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FFR Research Business Case: Improved Stem Scanning

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EXECUTIVE SUMMARY

This business case suggests that a significant return can be made for doing research into improved detection of important stem quality characteristic. Scanning technologies such as RADAR and laser scanning technologies has moved forward since the last significant research was done in New Zealand on this topic. This small business case shows that large financial gains (over $1/m^3) can potentially be made by accurate detection of; pruned height location, diameter and length measurements and bark on/off status. To achieve these gains will require a relatively small amount of applied research to show the true potential and how it could be commercially implemented. This business case suggests that this should be undertaken in the areas of RADAR and laser scanning to detect changes in stem quality.

INTRODUCTION

Goal

The goal of this project is to develop a research business case around stem measurement/scanning for optimal bucking. This document is designed to provide guidance to the Future Forest Research Technical Steering Team on their decision on whether to investigate funding into this area over the next three years.

Rationale

In the eighties and nineties a significant amount of research was carried out in the area of optimal log bucking. In New Zealand during that time saw the Timbertech (Invader) optimising caliper was developed and implemented. In Scandinavia significant improvements were made on implementing optimal bucking onto single grid harvesters. Since that time little progress in New Zealand has been made in this area. However in recent years significant research has been carried out on scanning technologies both outside and within the forestry industry.

Overview of Research Area

The optimisation of value produced when trees are cut into logs was first thought about as early as 1913 (Bryant 1913), however, even today the forestry industry is still struggling to extract the optimal value from it forests (Marshall 2005). Mathematical optimisation techniques have existed for over 45 years. Mathematical optimisation techniques, such as those used for log making, can only optimise using the data available to them. For example if the measurement system does not provide the raw data on sweep measurement to the log bucker then the optimised solution will not consider sweep.

Murphy 2003 and Marshall 2005 collated 60 published and unpublished value recovery studies. The studies covered a range of species and countries. The average value loss was 18 % with individual studies ranging from 1 to 68%. Depending on the studies these value losses can be contributed to either not using optimisation, input data quality or in most cases both.

Marshall and Murphy (2004) carried out an economic evaluation of implementing improved stem scanning systems on mechanical harvester/processors. The study evaluated the costs/benefits of different scanning procedures including:

a) Conventional operating where quality changes and bucking decisions were made by the machine operator;
b) an automatic full scan of the stem prior to optimisation and bucking;
c) partial scanning where a portion of the stem was scanned and then qualities and dimensions were forecast before the optimal bucking took place.

They found that breakeven capital investment costs for new scanning and forecasting, and optimisation equipment ranged between zero and US$ 2,120,000. The study focused on two fully mechanised operations, one in Washington harvesting Douglas fir and the other in Eastern Oregon harvesting Ponderosa pine. This study highlighted that when harvesting high value timber a significant amount of extra money can be invested to obtain accurate information on the stem dimensions and quality used to optimise logs being cut.

Most value recovery studies focus on determining how much value was lost. However there is even more value not being captured either because we are not, or cannot, capture the information about other end product performance characteristics that are required during log making to make the informed decision to maximise value extraction.

VALUE RECOVERY ANALYSIS

The four areas that have been chosen for this business case to demonstrate the potential returns from the research into the implementation of improved scanning\measuring systems that could improve value maximisation are:

- Pruned height
- Bark on or off
- Length and diameter measurement.
- Stem Sonics\Density

Where appropriate literature and previous studies are available, the value analysis was based on the results of these published reports. However in the case of the pruned height, no literature is available to base the value analysis and hence a small study was carried out as part of this report. The $/m^3 value figures quoted in this report are based on a 60 pruned stem sample. The stems had an average pruned height of 5.51 m and average piece size of 2.59 m^3. The cutting pattern used to buck these stems is given in Table 1.

Table 1. Log Grades used in this Study

Grade Name	Length (m) (steps)	Max/Min SED (cm)	Max/Min SED (cm)	Branch Size (cm)	Price ($/m^3)
P1	4.10-6.5 (0.6)	90/40	90/40	Pruned	135
P2	4.10-6.5 (0.6)	90/30	999/30	Pruned	120
A	4.0-12.0 (4.0)	34/20	80/22	12	106
J	4.0-12.0 (4.0)	26/20	80/20	12	85
K	3.6-11.0 (2.0)	26/20	80/20	12	102
S1	4.9-6.1 (0.6)	90/40	90/40	7	90
S2	4.9-6.1 (0.6)	90/40	90/40	7	87
S3	4.9-6.1 (0.6)	90/20	90/20	7	67
L1	4.9-6.1 (0.6)	90/40	90/40	14	72
L2	4.9-6.1 (0.6)	90/30	90/30	14	72
L3	4.9-6.1 (0.6)	90/20	90/20	14	66
Pulp	3.0-6.1 (0.1)	999/10	999/10	-	58

Pruned Height

Significant investment has been made in tree pruning so it is important to extract the maximum value from every pruned stem. However finding the pruned height of stem once it has been delimbed is often difficult meaning the exact length of the pruned zone is often estimated. This combined with the market's requirement for fixed length pruned grade means that significant pruned value can be lost from incorrectly measuring pruned length. A small analysis has been carried out as part of the project to assess that impact of mismeasurement of pruned height.
A negative pruned length scanning error was inserted into the study stems to investigate its effect on value loss in pruned grades. A C# script was developed which inserted pruned length error into the study stem data. The pruned length error inserted was negative as this is the most widespread error in log scanning systems as operators tend towards conservative estimates for this quality feature. The original scanned logs were optimised against a simple cutting strategy based on the generic MAF log grades and the average log prices for the past quarter. An optimal log bucking software (based on dynamic programming) was then used to re-optimise the stems with the inserted pruned length error and the optimisation outputs were compared to ascertain the effect of value loss associated with negative errors in the measurement of pruned length.

Figure 1 show the value lost both in terms of total value and pruned log value.

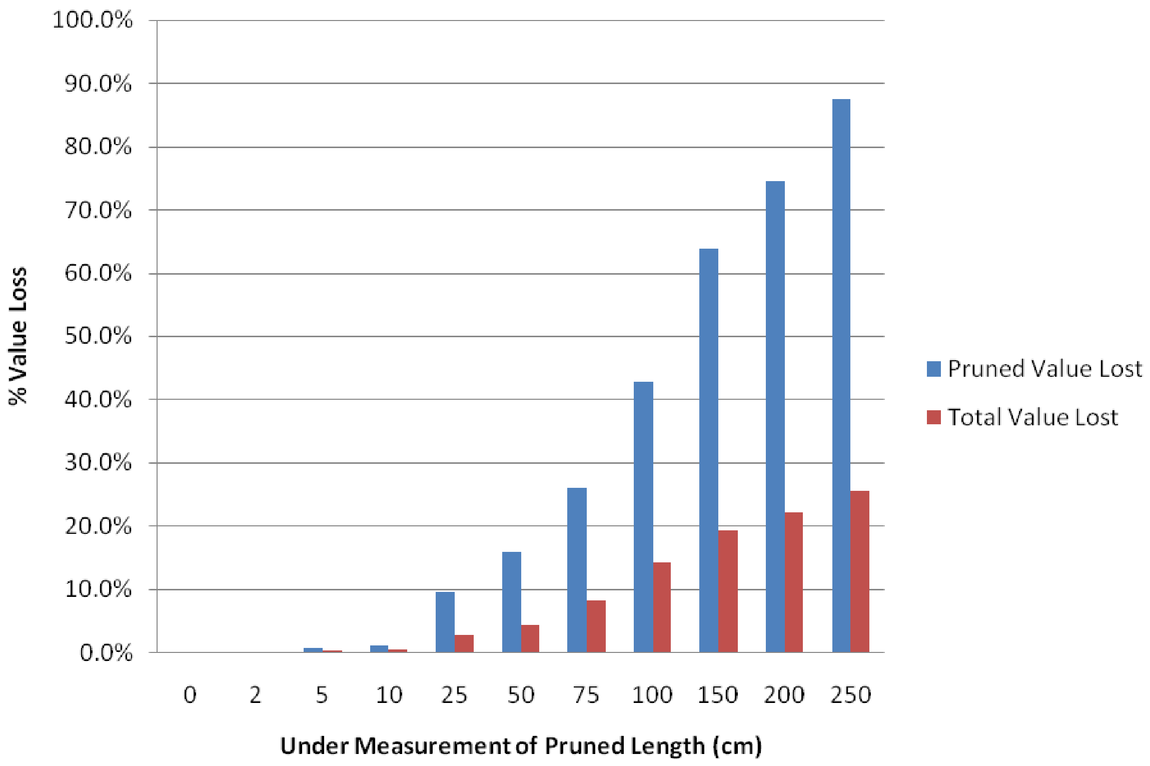

Figure 1. Value lost from under estimating the length of pruned on sample of 60 pruned logs.

Using a sample of 60 stems (total value = $ 16,117.90, total volume = 181.71 m^3) and assuming that on average pruned length is measured 25 cm under, up to $ (NZ) 2.30 /m^3 could be spend on improving the accuracy on measuring pruned length accurately. Any amount spend under this figure would mean a positive payoff to the forest owner.

Bark On or Off

On the face of it, whether the barks on or off a stem at the point at which a diameter measurement is made would seem relatively trivial. However the absence or presence of bark can easily impact on whether a log is able to be cut from the stem or not. Most modern harvesting heads have bark thickness equations so that a better estimate of the diameter under bark can be determined than just using diameter over bark. The Timbertech callipers required operators to add bark present/absent value (0 = no bark, 1 = 1 side of bark and 2 = 2 side of bark) for each diameter measurement. This was then used with a bark thickness equation to determine the true under-bark diameters.

Marshall et al. (2006) looked at the impact of using different bark thickness equations on the value of 6 different stands of 3 different species. They found that up to 11% of the forest owner's value could be lost simply by using the wrong species coefficient in the bark thickness equation. This is important when implementing a Scandinavian harvesting machine into Radiata pine to make sure Radiata pine bark thickness equation coefficients have been used in place of the defaults.

It was found that in New Zealand Radiata pine, loss of greater than 1% can be produced by not estimating diameter under bark when diameter over bark was measured. Based on the stem sample and cut plan outlined in tables 1 and 2 up to $(NZ) 0.88 / m^3 could be spent obtaining bark thickness coefficients for that stand given that no bark thickness coefficients existed.

In situations where sections of bark have been lost from a stem a proportion of that US$ 0.88 /m^3 (1 % of the value) would need to be spent on determining whether the bark is present or absence on locations where diameter measurement are being made. Although is amount seem insignificant, at a national level this value lost could be significant particular as log making becomes increasingly mechanised.

Length and Diameter Measurement

The assessment of improving diameter and length measurement is based on a paper by Marshall et al (2006). The authors study the errors associated with six different single grip harvesting heads. A simulation model was then developed to investigate the impact on different levels of the length and diameter measurement error on value recovery of single grip harvesters. They found that on average value lost from measurement errors for the six studies was 18%, with the losses ranging from 3% to 23 %.

Using a sample of 60 stems (total value = $ 16,117.90, total volume = 181.71 m^3) means that up to $ (NZ) 16.02 /m^3 could be spend on improving the accuracy of the length and diameter measurements.

In the mid-nineties a Swedish project investigated the development of a touch-free measurement system for diameter. They estimated that the new system could produce 90 % of all logs within 4 mm range and lead to potential increase in revenue between US $ 5,000 and US 85,000 per single-grip harvester per year. The estimated purchase cost of fully develop systems was estimated to be about US$ 20,000 (Lofgren and Wilhelmsson 1998). It should be noted that to date, to the authors knowledge, no harvesting head are operating touch-free measurement system. Scan bench systems such as those at the KPP and Logmaister should in principle, measure the stem diameters and lengths at a much greater accuracy and precision. However these systems do come at extra cost.

Sonics/Wood Density

Acuna and Murphy (2005) studied the optimal bucking of Douglas fir taking into consideration external properties and wood density they concluded that increase in value could be as high as 40% assuming no increase in price for higher density logs. A study carried out by Amishev and Murphy 2009 on how acoustic tools could be used to estimate prices or price premiums for veneer logs in Oregon. They concluded that “stand stiffness grading based on acoustic velocity measurements on Douglas-fir peeler logs at the time of harvest could be used as surrogate measure for potential net returns from the harvested forest and hence a premium price to be afforded on such stands. The sample with the greatest net revenue ($1,145 per thousand board feet) was 3 % higher than the nest one and more than 16% higher than the lowest one.” (Amishev and Murphy 2009).

How one converts the results of these two studies in a $/$m^3$ gain from sonic testing is beyond the scope of this report, however significant value gains are possible through the measurement and optimisation of stem stiffness. Fibre-gen, the developers of the Director HM200 and ST300 are currently developing the PH330 which is a sonic tool that is designed to be implemented harvesting heads.

PROPOSED RESEARCH AND APPLICABILITY

The proposed research is designed to capture as much value as quickly as possible and not targeted around developing new scanning technologies. This means targeting research based on the following considerations:

- A price gradient already exists for this log quality feature.
- The scanning hardware is well tested in other application and is ready for implementation into the stem scanning applications.
- There are sufficient value prospects to justify the research.

Based on the analysis carried out in this paper the focus areas in the first phase of research should be:

- The use of RADAR for determining the length of pruned and the location of the branch along the length of the stem. The use of RADAR technology is well developed in many applications; it has been tested on logs in the past and has shown some potential in is for this application. RADARr has some real advantages over other surface penetrating scanning system such as X-Ray and NMR as it poses very little threat to human health. RADAR is also a relatively cheap technology to implement.

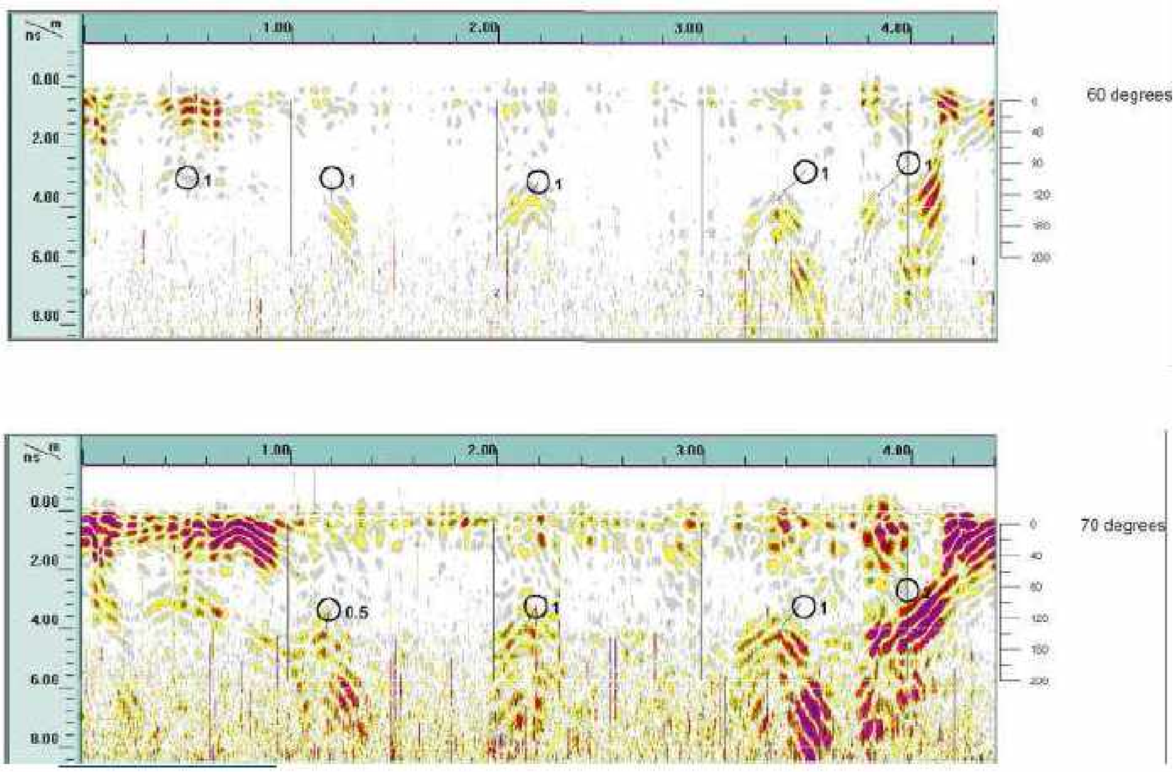

Figure 2. RADAR image of the internal structure of a radiata log and actual location of knots (Source: Parker et al. 2006)

- The use of Laser/LIDAR for determining surface features such as bark on/off at diameter measurement points and the presence/absence of knots. Simple laser dots are now being used on boards to determine grain angle (as way of determining timber stability), it seems that this same technology could be used to determine the presence/absence of important surface features that are currently being determined by human eye.

In New Zealand the process of bucking stems into logs can be largely categoriesed into three platforms:

- Manual – The research to carry out this proposal would have little in the way of improving value maximisation in this area. The research would potentially show the benefits of moving away from manual log making to the other platforms.
- Harvesting Head – In New Zealand, Waratah heads dominate this platform. This research has significant potential on this platform.
- Scan Bench – This group includes the Timberland's KPP, Pan Pac's and Wentia new log bucking system. Clearly this research has more short term applicability to this type of platform.

Although this research is not equally applicable to all of these platforms, research developed around one platform could be in the future applied to others.

CONCLUSION

There are many other quality features such as grain angle (stability), resin pockets, internode wood that could have been included in this business case. However it still clear that significant value is not being captured from New Zealand forest through stems not being accurately measured before log making decision are made. Table 3 summarises the potential value return ($/m3) from accurately detection of; pruned height location, diameter and length measurements and bark on/off status.

Table 3. Potential value gains for improving defect of certain stem characteristics.

Characteristic	Potential Value Gains
Pruned height location	$ 2.30 /m^3
Improved diameter/length measurement accuracy (on harvesting head)	$ 16.02 /m^3
Bark on/off (including bark thickness equation)	$ 0.88 /m^3

The industry, through Future Forest Research, is spending millions of dollars per year developing detailed tree growth and quality models that will be able to model and predict wood quality down to the cellular level. Yet when it comes to determining some relatively simple quality changes in a stem such as the precise location of the pruned length there has been no investment to date. This business case indicates that a relatively small investment in this area could result in a large financial gain.

It is proposed to carry out research in the areas of using RADAR and laser/LIDAR to improve the detection of pruned height, branch location and bark on/off. This work, if successful, could lead on to additional research into the detection of other important stem characteristics.

In Future Forest Research there is always the question of whether this type of work should sit in either the Radiata Pine Management or Harvesting Theme. This area clearly sits in between these two themes, yet it seems that given the relatively fast gains that can be made, it is too important to waste time arguing what management silo to place the work into.

This business case is built on past research and simple analysis, it however still shows that in a couple of areas only small amount of applied research is needed to potentially provide relatively fast returns to the New Zealand forestry industry.

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