A Simulation of the Impact of Pre-emptive Cutting for Transportation on Value Recovery

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ABSTRACT

Centralised processing may be an alternative to skidsite processing for some regions of New Zealand where radiata pine plantations now await harvest. However, a pre-emptive cut will generally be necessary to reduce felled stems to lengths which can be trucked to a central processing yard. There are various strategies for determining where a single pre-emptive cut should be placed. The effect on potential stem value has been compared for samples of trees using the bucking simulation program AVIS. All strategies tested reduced stem value but the amount of loss varied with the strategy chosen and the subsequent cutting pattern used in the yard.

Keywords: *harvesting, bucking, log-sorting, optimisation, plantations*

INTRODUCTION

The volume from New Zealand's predominately radiata pine plantation forests will increase markedly over the next two decades. As harvesting is set to expand beyond its traditional centres, interest in new methods of log-handling is increasing. The terrain and soil types in some regions due for harvesting are unsuitable for traditional landing log production, which requires a large well-drained and reasonably flat site. Instead the log-handling area is likely to be constrained in size, and there may be surface problems, especially in spring and winter, which will make log-making difficult.

In addition, forest managers are now striving to meet customer demands for specialist log products. This means an increasing number of log sorts, sometimes up to 16, are being cut at one landing.

The use of centralised processing is accepted practice in some other countries, for example Canada and Chile, but still in its infancy in New Zealand. In the mid-1970's two small woodyards were established on the West Coast of the South Island to examine the practicality of centralised log processing. Logs were trucked on-highway to the yards for processing.

Some benefits were obtained from the yard, but the small daily volumes passing through the yard meant that unit costs were unacceptably high. More recently, two yards have been established within plantation forests allowing off-highway cartage (i.e., using non-public roads). One has since closed because of changes in log supply, while the other continues to be active since its formation in 1986.

Radiata pine stands are normally clearfelled at age 30 to 35 years, at which time they are about 40 metres tall and are approximately 2.5 m^3 in volume. Because of their size trees are predominately felled, delimbed, and extracted to roadside by motor-manual techniques. Log production occurs at the landing.

Breakage upon falling reduces the main butt piece to about 25 to 30 metres, with this butt stem section containing about 99% of the merchantable value [4]. Despite breakage, most stems would be too long to be easily carted on traditional trucking configurations which are designed to handle logs of up to 13 metres (see Figure 1). Longer lengths would create difficulties in negotiating roads in many forests where horizontal alignments are inadequate.

Thus, to deliver the stems to a central location the main butt piece must be cut into at least two sections. By cutting the stem, the cuts will pre-empt

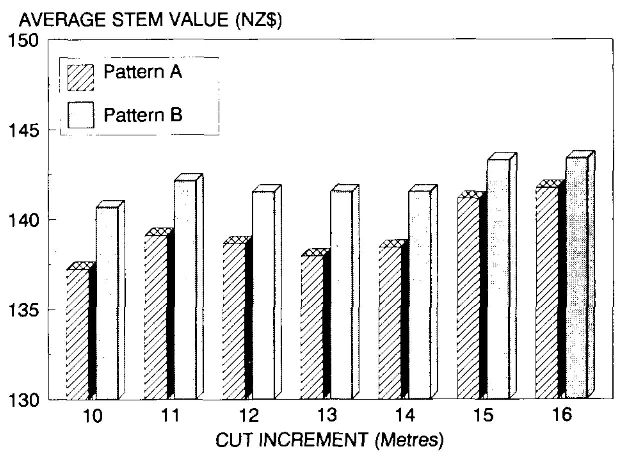

Figure 1: Stem length to first break-point for base data stands.

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subsequent log-making decisions by reducing the number of length options available.

This article examines the impact that varying cutting strategies have on subsequent log-making options. For the majority of this analysis it is assumed that transportation to a yard is off-highway. Log yards are likely to be most successful where there are fewest restrictions on stem length and the longest possible piece is presented at the yard for processing.

CUTTING STRATEGIES

An advantage of the central processing yard concept is that the main material handling phase of the harvesting operation is separated from the value-orientated component. Thus the logging crew can concentrate more on system productivity without being restricted by value issues as they relate to log-making. The main criterion used to select cutting strategies for testing was therefore simplicity, while still trying to maintain the longest possible piece.

Two options for a single cut which maximises stem length are either at some identifiable point around one-third stem length, or towards the tip at about one-half to two-thirds stem length.

Opting for a cut closer to the butt end has the apparent advantage that there is an identifiable position for the cut for many stands, i.e., at the end of the pruned zone. This strategy also removes a large proportion of the volume from the stems, reducing the average piece weight that must be lifted by the loading unit.

Making the cut toward the tip has the opposite effect, i.e., the cut position is not likely to be in an easily selected position and the piece size variation will be larger. However, it is advantageous with centralised processing to delay the main log-making decisions as late as possible. Making a cut in the highest value segment of the stem in the forest potentially limits the range of subsequent log-making strategies; for example, combinations of partially pruned logs would be restricted if the pre-emptive cut is placed incorrectly. Also, consistent accuracy in finding the end of the pruned zone has been shown to be a difficult task [5], so this important decision should be left to when the stem can be more carefully examined in the yard.

A further disadvantage of cutting near the butt is that variations in both pruned height and stem diameter result in a number of different cutting options. Therefore, without measuring each stem, the person responsible for making the pre-emptive cut in the forest is unlikely to be able to use a standard method to decide where to place the cut. Due to restricted landing sizes, piling of stems is frequently likely to occur, making it difficult and possibly dangerous for the worker to closely inspect individual stems. Under these circumstances detailed measurement could not be safely made, especially in spring and winter when rain and mud compound working problems.

For these reasons the option of making the pre-emptive cut closer to the butt end was discarded, and only strategies which involved cutting further up the stem were considered.

The strategies selected were:

1. 'RANDOM', a random cut within a restricted zone, 13 to 16 metres above the butt. This simulates a strategy of cutting anywhere between a defined maximum and minimum length. It is equivalent to a worker running their saw through a heap of stockpiled stems which have unevenly positioned butts.

2. 'GRADE', a cut made at the first occurrence of a grade change in the 13 to 16 metre zone. If no grade change occurs the cut is to be made randomly within the zone. This strategy was included to test what level of increase was obtainable over the RANDOM strategy with some, even though very limited, quality decision was made in the forest.

3. 'FIXED', a fixed length cut at 15 metres from the butt.

STEM DESCRIPTION

The stands used in this analysis are based on two sets of data collected in 'typical' managed (i.e., pruned and thinned) stands in New Zealand. The sample from Stand 1 consisted of 100 trees from a central North Island forest. Stand 2 had a 95 tree sample, and was collected from the lower North Island forest where the only currently operating centralised processing yard in New Zealand is sited. The basic details of both stands are provided in Table 1 below.

Table 1 : Stand parameters of sampled stands

PARAMETER	STAND 1	STAND 2
Stand age (years)	31	30
Total live volume (m^3/ha)	722	432
Stocking (trees/ha)	300	206
Basal area (m^3/ha)	54	42
Mean tree volume (m^3)	2.4	2.1
Mean tree height (m)	39.4	30.7
Mean DBHOB (cm)	47	50

Data were collected as the two stands were being harvested. Stems were randomly selected after being felled, but before extraction to the landing. Detailed measurements of length, diameter, and stem quality were made on each stem as required for input data for AVIS [3]. Quality assessments were based on standardised log grading [6].

LOG MIXES

Two processing options were examined to test the effects of different pre-emptive cutting strategies on the final log mix and value.

The first, Log Pattern A, had a pruned log sort, unpruned sorts of two grades and two size classes, and a pulpwood residual component (see Table 2). This option included the full range of log assortments which might be used in the more diversified forestry region.

The second, Log Pattern B, was a more restricted mix, with a pruned log sort and two grades of short unpruned logs with one size class. A smallwood sort (posts and poles) was segregated from the residual component. This option simulated the more limited set of log sorts which might be used in smaller forestry areas with no pulpwood or chip outlets.

All sawlogs were cut to fixed lengths; long logs to an incremental length of 0.6 metres and shorts to a length of 0.3 metres.

Log values vary considerably among different regions of New Zealand. A set of 'typical' on-truck values around the middle of the range was assumed for the purposes of this analysis (see Table 2). For unpruned sawlogs, the lengths 9.8 to 12.2 metres, for long logs, and 4.9, 5.5 and 6.1 metres, for short sawlogs, were given a 7.5% value premium above all other lengths of the same grade, to reflect general industry preference for these lengths.

Table 2 : Log Grade mixes for each cutting pattern

Assortment	Grade components	Length (m)	Value (NZ$)
Pattern A			
Pruned sawlog	P1 + P2	4.3 - 7.0	95.00
Pruned sawlog	P1 + P2	3.1 - 4.0	92.50
Unpruned long sawlog	S1 + S2	8.6 -12.2	76.00
Unpruned long sawlog	L1 + L2	8.6 -12.2	59.00
Unpruned short sawlog	S1 + S2	3.7 - 6.1	61.00
Unpruned short sawlog	L1 + L2	3.7 - 6.1	54.00
Unpruned short small sawlog	S3	4.9 - 6.1	36.00
Pulpwood	S4 + L4 + R	2.4 - 6.0	25.00
Pattern B			
Pruned sawlog	P1 + P2	4.3 - 7.0	95.00
Pruned sawlog	P1 + P2	3.1 - 4.0	92.50
Unpruned short sawlog	S1 + S2 + S3	3.7 - 6.1	55.00
Unpruned short sawlog	L1 + L2 + L3	3.7 - 6.1	49.00
Smallwood	S4	1.8 - 6.1	25.00

Table 3 : Effect on stem value of cutting strategy and cutting pattern

Strategy	Pattern A			Pattern B		
	Mean stem value	Significance level	Stem value loss (%)	Mean stem value	Significance level	Stem value loss (%)
Control	145.2		-	145.3		-
		} 0.01			} 0.01	
FIXED	141.5		2.5	143.7		1.1
		} 0.01			} 0.01	
GRADE	140.4		3.3	143.3		1.4
		} NS			} NS	
RANDOM	140.2		3.5	143.1		1.5

STUDY METHOD

The AVIS program [1] was used to simulate the imposition of the two cutting Patterns A and B on the stem descriptions of the field measured trees. The resultant output of the various log grades was noted.

Subsequently, the sample stems were 'severed' according to the various pre-emptive strategies, and the new grade outputs from imposing the cutting patterns on each stem recorded.

The changes in stem value, and proportions of log grades, were compared amongst pre-emptive strategies.

RESULTS

i) Effect on Stem Value

Pre-emptive cutting significantly reduced the potential stem value (t-test, p=0.01 level) but on average the percentage losses were low, ranging from 1% to 3%.

The FIXED strategy caused the least reduction in value for both cutting patterns, while GRADE and RANDOM strategies were not significantly different in their effect. Results for the Stand 1 sample are summarised in Table 3. The percentage stem value losses for Stand 2 were almost identical so are not included.

ii) Effect on Log Mix

Pre-emptive cutting resulted in twice the value loss with log Pattern A than with log Pattern B. This was due to the effect of the pre-emptive cut on the premium unpruned long log sort included in Pattern A.

Most of the long logs between 11.0 and 12.2 metres were eliminated, increasing the proportion of the shorter preferred-length long logs, and of the non-preferred long logs.

As the effect on the proportions of the preferred and non-preferred long logs was almost identical for both samples, to better illustrate the impact on log length the results have been presented as combined totals in Table 4.

This reduction in the longest log lengths could be very important where export logs are sought. Long logs (11-12 m) are usually a priority in export sales, so a requirement to obtain them would increase the negative impact of the pre-emptive cuts.

iii) Effect on Residue Production

Any arbitrary cut placed in a stem where fixed increments are being cut must tend to increase the proportion of residues. Disposal of additional residues may represent increased cost to the yard. With both patterns, the amount of residues (pulpwood/smallwood plus waste) was increased. As a result residues comprised 10% and 5% for Patterns A and B, respectively, of the total volume produced in the yard (Table 5).

Using Pattern B, most of the increased residue was additional pulpwood rather than waste.

iv) Effect of Moving the Cutting Zone

The cutting strategy FIXED had the least impact

Table 4: Effect on proportions of preferred length logs with Pattern A (samples 1 & 2 combined)

No. of preferred Long S logs	Cutting Strategy			
	CONTROL	FIXED	GRADE	RANDOM
12.2	100	0	10	10
11.6	100	50	25	25
11.0	100	40	50	50
10.4	100	10	65	60
9.8	100	200	155	150
TOTAL	**100**	**85**	**65**	**65**
No. of non-preferred Long S logs				
9.2	100	265	165	200
8.6	100	175	625	675
TOTAL	**100**	**215**	**430**	**470**

Table 5: Proportion of volume by utility class

	Strategy			
	CONTROL	FIXED	GRADE	RANDOM
Pattern A				
Sawlogs	92.6	90.0	89.2	89.3
Pulpwood	6.8	8.9	9.5	9.5
Waste	0.6	1.1	1.3	1.2
Pattern B				
Sawlogs	95.8	95.3	95.1	95.1
Smallwood	2.6	2.7	2.6	2.6
Waste	1.6	2.0	2.3	2.3

Table 6: Effect of moving RANDOM zone

Cutting Zone	Pattern A			Pattern B		
	Mean value (NZ$)	Significance level	Value reduction (%)	Mean value (NZ$)	Significance level	Value reduction (%)
Control	145.2		-	145.3		-
		} 0.01			} 0.01	
15-18 m	141.5		2.5	143.7		1.1
		} NS			} 0.01	
14-17 m	141.3		2.7	143.2		1.4
		} 0.01			} NS	
13-16 m	140.2		3.4	143.1		1.5

on stem value, however it has the operational advantage of requiring the measurement of each stem. Its advantage over other strategies arises mainly because there is a longer average length before the cutting position. The effect on potential stem value of setting a longer minimum length before the cutting zone in the RANDOM strategy was tested for both cutting patterns. (Table 6)

The results showed that increasing the length before the cut reduced the impact on stem value. With log Pattern A, the value loss significantly decreased when the cutting zone was shifted from 13-16 metres to 15-18 metres up the stem. However, there was no significant difference in stem value between the cut made at 15-18 metres and at 14-17 metres.

With log Pattern B, in which percentage value loss was about half that of Pattern A for each cutting zone, moving the cutting zone from 13-16 metres to 14-17 metres had no significant effect. However, the difference in stem value with the cut made at 14-17 metres and at 15-18 metres was significant.

Clearly the cutting strategy leaving the longest butt piece has the least impact on stem value, as the cut is made up in the part of the stem with the lowest diameter and hence lowest cost. However, where only short logs are to be cut, as with Pattern B, the differences in stem values resulting from the different positions of the pre-emptive cut are so small as to be operationally unimportant. With Pattern A, having a long S grade sort, it is more important to make the pre-emptive cut further up the stem in the 14-17 metre zone or higher.

v) Carting on-highway

The longest current legal long log length able to be carted on New Zealand highways without special permit is about 13 metres. To carry mature radiata pine stems on-highway to a processing yard would therefore require additional pre-emptive cuts to be made in the stem.

Using a RANDOM strategy, with a cut within the 12.5 to 13.5 metre incremental zone, value losses of 4.5% and 2.4% were obtained for log patterns A and B, respectively. Similar levels of value loss for on-highway cartage were reported by Murphy [2].

The effect of cutting for on-highway cartage was further examined by imposing increasing fixed in-

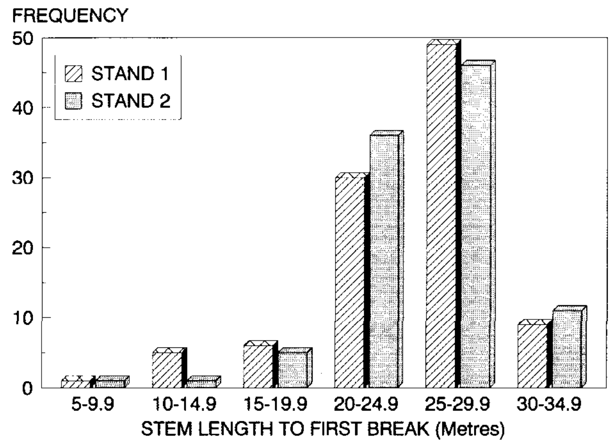

Figure 2: Impact of increasing the fixed length cut position.

crement cutting lengths on the Stand 1 sample (see Figure 2). Cutting shorter lengths tended to reduce average stem value, however the reduction in stem value did not evenly match the shortening in cut length.

When cutting long logs (Pattern A), value loss for fixed lengths between 10 and 14 metres was from 4.2% to 5.5%. A distinct change occurred when the length was increased above 14 metres, where the losses were roughly halved. This same trend was followed when Pattern B was applied, although the size of the losses were lower, from 2.6% to 3.2% in the 10 to 14 metre cut increments.

The indications from this analysis are that if stems must be pre-emptive cut for on-highway transportation, then the impact will be an additional 1% to 2% value loss above cutting longer lengths for off-highway transportation.

DISCUSSION

In practice, the operational cutting of stems into logs involves a reduction in value as compared to the simulated value optimal solutions provided by the AVIS program. However, incorrect decisions will be made whether the whole stem is being processed or stem segments are being recut.

Under existing techniques it is clear that pre-emptive cutting of the stem to allow log-length transportation will involve the sacrifice of some of the potential value of the stem. That value loss is relatively low, about 1 to 4%, if off-highway transportation can be used, but higher if shorter or additional cuts must be made. This loss would have to be considered in any cost/benefit analysis of a log yard option.

This simulation exercise has indicated that the longer the piece length that can be maintained the better. However, for trees of the size examined, the gain from extending piece length falls off rapidly above about 17 to 18 metres. In deciding the piece length to cut, the worker will have to take into account the capacities of the loading unit and the limitations of the trucking unit.

There may be other cutting strategies which are suitable for use in the transfer deck in the woods besides those discussed above. These will also need to be simple to apply and ideally will not require the worker in the woods to make measurements.

SUMMARY

1. Pre-emptive cutting, to allow the transportation of long-length material from the woods to a centralised processing yard, reduces the total potential value of the stem.

2. The amount of value lost due to the pre-emptive cut will depend upon the wood cutting strategy, the log mix into which the stem is subsequently processed, the relative values of the log sorts, and if the stems must be carted on-highway or off-highway.

3. Using a set of 'typical' log values, pre-emptive cutting for off-highway cartage was found to reduce the total potential value by 2 to 3% when including a long (9-12 m) unpruned sort in the log mix, and by 1 to 2% when cutting only short logs (3-6 m).

4. While the three main woods cutting strategies examined had differing effects on value, there appears to be little gain in selecting any particular one. A simple one to apply would be the 'GRADE' strategy, where an attempt is made to cut stems at the quality change within approximate length boundaries. This option has the advantage of using some of the decision-making skills of the woods worker.

5. If a long-length unpruned sawlog assortment is to be produced, the pre-emptive cut should be high up the stem at around 14-17 metres. Where only short sawlogs are to be produced there is less advantage in having a long butt piece, but the cut can be made about the same length up the stem, 14-17 metres, to allow economies during truck transport.

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