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Development of an Improved Grapple Carriage Control System: A Feasibility Study

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EXECUTIVE SUMMARY

The primary goal of the FFR Harvesting Theme is to reduce the cost of harvesting on steep country by introducing new technology that is more productive and cost effective than existing equipment. The secondary goal is to remove workers from the hazardous tasks of manual tree felling, breaking out and unhooking. One way to achieve this is to improve the productivity of grapple yarding, a highly productive cable yarding system that eliminates the need for manual breaking out.

The specific aim of this project was to investigate the feasibility of improved control of the grapple/carriage in order to reduce element times for “position grapple/carriage”, “load” and “breakout” parts of the hauling cycle, resulting in increased daily production. Development of a remote control system for grapple extraction by swing yarder where the grapple/carriage is controlled by the “spotter” (or bunching machine operator) could achieve these aims.

Initial investigations indicated that remote control systems are in use in small processor-tower yarders in Europe. This study addressed the development of a similar remote control system for swing yarders in New Zealand. Based on reasonable assumptions of a swing yarder operation in New Zealand, an increase of 3% in overall hauler productivity could be expected. A cost-benefit analysis of the proposed remote control system indicated costs of less than 2% of the annual total logging system cost. Given these costs and the estimated productivity improvement, this would translate to a decrease in the effective logging rate of up to one dollar per tonne. At the highest estimated cost of the system, the break even usage rate was 42% of productive time.

INTRODUCTION

The forest industry has identified harvesting on steep country as a priority, requiring a concerted collaborative research effort between industry and government to improve productivity, reduce costs and lower the cost and social impact of accidents in order to improve the profitability of forestry on steep land in New Zealand. As harvesting increasingly moves on to steeper land (>20% slope) and smaller more isolated holdings that were planted during the 1990s, the challenges of maintaining international competitiveness with existing logging methods (that have changed little in 50 years) will increase. Overseas harvesting research and equipment development is focused primarily on mechanised operations on flat terrain. New Zealand's unique combination of soils, terrain, climate, forest type and infrastructure means we cannot rely on overseas research to solve our problems.

On 30 October 2009 the Primary Growth Partnership (PGP) Investment Advisory Panel approved the first phase of a new PGP programme "Innovative Harvesting Solutions". The programme focuses on the industry's need to improve the profitability of forestry on steep land in New Zealand, and to improve the safety of harvesting operations on steep terrain, which are often physically demanding and in hazardous environments. The research aims to find ways of eliminating the most dangerous and physically demanding jobs and making the work more attractive to people.

The Programme has been divided into three inter-related Objectives:

1. Mechanisation on steep terrain.
2. Increased productivity of cable extraction.
3. Development of operational efficiencies.

The purpose of FFR's harvesting theme Objective 2 is to reduce the cost of the extraction phase of cable harvesting on steep country by introducing new technology that is more productive and cost effective than existing equipment. The secondary goal is to remove workers from the hazardous tasks of breaking out and unhooking.

This project, Task 2.2, is one component of Objective 2. The specific aim of this project is to decrease yarder element times for "outhaul", "position grapple/carriage", "load" and "breakout", resulting in increased production within existing systems. These aims will be achieved by developing an improved grapple/carriage control system where the grapple/carriage is controlled by a spotter or bunching machine operator.

Improving grapple control may also increase the use of grapple yarding systems and consequently eliminate manual "breaking out", one of the most physically demanding and dangerous roles in harvesting on steep terrain. Improving grapple control complements other projects in the FFR Harvesting Theme programme aimed at improved load accumulation (Task 1.1) and better vision for hauler operators (Task 2.1).

This report describes a feasibility study carried out to investigate the economic and technical feasibility of a technological solution, namely a remote grapple control system for swing yarder grapple extraction.

METHODS

Engineering developments often follow five distinct stages:

1. **Feasibility** – brainstorming what's out there that can be adapted, development of concepts, etc.

2. **Simulation** – computer modelling to test if a concept can deliver the expected benefits, identifying the flaws and ability to develop some very early stage prototype.

3. **Alpha prototype** – development of a lab prototype to test the concept and develop the specifications for a working model.

4. **Beta prototype** – development of a working prototype that can be field tested under carefully monitored conditions and used as the basis for a commercial design.

5. **Commercialisation** – going from the Beta prototype to production of the commercial unit, and securing uptake of the unit by industry through technology transfer.

A feasibility study is an investigation into whether or not a proposed development is possible, and how successful it is likely to be[1]. Commonly there are four main feasibility criteria, typically covering technical, social, economic and operational aspects, but there may be other considerations depending on the nature of the project. In this feasibility study, titles and approach are based on comprehensive feasibility study guidelines issued by the US Department of Energy[2].

This report covers stages one and two (feasibility and simulation) of the development process outlined above. The feasibility study methodology used in this report is described by the following headings:

- Current systems and processes
- Description of improved system
- Assumptions and constraints
- Cost-benefit analysis
- Potential markets and scale-up issues.

CURRENT SYSTEMS AND PROCESSES

Cable Yarding Systems

Yarders (commonly called haulers in New Zealand) can be categorised as stationary or mobile[4]. Most modern yarders are of the mobile type, and have either an integral fixed tower (tower yarder) or a swinging lattice-crane (swing yarder).

Table 1 summarises some of the differences noted between grapple yarder and tower yarder skyline systems as noted by Conway [7] and MacDonald Conway[8].

Table 1: Some differences between grapple yarder and skyline (tower) systems[7, 8]

Grapple Swing Yarder	Tower Yarder
Can operate from small skids (and roads)	Needs larger skids
Highly mobile	Less mobile
Fast outhaul/inhaul speeds due to interlocked drums	Slower inhaul/outhaul speeds
Operator needs to see logs or trees for best productivity – suited to shorter haul distances	Works at greater yarding distances. Operator does not need to see the logs or trees.
Highly productive with a skilled operator and in bunched timber, short haul cycles.	Less productive, longer haul cycles, capable of large haul volumes

An informal survey by Finnegan and Faircloth[5] in 2002 suggested that 75% of the current cable haulers working in New Zealand were of the tower or pole design (160 haulers). Of the remainder 23% were the swing yarder type (49 haulers). Five excavator-based haulers (2%) were recorded. A more recent sample of FFR members surveyed in 2009 and 2010[9] recorded 64 tower hauler operations and 35 swing yarders in New Zealand, indicating that the proportion of swing yarders had increased marginally to 35% of total hauler operations. The FFR benchmarking study in 2010[9] also illustrated some of the differences in use and performance between swing yarders and tower systems (Table 2). This indicates that swing yarders are used in settings with shorter haul distances, higher volume per hectare and larger piece size, resulting in higher hourly productivity.

Table 2: Performance differences between swing yarder and tower yarder systems[9]

Factor	Swing Yarder	Tower Yarder
Average piece size (m^3)	2.5	2.1
Extraction distance (m)	180	216
Volume per hectare (m^3)	524	502
Productivity (tonnes/hour)	26.5	21.0

A number of rigging systems are used with both towers and swing yarders, but in general, the majority of hauler operations do not use grapples. A recent survey by Harrell and Visser[6] of 37 hauler operations revealed that only 10% of those surveyed had recently used a grapple in their operations (within the last 5 years). This indicates that there is a big opportunity to increase the use of swing yarders, and more specifically grapple yarders, in New Zealand.

Cable Logging Carriages

Cable logging carriages have traditionally been divided into slackpulling and non-slackpulling types, with non-slackpulling carriage systems described as either choker- or grapple-based. A schematic of the different skyline carriage types is shown in Figure 1. Different configurations are available and are often used selectively, depending on a number of factors. These include the kind of cable rigging system used, yarding conditions (long vs. short haul, uphill vs. downhill, etc.), the terrain and available deflection, as well as operator/contractor familiarity with the system.

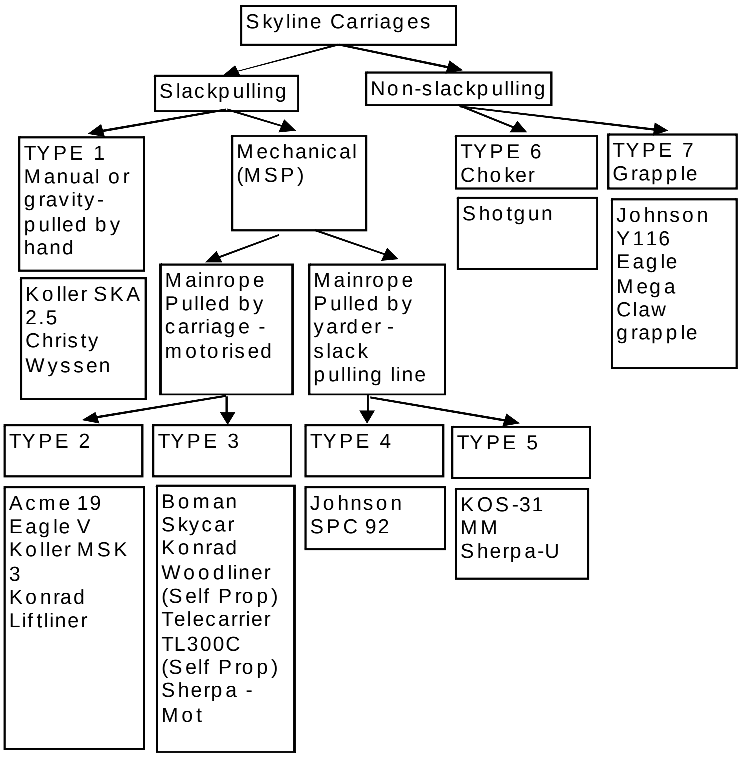

Figure 1: Skyline carriage schematic (with examples) (after Studier, and FIT)[3, 4].

Grapple Design and Use

In general, grapples are used almost exclusively by swing yarders (commonly called grapple yarding), and all the other carriages can be used by both swing yarders and tower yarders.

A common grapple design is shown in Figure 2. "Spotting" the grapple onto the log or bunch has been likened to controlling a load suspended between two points[10]. Slackening or tensioning either the main rope or tail rope while applying sufficient brake to the opposing rope causes the grapple to move closer to or away from the yarder (Figure 3). Slackening both ropes together causes the grapple to lower, and then tensioning the grapple opening cable (tagline) will close the grapple. Additional manipulation (swinging the yarder crane during outhaul) is required to turn the grapple, or move it laterally.

Due to the complexity of these controls, grapple yarding commonly involves the use of a "spotter" who calls instructions to the yarder operator. The yarder operator must then also react to radio instructions from the "spotter", as they are often unable to see the logs they are attempting to grapple.

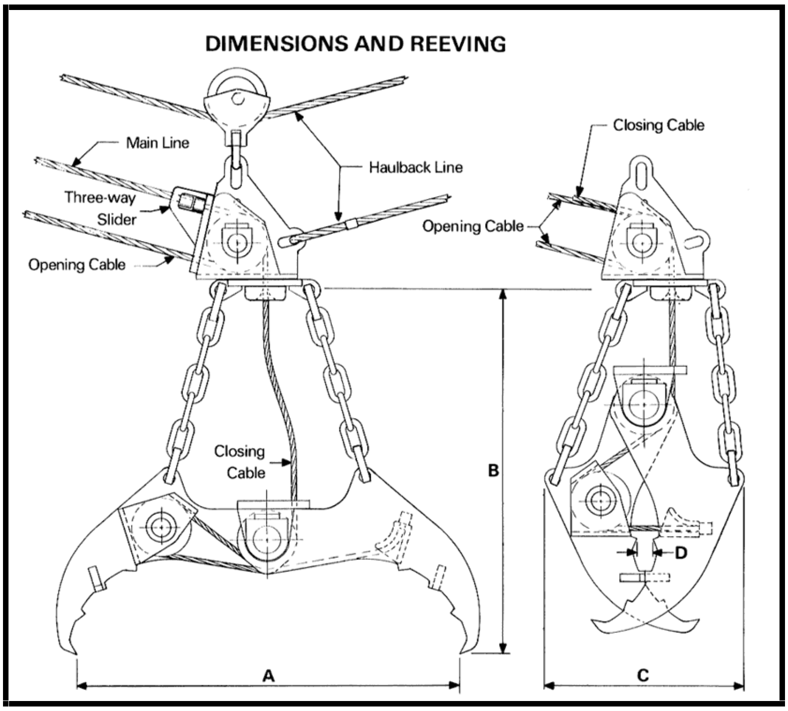

Figure 2: Johnson Grapple design[12].

Use of a “spotter” to grapple trees that are unseen or poorly visible to the yarder operator is a slower process than if the yarder operator was able to see the grapple and the tree [10]. Evidence suggests that this is largely because of a time delay between instructions and the effect of the operator’s actions as well as difficulties with communication of instructions.

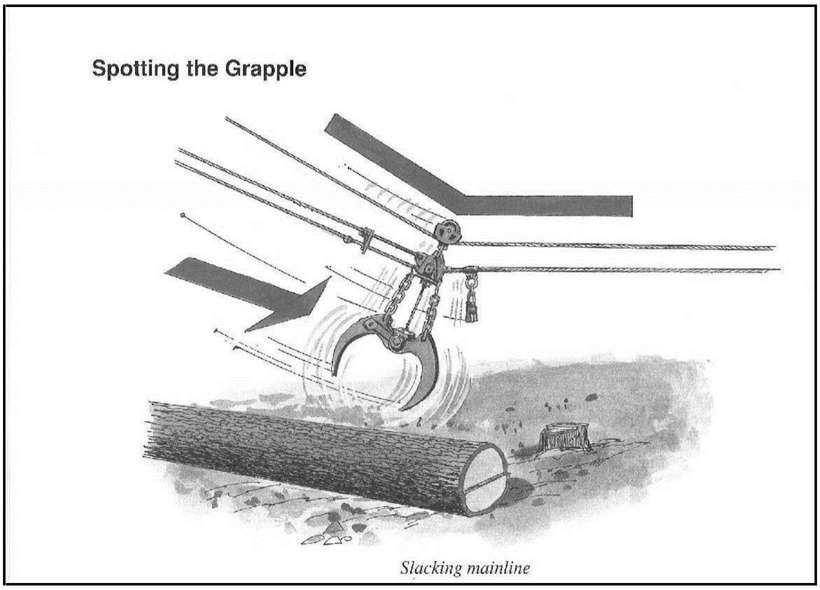

Figure 3: Spotting the grapple into position on the tree stem[10].

An additional factor affecting grapple time is that the standard grapple design means the grapple tines are free to rotate unless restrained, for instance by a light chain connected to the butt rigging/tail rope (a method used by some contractors). Positioning the grapple or orientating it to the tree can be a reflection of the skill of the operator/spotter as well as a function of chance. Some contractors shorten one of the grapple support chains by one link, causing the tip of one tine to sit lower than the other. This forces the grapple into a position where cable tensions will cause it to turn after it contacts the ground (Kinney, pers.com). Operationally, the grapple is dropped to the ground during outhaul just before it contacts the target tree rather than lowering the grapple directly from above.

For the above reasons, it is proposed that it would be more productive if the manual spotter could operate the grapple directly through remote control. Discussions were held with current grapple yarder contractors and further investigations were made into remote carriage control systems.

Productivity Concerns of Grapple Yarder Contractors/Operators

Discussions were held with several grapple yarder contractors/operators in New Zealand (contractors Kinney, Harvey, Hancox, Whyte, McCormack and Barnes). When asked to identify their biggest concerns, three of the six contractors noted the following issues relating to grapple yarding:

- Planning – unsuitable setting selection and landing location by company planners.
- Operational system – Grapple yarders work best in an unconstrained environment e.g. piling trees in the chute or at roadside.
- Operator training – operator ability is seen as a key factor for yarder productivity. Operators learn "on the job".
- "Spotter" safety – this was identified as an issue when they are close to the grappling area.

In summary, chokers are sometimes used in preference to a grapple. This may be for a number of reasons:

- Chokers were often used by swing yarder operators in areas close to the tail hold, and in other areas where a grapple was ineffective, such as gullies and dips where trees might be crossed and small pieces were to be extracted (unbunched).
- Large piece size and/or large bunch size or windrow bunching may provide sufficient production to match the processing system production. Grapples are seen as being inefficient for grappling from a large bunch. Chokers can be used to hook two or three trees consistently. In bunched wood, breaker-out safety is increased and workload reduced.
- A choker may be attached to the tail rope end of the rigging for hooking trees at the far end of the haul corridor close to the tail hold.
- Breaker-outs are seen as a necessary resource, and skills and personnel need to be retained for subsequent settings or harvest areas.
- A trained grapple operator may not be available.
- Setting terrain is unsuitable (e.g. a convex terrain profile).
- Poor visibility of stems due to gullies, standing scrub and vegetation.

Despite the widespread use of chokers in the New Zealand logging industry, grapples may be used more productively than chokers in the following situations:

- Reduced hooking (grappling) time with trained spotters and good spotter/operator communication.
- Larger piece size means a single tree haul is economic, due to faster inhaul time.
- Safety concerns for breaker outs (heavy branching, rough terrain).
- With head-pulls and where there was heavy branching around the grappling point, the grapple would be dropped to the ground, so as to break a path to the tree.
- Problems recruiting suitable breaker outs (high turnover, absenteeism, substance abuse, fitness).
- Use of grapple-sized bunches in smaller piece size.
- Trained grapple operator available.
- Suitable setting terrain (short even or concave slopes).

DESCRIPTION OF IMPROVED SYSTEM

Communication systems between the breaker outs and the yarder operator have traditionally involved Talkie Tooter systems[15] and more recently hand-held radios. The Talkie Tooter enables communication through audible signals either way but has one-way voice communication from the breaker out to the yarder operator only. Communication and activation of skyline carriage functions has been achieved in three ways:

- Yarder ropes
- Timer delays
- Radio controls

Radio controls have enabled breaker outs to control the main rope or drop line in slack pulling carriages as well as the skyline or main line clamps in clamping carriages. Remote systems that are integrated with the yarder's computer system have become a standard feature in European yarders of the Processor-Tower Yarder (PTY) design[13]. A PTY has an integral boom and arm with processor attachment, mounted on the yarder frame and operated by the yarder operator (Figure 4).

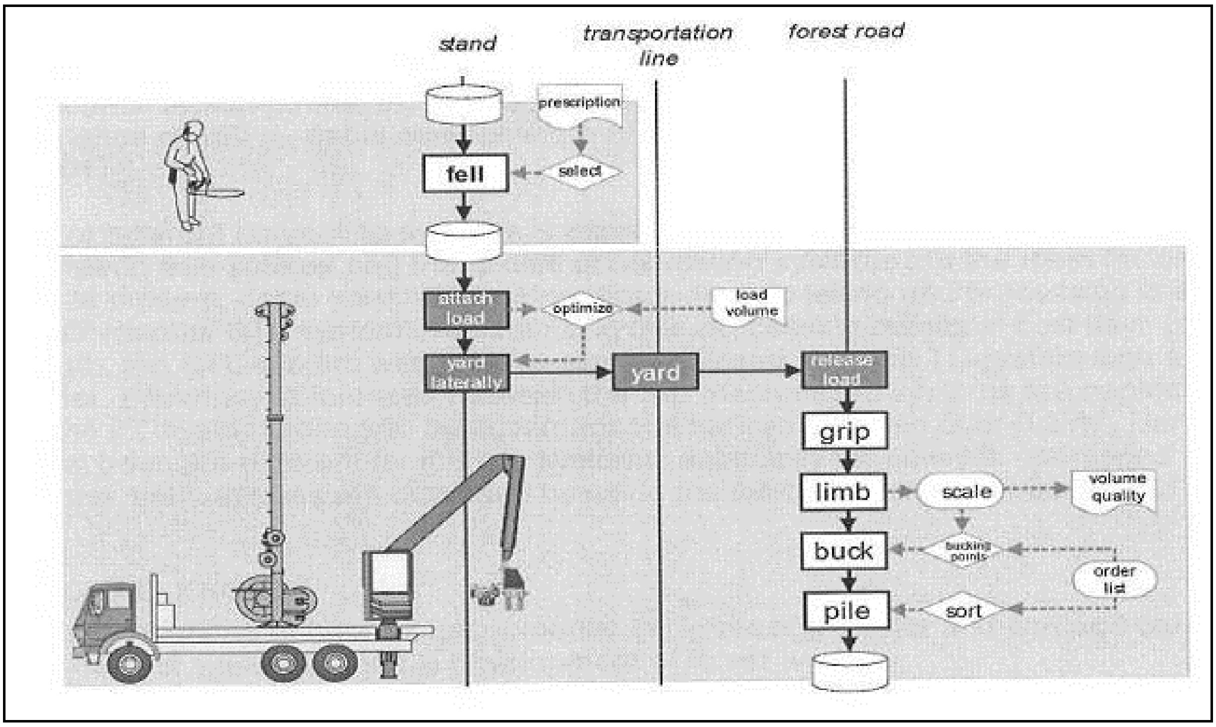

Figure 4: A tree-length PTY system[13]

In several European Processor-Tower Yarder systems such as the Synchrofalke hauler the breaker out has control (via radio remote control) of the yarder drums as well as the functioning of the skyline carriage (Figures 5 and 6). [14] [16] [17]

In addition to the manual controls in the cab, there is also an automated carriage return function. The distance from the tower to the carriage, and the carriage speed, are derived from an encoder in the main rope sheave on the tower. Information is displayed in the cab. Systems now include range programming, which tells the drum control computer at what point carriage speed should change. The system enables the yarder operator to perform another function, namely that of processing with a harvester head. Such systems are now well established in PTYs in Central Europe[13]. Figure 7 shows the sequence of operation in a PTY system.

Figure 5: A Synchrofalke control unit[16].

Figure 6: The Koller MultiMatik system[17].

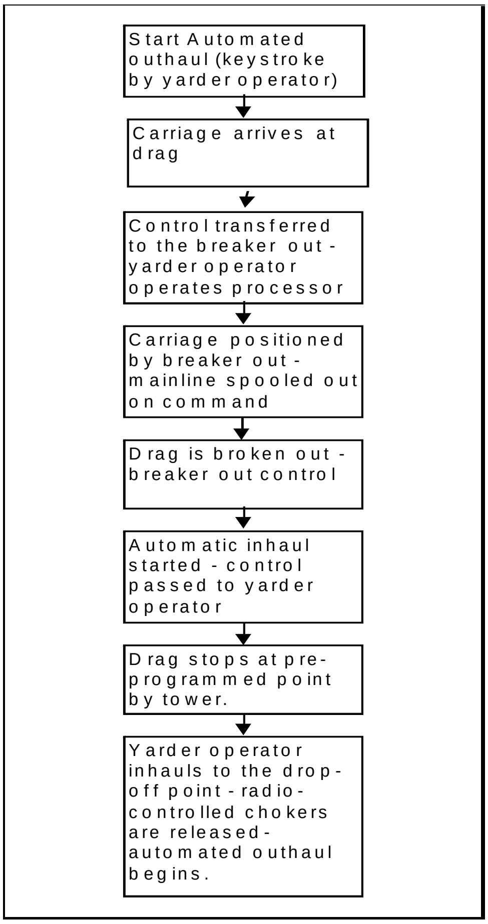

Figure 7: Sequence of operation with a PTY system[14].

The improved system proposed in this project is a remote control system for a grapple swing yarder, which enables the "spotter" to control grapple functions and some yarder functions remotely, similar to the sequence of operation in a Processor-Tower Yarder.

ASSUMPTIONS AND CONSTRAINTS

Expected Benefits

- It is expected that a prototype control system will show improvement (i.e. reduction) in the grapple load element of hauler cycle time for both uphill and downhill yarding by experienced and novice yarder operators. As a result of improved grapple time, yarder productivity in swing yarder-grapple operations is expected to increase.
- Benefits may also arise through making the grapple rotation itself more controllable. The grapple is normally free to rotate, and this is often problematic for locating the grapple onto the tree stem.
- There may be reduced stress on the yarder operator, arising from improved control.

Assumptions regarding Improvement to Grapple Time

- A remote control system based on spotter control of all the grapple functions and some yarder functions can most easily be developed and used with a yarder that is computer controlled, i.e. is equipped with an PLC (Programmable Logic Controller) or micro-controller (such as a Harvestline hauler).
- Historical data were used to estimate the effect of system productivity gains made through a reduction in grapple time using remote control, assuming better vision. Mean grapple times were derived from Howard's comprehensive investigation of grapple yarding productivity in coastal British Columbia in 1991.[11] This large dataset comprised 16 studies, 12,095 yarder cycles, in both uphill and downhill extraction (Table 3).

Table 3: Average grapple times for different haulers and haul distances (Ref: Howard, 1991).
(N.B. Observations in bold italics were excluded from this analysis as unrepresentative).

Study (Hauler Type)	Stratum No.	150m Haul Dist. (min)	200m Haul Dist. (min)	Grapple Time Increase (%)
Madill 044	1	0.59	0.91	54%
	2	0.32		
	3	0.53	0.64	21%
	4	0.62	0.92	48%
Cypress 7280B	1	0.35	0.43	23%
	3	0.33	0.39	18%
	4	0.51	0.71	39%
Cypress 7250	1	0.67	0.85	27%
	4	0.33		
Cypress 7220	***1***	***1.48***	***2.52***	***70%***
	2	0.31	0.35	13%
Skagit GT3	1	0.41	0.48	17%
Madill 144	2	0.42		
	3	***2.14***	***3.61***	***69%***
Madill 122	2	0.35		
	3	0.44	0.53	20%
Average		0.44	0.62	41%

Note: Stratum 1: Uphill 1; Stratum 2: Uphill 2; Stratum 3: Downhill 1; Stratum 4: Downhill 2.

- To simulate the effect on grapple time of remotely controlling the grapple functions of the yarder, the mean grapple time derived from the large Howard dataset (0.628 min) was reduced by a percentage value. This value represented an assumed change/reduction in mean grapple time which was derived from data from an earlier FFR study of the Kelly Logging Ltd steep slope feller buncher in a swing yarder operation in New Zealand (Evanson and Amishev)[19].

- A conservative reduction in grapple time was estimated in terms of the variability of grapple times found in grapple yarding operations for both bunched and unbunched wood. This value was assumed to be 0.25 of one standard deviation of the mean grapple time derived from the Kelly study. The distribution of grapple times for unbunched wood from this study, and an example of the calculation of the reduced mean grapple time is shown in Figure 8. These data showed a base standard deviation of 0.305 minutes. Applying the reduction of 0.25 SD (0.25 x 0.305 = 0.076 min) to the mean of 0.576 min gave an estimated grapple time using the remote control system of 0.50 min. As a percentage of the mean grapple time for unbunched wood, this was equivalent to a reduction of 13% in grapple time.

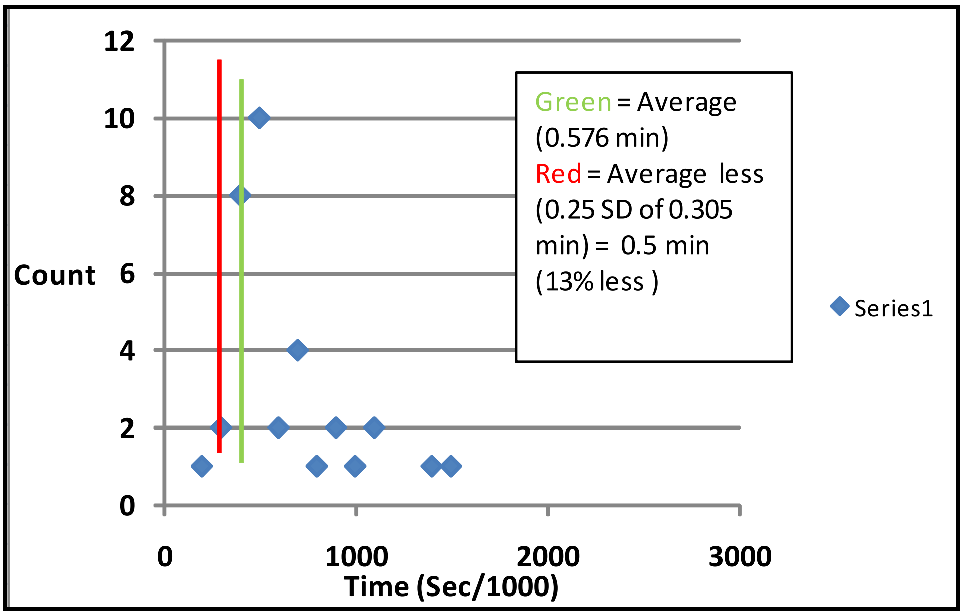

Figure 8: Distribution of grapple times for unbunched wood from the Kelly study. This shows the effect of a reduction of 0.25 standard deviation of the mean grapple time. (Ref: Evanson and Amishev 2010[19]).

- This calculation was also done for grapple times for bunched wood from the same study. The reduction in grapple time for bunched wood was calculated to be 15%, giving an average reduction in grapple time for both bunched and unbunched wood of 14%.
- The variation in grapple times in this study was similar to that reported in other time studies of grapple yarding operations, where a standard deviation value of 0.3 min for unbunched grapple times was reported (with a mean value of 0.39 min)[20]. In comparison, in bunched wood the standard deviation of grapple times reported was 0.42 min (with a mean value of 0.64 min)[19].
- Variation in grapple time with haul distance was also considered in this analysis. The Howard dataset showed an average increase in grapple time of 40% for a 50 m increase in haul distance from 150 to 200 m. Consequently, 200 m was used as the base average haul distance with which to compare non-system and system-assisted productivity for two reasons. Firstly, it was felt that 200 m represented the range of haul distances common in New Zealand yarding operations, and secondly any improvements due to the grapple remote control system would be better reflected at longer haul distances.
- Table 4 shows the values used to derive productivity costs for system/no system scenarios. The element times for the grapple yarding cycle time were held constant with the exception

of the grapple load element. The average grapple time from the Howard dataset for 200 m (0.628 minutes) was used for the base system. The 14% improvement in grapple time derived from the analysis of the Kelly dataset was applied to determine the mean grapple time for the improved system (0.540 min).

Table 4: **Kelly data: Inhaul, Outhaul, Other elements, and system costs used in the analysis.**

Cycle Element (min)	**Value**
Inhaul	0.995 min (200 m)
Outhaul	0.514 min (200 m)
Grapple	0.628 min Base (No system) 0.540 min System assisted
Other values	0.720 min
Total Time	2.857 min Base (No system) 2.769 min System assisted
Other variables	
Butts/haul	1.06
Piece size (m3)	1.92
Productive hours/day	6.0 PMH
Total logging system cost	Base total annual logging system cost: $1,864,525 /year Estimated total capital costs: ($60,000, $80,000, $120,000) converted to annual system costs and added to base system cost.

Costing Assumptions

- Base total annual logging system cost was calculated at $1,864,525 ($7,934 per day).
- Actual costs for the remote control system were unknown, so a range of estimated capital costs were used, namely $60,000, $80,000 and $120,000.
- Total cost comprises approximately 40% hardware and 60% software components.
- These capital costs were converted to annual system costs and added to the base system costing, giving additional annual costs of $14,787, $19,017 and $27,475, respectively. This represents the expected range of cost components of the improved system to users.
- A six-year economic life for all equipment was assumed.
- As was a 5% interest rate on finance.
- No change was assumed in costs of other components of the harvesting system. A “spotter” may not always be in a position to see where the grapple is operating, such as in deep gullies. In such situations, the grapple may have to be converted to chokers and a breaker out will be required to hook on the felled trees. Therefore no changes to crew labour costings were made.

RESULTS OF COST BENEFIT ANALYSIS

Estimated Costs

Estimated capital costs for the remote grapple system are given in Table 5. The system development cost has been included in the estimates of the remote control system and control valve modifications.

Table 5: Estimated Capital Costs – to be spread over a nominal 6-year operational life.

Item	No required	Cost per item ($)	Total Cost ($)
Remote control system (wireless)	1	60,000	60,000
Modem/router	2	250	500
Modifications to control valving	1	30,000	30,000
Installation and testing	1	$1,000	$1,000
Total			$91,500

Calculated Benefits

The calculated reduced grappling time of 14% (0.087 min/cycle) would result in a productivity gain from 256.4 m^3 per day up to 265.5 m^3/day (+3.2%). This reflects the scale of overall improvement possible when small element time gains (of 5 seconds) are made to multiple recurring cycles (over 130 extraction cycles per day for a swing yarder operation).

Sensitivity Analysis

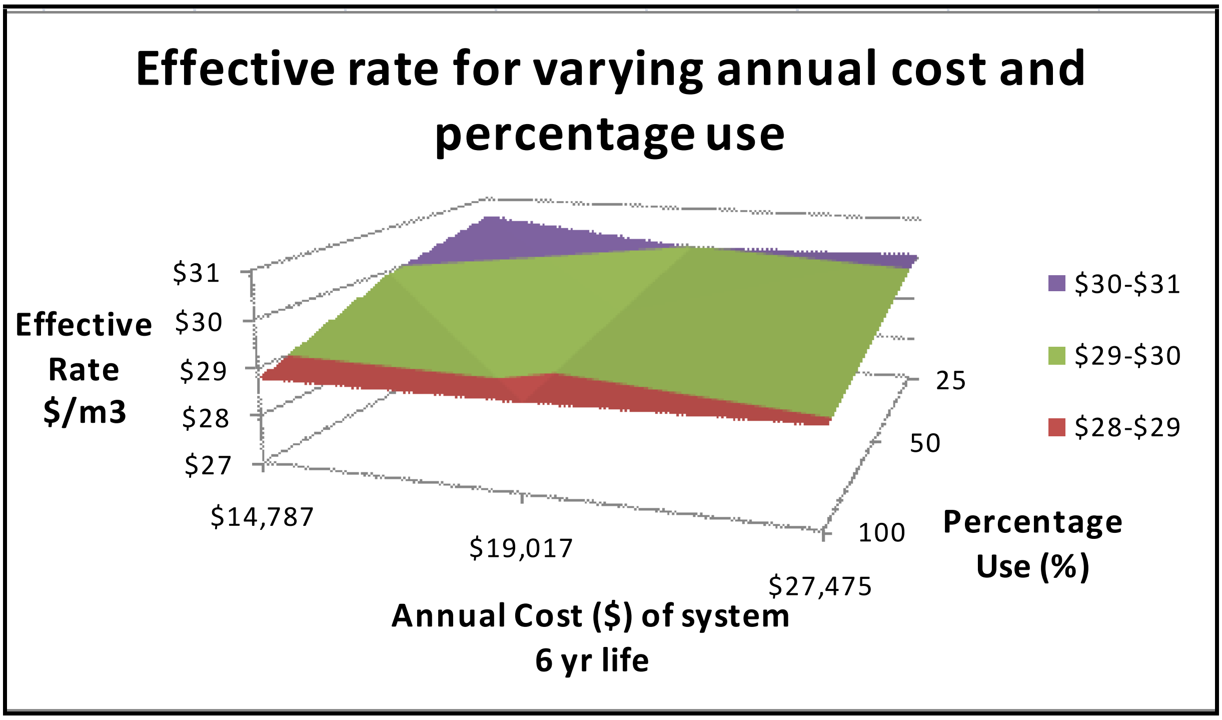

Figure 9: Effective rate for a range of annual costs and varying use of a remote control grapple system.

The change in effective logging rate (based on improved production rate) was calculated for varying usage rates (Figure 9). This reflects occasions when the operator can grapple trees unaided, or it is not possible for the spotter to assist with remote control.

The base logging rate for no remote system was $30.94/m^3. Over the range of usage from 25% to 100%, the logging rate advantage is of the order of $1.00/m^3 (green shaded area on the cost-productivity surface). The cost-benefit model was relatively insensitive to annual cost because the remote control system costs were only 0.8-1.5% of annual logging system costs.

Break even Analysis

A break even analysis showed that at the highest total cost value, the remote control system would have to be used for less than 50% of operating time to justify installation of the system. At the highest estimated cost of $120,000, the break even usage was only 42% (Table 6).

Table 6: Breakeven analysis

Capital Cost $	Annual Cost $	% Use for break even
$60,000	$14,787	23%
$80,000	$19,017	29%
$91,500	$21,450	33%
$120,000	$27,475	42%

Net Present Value Analysis

An analysis of the net present value of the investment in a new remote grapple control system was undertaken, assuming a six-year life of the system, 50% annual usage and annual additional cash flows of $33,083. The annual costs were escalated by an estimated annual maintenance cost of $5,000. The net annual benefits of the system were discounted at an assumed discount rate of 8%. This showed that at even at the highest capital cost, the net present value was positive (Table 7).

Table 7: Net Present Value of Investment

Capital Cost $	Annual Cost ($) plus maintenance	NPV $
$60,000	$14,787	$67,129
$80,000	$19,017	$47,129
$120,000	$27,475	$7,129

POTENTIAL MARKETS AND SCALE UP ISSUES

Current wood availability forecasts indicate that by 2020 the national annual harvesting volume could increase to 30 million cubic metres from the current level of around 26 million cubic metres. Of this total additional volume it has been estimated that 58% will be from cable hauler operations. Assuming an average daily production rate for each cable logging operation of 250 tonnes per day (57,500 m^3 per annum) it is estimated that an additional 11 cable logging operations will be required per year, or one every four weeks, to realise this potential increase in available cable logging.

The spotter remote control system for grapple functions and some yarder functions could most easily be developed, and is most compatible with haulers that are computer-controlled (i.e. equipped with Programmable Logic Controller, PLC). There are currently only four swing yarders that have these systems, having been converted by Brett Henderson of Brett Henderson Limited (BHL) and Tony Taylor of EMS Ltd. [18] In addition, all Harvestline haulers produced (10-12 in New Zealand) have been equipped with these systems.

As this would limit this development to a small potential market, further investigations will be undertaken to apply this remote control system to all haulers using electric controls, thus widening the market potential. A current estimate for the number of swing yarders in use is 45 to 50 machines, with 10 – 12 excavator conversions (Chris Hancock, pers.comm.) to give a total of 55-62 machines. It is possible that future development of swing yarders such as the Brightwater Engineering Ltd Madill 124 might incorporate similar control systems, and so be capable of modification to use spotter remote control.

Scale-up issues include:

- Compatibility of the new remote system with previous versions of PLC system in terms of suitable modems available and possible changes to software.
- Skills in programming PLC systems in haulers are limited in New Zealand.

If tower hauler systems start to adopt the new hydraulically controlled grapple carriages designed for 2-drum and 3-drum haulers, the next logical development step could be remote control of the grapple.

CONCLUSIONS

Remote control systems for breaker outs have been in widespread use with processor-tower-yarder type haulers in Central Europe since 2000[13]. The technology for these systems is not new, or restricted to harvesting, as many cranes and winches can now be remote controlled.

The aim of a spotter remote control system is to reduce the time losses occurring from the use of the spotter, namely poor communication and inevitable time delays in carrying out instructions. Effectively, there would be more productive cycles (i.e. outhaul, grapple, inhaul).

The economic analysis of a swing yarder application showed that on the basis of some reasonable assumptions, including a relatively small reduction in average grapple time of 14% as a result of the remote control of a swing yarder's grapple functions by the spotter, an increase of 3% in overall hauler productivity could be expected.

With an estimated maximum capital cost of $120,000 over an expected 6-year life, the annual costs of the proposed remote control system amounted to less than 1.5% of the annual total logging system cost. Given these costs and the estimated productivity improvement, this would translate to a decrease in the effective logging rate of up to one dollar per tonne. A cost benefit analysis showed that a remote control system would require a usage rate of only 42% to break even.

It has been noted that the spotter remote control system for grapple functions and some yarder functions is most compatible with haulers equipped with suitable micro-controllers or suitable PLC systems. Haulers equipped with suitable micro-controllers or PLC systems currently number only about 14-16 machines in New Zealand. If this remote control system could be applied to all haulers using electric controls it would considerably widen the market potential for this development.

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