HARVESTING TECHNICAL NOTE

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Matching Rigging Configurations to Harvesting Conditions

Summary

Worldwide there are significant differences in cable yarding practices, types of machines and the selection of rigging and accessories used. Cable logging as it is practiced in New Zealand differs in several respects from that in the Pacific North West and central Europe, especially in the preference given to rigging configurations such as North Bend, running skyline and highlead. Results are presented of a Delphi analysis of New Zealand cable logging practitioners' rankings of the advantages and disadvantages of the common rigging configurations. Preferred rigging configurations for different stand and terrain conditions are presented. This report provides logging practitioners and planners with guidance as to which configurations are most suited to specific conditions.

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INTRODUCTION

Cable yarding practices vary widely worldwide from the Pacific North West of the USA to Europe. In the Pacific North West there is a preference for large tower yarders and the use of motorised carriages when and where possible. In comparison, central Europeans prefer more automated small or medium-sized yarders with mechanical slack-pulling carriages.

Cable logging practiced in New Zealand differs in several respects from the USA and Europe, especially with the preference in New Zealand towards rigging configurations such as North Bend, running skyline and shotgun. The reasons are various, but the nature of *Pinus radiata*, the value of the wood recovered, the features of New Zealand's terrain and climate, and the reliance on plantation forestry, have been identified as influencing factors (Liley, 1983).

In this project a survey of logging practitioners was undertaken aimed at determining which cable rigging configurations are commonly known and used in New Zealand, and the advantages and disadvantages of those configurations. This report presents the survey information relating the preferred rigging configurations to stand and terrain conditions. The purpose of the study was to provide guidance to logging practitioners and planners in deciding which configurations are most suited to specific locations.

METHODS

The rigging configurations referred to in this report were originally presented by Studier and Binkley (1974) and Studier (1993). Interviews were conducted using a structured questionnaire during visits to active logging operations, forest management offices, and equipment manufacturers.

The questionnaire comprised two parts: the first part gathered information about the logging practitioner's knowledge and use of different cable rigging configurations and the perceived advantages and disadvantages of the common rigging configurations in use. These results were presented in an earlier FFR report (Harrill and Visser, 2011).

The second part of the study used an expert panel to synthesise common elements of the individual responses gathered in the survey. Preferred rigging configurations are presented for various operating scenarios such as the amount of deflection in a setting, short or long haul distances, uphill or downhill yarding and other operational constraints. The results summarise a total of 50 completed responses, of which 17 were crew owners, 13 were crew managers (forepersons), 6 were yarder operators and 14 were forest company planners.

Delphi process – A way to gain expert opinion

The Delphi Method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts to converge towards a commonly accepted result. The Delphi Method is based on the principle that structured judgments and decisions from a selected group of "experts" are more accurate than those from individuals or unstructured groups.

In the first part of this project, the perceived advantages and disadvantages of each the common rigging configurations from the survey were in some

cases not clear, contradictory, or potentially unfounded. A panel of five individuals known to have deep knowledge and wide experience of cable logging was selected by the researchers. The goal of the panel was to synthesize the responses from the interviews and provide their expert opinion to resolve conflicting responses and viewpoints over the course of several discussion rounds.

The panel members comprised:

- Daniel Fraser, Hikurangi Forest Farms Ltd, Gisborne
- Alan Paulson, HarvestPro NZ Limited, Gisborne
- Brian Tuor, Independent Consultant, Washington, USA
- Brett Vincent, FITEC, Rotorua
- Rob Wooster, Moutere Logging Ltd, Nelson

The survey results (Harrill and Visser, 2011) were presented to the panel in an interactive ranking spreadsheet. This was developed for use during the Delphi process (Dalkey and Helmer, 1962). In the first round, the panel members ranked each response for the advantages or disadvantages of each rigging configuration on a four-point scale (1: strongly disagree to 4: strongly agree). Each of the experts remained anonymous to one another, but each was able to view how others had ranked the responses once each round was complete.

In Round Two, panel members were given the opportunity to change their rankings and provide comments about why they either retained or changed their rankings. The Delphi process was complete once the expert panel members reached a consensus on rankings after Round Three.

RESULTS

Stand and Terrain Factors

Deflection

Deflection is the leading criterion for appropriate rigging configuration selection, since it dictates payload capacity and ground clearance. Deflection is expressed as a percentage of the horizontal span length and commonly ranges between 5 and 15%. Low deflection is defined as less than 6%, and high deflection is greater than 15%.

For low deflection scenarios, highleading was most popular (Figure 1). In fact, low deflection scenarios were the only situation where highleading was preferred. As deflection increased, the preference for highlead reduced and other configurations were preferred. Running skyline was the second choice configuration in low deflection conditions. North Bend, shotgun and motorised carriage configurations were not preferred in low deflection settings.

In medium deflection situations, North Bend was the most preferred configuration, followed by running skyline. This is a function of the versatility of these two configurations.

For high deflection scenarios, North Bend was also the first choice, with shotgun the next most popular as deflection increased from medium to high. The shotgun configuration was never the first choice, but greater consideration should be given to this configuration as deflection increases, or slopes become steep enough. Similarly, motorised carriages had a growing preference as deflection increased, and were most preferred in very high or extreme deflection scenarios.

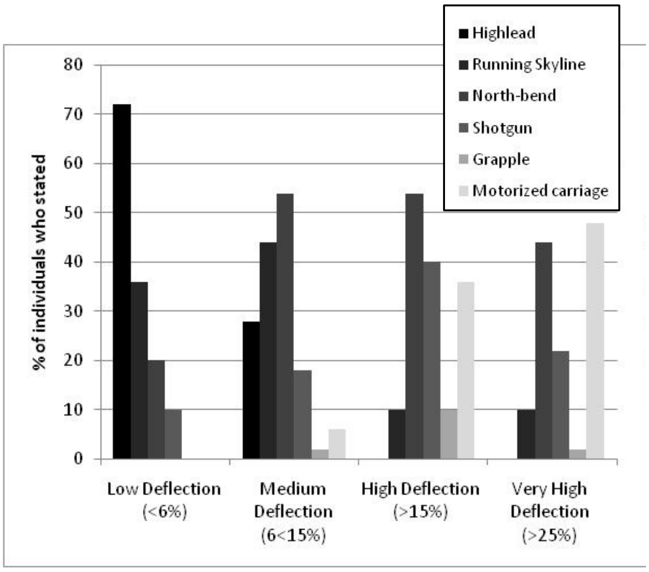

Figure 1: Preferred rigging configuration given percentage deflection.

Yarding direction

Participants' preferences for uphill and downhill yarding are given in Table 1. For uphill extraction the preferred configuration was shotgun and motorised carriage. For downhill yarding the preferred configuration was running skyline. The versatility of North Bend was demonstrated with a similar number of respondents choosing this configuration for both

uphill and downhill yarding (due to good control of the drag).

Table 1: Preferred rigging configurations for uphill and downhill yarding.

Rigging Configuration	Uphill (#)	Downhill (#)
Shotgun	34	0
North Bend	19	20
Motorised carriage	15	2
Running skyline	7	32
Grapple	4	9
Highlead	3	10
Mechanical carriage	2	0
South Bend	2	1
Slackline	2	6

Short or Long Haul Distances

Survey participants were asked which rigging configurations were preferred for short and long hauling distances (Table 2). Most individuals (32) agreed that running or "scab" skyline was a good option for short distances. Other options for short haul distances included highlead (15), and grappling (13). The preferred configurations for long haul distances were North Bend (29), shotgun (25) and motorised carriage (15).

Table 2: Preferred rigging configurations for short and long haul distances.

Rigging Configuration	Short (#)	Long (#)
Running skyline	32	9
Shotgun	19	25
Highlead	15	1
Grapple	13	2
North Bend	12	29
Motorised carriage	7	15
Slackline	2	7
Mechanical carriage	1	2

Operational constraint scenarios

Part of the questionnaire asked individuals which rigging configurations had the ability to handle certain operational constraints or challenges. Excluding all other variables, participants then stated which configuration they thought would work best given the scenario.

Extracting across broken terrain

The presence of incised gullies and other broken terrain is a common challenge faced in New Zealand cable logging operations. Sometimes crews have to pull across several incised gullies or small ridges, which require the load to be raised and lowered during inhaul to navigate obstacles. Most participants stated that North Bend was their preferred rigging configuration for this scenario, but motorised carriages were also given strong consideration (Table 3).

Extracting around a native bush boundary or other obstacle

Pulling away from, or around, obstacles like native bush boundaries or rock faces often requires the configuration to have lateral yarding capability. Again North Bend was the preferred choice for most participants due to its bridling capability. The motorised carriage was also highly regarded due to its slack pulling capabilities (Table 3).

Table 3: Preferred rigging configuration for broken terrain, native bush, and Stream Management Zones.

Rigging Configuration	Broken Terrain (#)	Around Native Bush (#)	Over SMZ (#)
North Bend	27	33	15
Motorised carriage	16	21	33
South Bend	6	8	14
Slackline	5	3	9

Hauling trees across stream management zones (SMZ)

Best management practice guidelines in New Zealand recommend that trees are not dragged across any major watercourse. The only acceptable way to yard across a watercourse is by using full suspension of the load. Motorised carriage was the most common choice of configuration due to its ability to lock the load in place at a given height (Table 3). North Bend and South Bend were also popular choices due to their vertical lifting abilities. However, both configurations pose a challenge where the load

can be unexpectedly lowered during inhaul if there is insufficient tension in the tail rope.

Advantages and Disadvantages - Delphi Analysis

The following tables present the results of the final round of the Delphi analysis regarding the advantages and disadvantages associated with each rigging configuration. An average value of ‘3’ indicated the experts agreed (or were balanced in agreement and disagreement), whereas values closer to ‘4’ indicated they all strongly agreed.

North Bend

The initial survey showed that North Bend is currently the most commonly used rigging configuration in New Zealand, primarily because of its ability to lateral yard due to bridling, and its versatility over a range of conditions (Harrill and Visser, 2011). This analysis has shown its versatility in medium to very high deflection, over long hauls, in both uphill and downhill yarding. Other common advantages stated were its increased lift, lower soil disturbance, robustness (being easy on the yarder and ropes) while still having good productivity and payload capability (Table 4).

Table 4: North Bend: Advantages

Response	Avg.
Bridling capability/Lateral yarding/Versatility	3.8
Productivity/Good payloads	3.6
Increased lift/Less soil disturbance	3.2
Easy setup and rope shifts/Simple to operate	3.2

Despite this being the most popular configuration in New Zealand, several disadvantages were stated (Table 5).

Table 5: North Bend: Disadvantages

Response	Avg.
Longer skyline shifts/Tempted to bridle too far	3.4
Overloading hazard/Pull out stumps	3.2
Need more expensive (3-drum) hauler	3.2

Disadvantages mostly were related to the temptation to bridle too far (reducing productivity), longer and more complicated line shifts (than running skyline) and higher operating costs (due to use of a 3-drum hauler).

Running skyline (Scab or Grabinski)

The second most commonly used configuration in the earlier survey was running skyline (“Scab”) at 22% (Harrill and Visser, 2011).

Table 6: Running skyline (Scab or Grabinski): Advantages

Response	Avg.
Simple/Quick setup & line shifts	3.8
Simple to operate/less skill required	3.8
Productive/Quick	3.6
Less ground disturbance/More lift than highlead	3.6
Easy to get slack in rope/Easy to land gear	3.4
Gear elevated off ground/Less rope wear	3.4
Can downhill yard	3.4
Less deflection required/Good for short distances	3.2
More control over drag	3.2
Inexpensive yarder required	3.2

The further analysis by the expert panel determined this preference was because it is simple and quick to setup and run, and it provides more lift than highlead (Table 6). The ability to make quick line shifts, especially when operating on short haul distances, was thought to increase overall productivity.

Table 7: Running skyline (Scab or Grabinski): Disadvantages

Response	Avg.
Brake wear/Pulling against self/tail rope	3.4
No lateral yarding	3.4
Lack of lift/need good deflection/need tall tower	3.2

Concerns were expressed over functional problems with running skyline such as brake wear (pulling against tail rope) and rope wear. Its improved lift over highlead was judged as good, but this configuration does not provide as much lift as other skyline configurations (Table 7).

Shotgun

This configuration was found to be the third most popular in the survey (Harrill and Visser, 2011). Reasons given were that it is the cheapest configuration to run due to its reduced fuel consumption, and it is highly productive, due to the gravity return reducing the outhaul element of the cycle time. It was agreed it is very simple to operate and setup, and worked very well in high deflection settings with large payloads (Table 8).

Table 8: Shotgun: Advantages

Response	**Avg.**
Fuel use/Cheap to run	4.0
Productivity/Quick	4.0
Easy setup/Simple to operate	4.0
Maximizes deflection & payloads/Full suspension	3.8
Easy on breaker outs/Easy to land logs & drop gear	3.8
Less rope/Gear wear	3.8

The shotgun configuration is limited to uphill yarding only, and where terrain is steep enough for gravity to return the carriage quickly. Some other disadvantages with this configuration were stated to be difficulty in getting drags unstuck without a tail rope to haul the carriage out. To log the back face of each setting also requires a tail rope (slackline configuration). Using a slack pulling or motorised carriage in a shotgun configuration can overcome the inability to lateral yard. There is a hazard with live skylines of overloading the skyline, and therefore strong anchors are required (Table 9).

Table 9: Shotgun: Disadvantages

Response	**Avg.**
Limited by terrain/Need slackline for back face	3.6
Need good anchors	3.4
Hard to get caught drags unstuck	3.2
Lack of lateral yarding	3.2

Highlead

Highlead is not one of the most often used configurations but it was well known with most loggers having used it within the last five years (Harrill and Visser, 2011). The agreed advantages of highlead included simplicity in operation, setup, and line shifts. The ability to function where there is limited or no deflection and most other configurations are not preferred was also a stated advantage (Table 10). Highleading is also one of the cheapest configurations to run, requiring only a 2-drum yarder.

Table 10: Highlead: Advantages

Response	**Avg.**
Quick to setup/Simple to operate	3.6
Easy line shifts/No skyline	3.6
Cheap system to run/Less expensive yarder	3.4
Good when there is limited deflection	3.2

Despite the advantages, the lack of lift with the highlead configuration poses a number of problems, such as the level of ground disturbance, and inability to clear obstacles resulting in breakage of stems and rigging (Table 11).

Table 11: Highlead: Disadvantages

Response	**Avg.**
No lift/Rigging drags on ground	3.8
Ground disturbance	3.8
Little control of drag/Drags get stuck/Breakage	3.8
Chains tangle	3.6
Rope wear	3.4
Fuel use is high	3.4
Limited to short distance/terrain conditions	3.2

South Bend

South Bend is one of the less common configurations, used by less than 20% of survey participants within the last five years (Harrill and Visser, 2011).

The configuration functions quite similarly to North Bend and has similar advantages and disadvantages. The amount of lift generated and the ability to bridle and/or have good control of the drag around obstacles were agreed as the main advantages of this configuration (Table 12).

Table 12: South Bend: Advantages

Response	Avg.
More lift	3.6
Good for getting around rocks and over creeks	3.6
Ability to pull 90 degrees from skyline	3.6
Less power required/more break out power	3.4
Good control of drag	3.2

Extra gear and rope is required and mainline wear due to lifting of the fall block all result in higher costs. Operators found landing the gear to be difficult in the same way as North Bend due to the arc that the fall block travels when lowered (Table 13).

Table 13: South Bend: Disadvantages

Response	Avg.
Rope wear/tangle	3.2
Higher costs/Extra gear & rope needed	3.2
Need secure anchors	3.2

Motorised carriages

Although used by fewer than 25% of survey participants within the last five years (Harrill and Visser, 2011), motorised carriages were highly regarded as having great versatility demonstrated in the associated advantages of this configuration (Table 14).

Table 14: Motorised Carriages: Advantages

Response	Round 3 Avg. Rank
Fewer line shifts/wide corridors	3.6
Quick/ productive	3.6
Lateral yarding	3.6
Lift/ Full suspension	3.4
Good getting around obstacles	3.4
Good control of drag/less breakage	3.4
Fuel savings/ shotgunning capability	3.4

Good lift and control of the drag, as well as its ability to lateral yard and navigate around or over obstacles were highly regarded. High associated productivity and fuel saving when shotgunning made motorised carriages attractive.

However, many could not justify the high capital investment in such a carriage, and were not willing to take on extra maintenance, risk skyline damage due to clamping, or the risk of dropping the carriage (Table 15). Problems similar to live skylines with the hazard of overloading and the need for secure anchors were also perceived disadvantages.

Table 15: Motorised Carriages: Disadvantages

Response	Round 3 Avg. Rank
Need good deflection/terrain limited	3.6
Maintenance	3.4
Drop carriage	3.4
Clamping damage, rope wear	3.4
Need strong anchors	3.4
Expensive	3.2

Mechanical carriages

Mechanical slack pulling carriages have many advantages similar to motorised carriages, with their versatility, lateral yarding resulting in wider corridors and fewer line shifts and relatively high level of production (Table 16).

Table 16: Mechanical Carriages: Advantages

Response	Avg.
Fewer line shifts/wider corridors	3.4
Lateral yarding ability	3.4
Good around obstacles	3.4
Cheap	3.4
Robust	3.4
No engine Maintenance/light weight	3.4
Productive	3.2
Works well uphill or flat ground/Versatile	3.2
Drag follows ground	3.2

They were favoured over motorised carriages when it came to simplicity, robustness (low maintenance) and lower purchase price. Issues with excessive rope wear and line twist were of concern. It was also noted that the configuration doesn't work well for downhill yarding, and lateral yarding can be limited by the length of the drop line (Table 17).

Table 17: Mechanical Carriages: Disadvantages

Response	**Avg.**
Need more drums	3.4
Line twist	3.2

Grapple yarding

With less than 25% of crews using them in the last 5 years (Harrill and Visser, 2011), grapple yarding is not a big feature of the New Zealand logging scene. Despite this, grapples are very productive having no hook on element and therefore usually shorter cycle times. They require no breaker outs and therefore are a lot safer to operate. They are relatively simple, easy to set up, and are good for short distances (Table 18).

Table 18: Grappling: Advantages

Response	**Avg.**
Less man power	3.8
Safety	3.8
Good for short distances	3.8
Unhooking	3.8
Productive/quick	3.6
Robust	3.6
Easy setup	3.4

If the yarder operator doesn't have good vision of the logs a spotter is required to communicate effectively with the yarder operator (Table 19).

Table 19: Grappling: Disadvantages

Response	**Avg.**
Need good communication/vision/spotter	3.2
Rope wear	3.2
More line shifts	3.2
Best suited for swing yarders	3.2

Other disadvantages stated included rope wear, increased number of line shifts due to the inability to lateral yard, and limitations to shorter haul distances and specific terrain (i.e. concave slopes).

RECOMMENDATIONS

As a result of this project several recommendations were made:

- Planners and operations managers are encouraged to review their planning process to ensure that all operating and stand conditions (such as direction of extraction, deflection, haul distance, and areas of difficulty) are considered, and appropriate cable rigging configurations are selected to match these conditions.

- The results of this study should be made available to FITEC, the industry training organisation, for inclusion in a future revision of the Best Practice Guidelines for Cable Logging (BPG).

- Consideration should be given to updating all national training literature with the results of this research. Creation of a guidebook for contractors and loggers on selection of appropriate rigging configurations is recommended.

CONCLUSIONS

A given harvest area can be typically harvested using a range of cable rigging configurations. The purpose of this study was to make the selection process easier for logging practitioners and planners by providing a summary of the advantages and disadvantages of each rigging configuration in specific conditions.

This project analysed the responses and opinions of 50 individuals practicing cable yarding in New Zealand at a professional level, with the validity of responses assured by a panel of 5 experts using the Delphi process to synthesize and resolve any conflicting responses.

Although there appears to be dependence on just three common configurations (North Bend, scab skyline and shotgun) most participants were interested in and recognised the potential of other configurations. In particular, motorised carriages, while not widely used, were recognised as having great versatility to work in broken terrain, around

obstacles, and providing full suspension across water courses. Grapples were perceived as being very productive, requiring fewer workers in hazardous roles, therefore being safer to operate.

The panel reached consensus on the advantages and disadvantages of each of the common rigging configurations. However the complexity of operational issues involved with cable logging operations, and the versatility of certain configurations, created a wide overlap of application between configurations.

Information from this study will be provided to the industry training organisation for inclusion in cable logging training guidelines. This report provides information for planners and operations managers to review their operational planning process to ensure that appropriate cable rigging configurations are selected to match all the operating and stand conditions (such as deflection, yarding direction, haul distances and operational constraints).

ACKNOWLEDGEMENTS

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REFERENCES

Dalkey, N. and O. Helmer. 1962. An experimental application of Delphi method to the use of experts. Management Science 9: 458-476.

Harrill, H. and R. Visser. 2011. Rigging configurations used in New Zealand cable logging. Harvesting Technical Note HTN03-11. Future Forests Research Limited, Rotorua, New Zealand. 6p.

Liley, W.B. 1983. Cable Logging Handbook. New Zealand Logging Industry Research Association. Rotorua, New Zealand. 134p.

Studier, D.D. and V.W. Binkley. 1974. Cable logging systems. USDA For. Serv., Div. of Timber Management, Portland, Oregon. 205 p.

Studier, D. D. 1993. Carriages for Skylines. Research Contribution 3, March 1993. Forest Research Laboratory, Oregon State University. 13 p.