. Damage to the butt such as splitting and slabbing is dependent upon operator skill. Delimiting and bucking quality has been studied and it is evident that it is possible to achieve length and small end diameter measurements with machines that are of a similar standard as motor manual systems (Evanson 1995). However, machine maintenance and operator ability play a large part in achieving this quality. Delimiting quality and the incidence of minor stem impacts such as bark removal,

slabbing, gouging and branch tear or draw vary between machines and operators. Although some of these logs look very different from motor manually produced logs, there are as yet no milling studies to show if any of these machine impacts reduce mill out-turn. Another issue is how machines can move radiata logs through delimiting knives when radiata's thick bark layer often slabs off. Do grapple marks or pineapple roller marks reduce mill recovery? Waratah have recently produced drive rollers with bars rather than spikes, which appear to have a lesser impact on the log surface. They are also investigating a variable pressure system that applies pressure to the log in proportion to log diameter to reduce stem impacts.

Sapstain

The loss of value caused by sapstain in logs is significant. Mechanised systems have the potential to help reduce the time between felling and treatment or processing. However, if there is no urgency in trying to reduce this time, machines, with their greater impacts on log surfaces (creating more entry points for sapstain vectors), may make the problem worse. Linked with the challenge of reducing this delay time between falling and treatment is the challenge of real time inventory systems to track logs and mechanised logmaking using computerised decision-making systems. Logmaking decisions, now made manually on the skid, are able to be made by computer optimising programmes. This leads to computer-aided decision making with hand-held systems on the skid or in central processing yards and eventually in processors. Part of the solution of an optimising programme is a description of each log by type, length, diameter and volume. When this exact information is given to log managers either instantly or on a daily basis, their decisions as to logmaking priorities for the forest to best meet market requirements will be made simpler.

Further, if each log's vital statistics are linked to an individual log tag, logs may be tracked as they are trucked, weighed, debarked, sprayed and marketed. Real time inventory systems are being investigated by the industry with vigour and the mechanisation or computerisation of logmaking decisions will be an important part of this process.

In smaller forests and woodlots the problems of sapstain and optimising value recovery will lead to a change in practice. Cutting multiple log grades on skids with low volume throughputs and only dry weather truck access is asking for sapstain problems. Cutting two grades by removing pulp to leave a long sawlog with pos-

sibly a pruned log (15 m maximum length) and emptying skids at the end of each day will minimise the risk of sapstain. Transporting these logs to a central location for mechanical logmaking will not only give better lines of logs to market, but will allow forest owners to be paid for sawlogs based on measured volumes. With large enough volumes, debarking and sapstain facilities may be added. Such a district yard may even be an independent business providing a service to a number of clients.

Operators

Another important issue for the industry is a lack of skilled machine operators. As more and more machines enter the forest, operators need to be found and trained, then retained in the industry. Learning curve studies show that training initially involves low production and higher repairs and maintenance costs (Parker, 1995). Preselection procedures and simulator training may reduce costs. Although the physical workload for operators is lower than if they were using a chainsaw, Scandinavian experiences suggest that there are other stresses involved and that shifts and variations in work patterns and well-designed cabs may be needed to prevent operator burnout and severe repetitive strain injuries. The Australian industry experience shows machine operators to be a more stable workforce (Beath, 1991).

The Resource and the Silvicultural Interface

The production rates of harvesters, delimiters and processors are very sensitive to the resource being offered. Mechanisation requires an even crop of good-form trees with small branches. Oversized trees and heavily branched or malformed trees make mechanisation slow and difficult to the point of being uneconomic. For instance, Jones and Evanson (1992) found that malformed and large-branched trees took 102% longer to delimit with a Bell static delimitter than normally formed *P. radiata* of 1.0 m³ mean piece size. Any machine must be carefully matched to the resource for the operation to be successful. We have a poor record in this area, as we are frequently tempted to push machines just outside their limits. The period that saw early thinning to waste and ultra low stockings giving large trees of poor form and large branches will be in the main unsuitable for mechanisation. The shift back to stockings of 250 to 350 trees per hectare and above will help. Another issue here is that much of the New Zealand resource is not well described in terms of its suitability for a mechanised harvest. Planning multi-mil-

lion-dollar machine purchases requires careful planning with accurate inventory data some way into the future.

With better-quality planting stock now available there are interesting options available where production thinning is planned. Outrow thinning systems where complete rows are left untouched by pruners (e.g. every fifth row) offer gains in productivity for mechanised operations. The machine removes that row, creating a roadway, and then either selection or pattern thins the adjacent two rows. At planting then, row direction should be planned to suit the machines, especially on steep slopes or on hauler country. It may be possible to use a higher planting density (of lower value stock?) in the rows to be removed to increase thinning yields. Thinning systems using harvesters processing at stump and forwarders moving logs to roadside will also reduce the area lost to landings in mid rotation. Silvicultural practice has a huge impact on any harvesting operation, but this especially applies to mechanised systems.

An Increasing Cut

The increasing size of the resource is putting more demands on the labour supply. Contractors and companies must attract, train and retain more labour. Mechanisation will lower this demand slightly, although the skills required will be different.

The Environment

Machines used in logging have the potential to either reduce adverse impacts on the environment or increase them. Refining systems to reduce adverse impacts will be an ongoing issue, but some good examples have already been set. An example is the harvester/forwarder thinning operation (McMahon and Evanson, 1994). Processing at stump means that nutrients contained in branches stay on site, and that harvester and forwarder travel on a mat of branches, reducing the risks of soil compaction. In addition the area in landings is reduced and no soil is exposed by skidding logs, so there is less risk of erosion with rain.

Waste Management

LIRO recently quantified the amount of skid and cutover residues left on ground-based and hauler operations by type. National volumes of this resource were estimated and two extraction and processing systems were costed (Hall, 1994). There is now some action in this area. Successful systems for handling large numbers of small pieces involve mechanised systems. Another topical issue is birds' nests around hauler landings and the risk of their collapse during heavy rain.

One Waratah delimiting on a hauler landing is able to work on a bed of slash rather than push it off the edge.

Conclusion

These are some of the issues confronting the logging industry as it approaches mechanised logging systems. As more of these are solved we will be able to offer better products to our markets and more sophisticated services to our principals. A key reason for mechanisation will continue to be the drive to make our forests safer places to work in, but while machinery costs stay so high it is unrealistic to expect mechanised operations in every forest or woodlot. Driven mainly by the safety legislation, and with managerial support, there is currently a level of experimentation with mechanised logging systems and a level of innovation not seen since the late 1970s. Is mechanisation here to stay?

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A Timberjack 2618 with Waratah 230 head in use in a thinning operation – Tasman Forestry Ltd. Photo: LIRO



A Bell static delimiting machine in operation. Photo: LIRO



Hurrings logging gang of Tapanui using an 071 Hauler, Bell 200B and Cat E200B with Waratah 230 head on the skid. Ernslaw One, Tapanui. Photo: LIRO

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Decision-support systems – new management tools

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ABSTRACT

Decision-support systems are integrated software packages comprising tools for processing both numerical and qualitative information (ideas). They are likely to be essential in future for forestry companies, as they facilitate consistent, thorough, and rapid decision-making. They differ from traditional forestry software packages in that they can process ideas, keep track of uncertainty, have higher levels of integration among software tools, and are easy to use. The development of programming tools for processing knowledge is reviewed. Steps in the development of decision-support systems are described, with emphasis on those required for knowledge-based software. Two decision-support systems designed for forestry are outlined.

INTRODUCTION

'Decision-support system' (DSS) is one of those buzz phrases that arise from time to time, and one might suppose that a DSS

would accompany 'upskilling', 'outcome', 'competitive environment', 'level playing field' and 'separation of providers and funders', and have 'upmarket' status. However, unlike most of those other novelties, decision-support systems offer managers a useful new set of tools for decision-making and therefore have a future.

This paper sets out to explain what DSSs are, what is new about them, how they are made, and to indicate some of their uses in forestry.

DECISIONS, DECISIONS ...

Those faced with decisions require ways of predicting results of alternative courses of action, as well as ways of judging the results. There is often plenty of information available, but turning this information into relevant knowledge by selecting the right facts is crucial. Moreover, simply selecting appropriate information is not enough; it often requires processing in order to be useful.

Forest managers are well acquainted with computer programs which select information and produce knowledge in numerical form. This knowledge may be simply attributes, such as volumes of wood per hectare, or it may be active knowledge, such as a model of changes in

characteristics of a stand given alternative tending regimes.

Some of the less commonly recognised knowledge used for decision-making is qualitative (non-numerical). As with numerical knowledge, qualitative knowledge, here referred to as ideas¹, may simply comprise descriptions of attributes or be active in the form of logical constructions. The most important knowledge of all, that which includes *how to make the decision*, is almost always qualitative.

It has been suggested that coding ideas into a computer program is a poor substitute for numerical coding, as science could eventually reduce all decisions to numbers (Oscar Garcia pers. comm.). Given unlimited research finance, plenty of lead-time for decisions, and vast computing power, this might be plausible. In the real world, however, budgets are limited, decisions are needed now, and computers have speed limitations. Some knowledge may never be represented in numerical form. Consider such simple examples as the frost-flat regime for establishing radiata pine, or the idea that woody weeds should be controlled prior to the establishment of a tree crop if at all possible. These two heuristics are essential components of decision-making about plantation estab-

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¹ It is recognised that ideas may be numerical, but for the purposes of this paper, the word "ideas" is used to refer to qualitative knowledge only.