

Cable Yarding in North America and New Zealand: A Review of Developments and Practices

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Abstract

Cable yarders have been an integral part of harvesting timber on steep terrain for over 150 years. They have developed from basic labour intensive steam powered winch operations to sophisticated and automated mechanised systems. While European yarder development has focused on relatively small but highly mobile machines operating with standing skyline configurations, the North American and Southern Hemisphere developments have tended towards larger, taller and more powerful machines capable of higher daily production. Two dominant North American brands, Madill and Thunderbird, produced over 3000 yarders and many of their machines continue to work today. Often working with 4 or 5 drums, they were able to develop and utilise an expansive range of rigging configurations to suit different extraction needs. Modern developments continue to focus on increasing production capability and cost-effectiveness suited to clear-cut plantation forestry. With safety becoming more paramount in terms of a licence to operate, a strong preference is given to fully mechanised systems. By definition, these are yarders with rigging systems that support grapple carriages, extracting timber that has been mechanically felled on steep slopes. While mechanical grapple carriages have long been combined with swing yarder systems, the further development of a motorised grapple carriage allows tower yarders to operate without choker-setters. Ergonomic improvements for the operator, long established in European machinery, are being integrated including cab design with greatly improved visibility and partially automated electric over hydraulic control systems. Logic would suggest that, over time, yarder developments will combine the strength and robustness of North American design and the finesse and automation of European design. However, recent machine sales in North America and New Zealand continue to show a clear difference with the preference of large swing yarders capable of running fully mechanised extraction systems.

Keywords: cable logging, extraction efficiency, system development, rigging configurations, ergonomics

1. Overview of yarder developments

Using cables to extract felled stems emerged as a common practice around the turn of the 20th century. It became known as »cable logging« and was a preferred method of extraction on steep slopes (Studier and Binkley 1974). While the use of rope logging practices date back centuries in Europe and Asia, modern cable yarding practices were developed in the late 19th century with the advent of steam powered engines like the Dolbeer Steam donkey in 1881 in Eureka, California (City of Eureka, 2010). The machinery used has improved over the years from the early steam pow-

ered winch sets to current yarders with highly-sophisticated diesel powered engines, water-cooled brakes, interlocking drums and electric controls (Mann 1976, Samset 1985, Sessions 1991). However, the challenges of productive cable logging remain the same; to get lift on the logs to provide partial or full suspension in order to avoid ground objects and reduce the friction, and thus the pulling force required (Pestal 1961, Lysons and Mann 1967, Falk 1981, Conway 1982).

In addition to being able to operate on slopes, where it is not physically feasible to operate ground-based systems, cable yarding can also be preferred on

intermediate slopes due to its reduced environmental impacts because of partial or full suspension of logs, and not needing to drive an extraction machine into the forest, reducing soil disturbance (Liley 1983, McMahon 1995). Despite its considerable developments and wide use, cable logging is expensive and is inherently more complex than either tractor or skidder logging (Kirk and Sullman 2001, Visser 2014). It has a high incidence of accidents to workers and is generally less productive than ground-based methods of harvesting timber (Slappendel et al. 1993, Spinelli et al. 2015). The alternatives for the extraction on steep slopes are the helicopters but they are not often preferred due to their high rate of fuel consumption and expensive operating costs (Horcher and Visser 2011).

There are many different cable logging systems that have been developed over the years in different regions of the world. They are composed of different machines, rigging systems and operating methods available: each with their own requirements and capabilities. This culminates in a very large number of different combinations, whereby texts and manuals provide a good overview (e.g. Studier and Binkley 1974, Larson 1978, Liley 1983). Standardised terminology can be found in Stokes et al. (1989). While early cable yarders used a spar tree or independent tower to keep the rigging off the ground and provide lift to the trees to bring them onto the landing, modern yarders are almost exclusively integrated tower yarders. »Integrated« refers to the winch set and the tower being on the same base machine.

A clear difference between North America and Europe in the design of the integrated yarders began in the 1950s. The North American systems were designed to operate in larger forest areas (initially native, but now predominantly in either second growth or plantations), so the emphasis was on larger machines that were able to harvest efficiently from a single purpose built landing location (Fig. 1). To accommodate modern high production extraction, processing and loading out operations, these landings are large and a recent survey showed the average yarder landing in New Zealand to be 3900 m³ (Visser et al. 2011). The infrequent yarder moves most often involved a relatively short distance shift to the next landing only a few hundred meters away. As such, most found favour with a strong and large track base that provided the ability to relocate on poor infrastructure. In comparison, the European design focus was based around smaller scale harvests with a need to relocate often, and required to be completed from existing forest roads (Heinimann et al. 2000). These smaller machines had relatively low payload capability and hence the need to design for speed of operation and relocation.



Fig. 1 A typical PNW or NZ yarder set-up, with a Madill 172 working a larger clear-cut operation from a purpose built landing

2. Madill Yarders as an Example

A few yarder manufacturers based in the Pacific Northwest (PNW) produced the majority of cable yarders that have been, and are still, operating in PNW and New Zealand; Madill, Skagit and Washington built between 1500–2000 yarders each, Berger around 1000–1200, and Thunderbird 350–500 (pers com Cole). Madill is considered one of the most successful and enduring manufacturers of cable yarders in the PNW and led many developments along the way. By the end of the 1990s, they had merged with other manufacturers like Cypress, Thunderbird, Skagit, Berger and Washington, but still retained their respected Madill name.

Early developments of diesel powered yarders revolved around integrating the tower to the chassis to reduce the dependence on time to rig-up a spar tree for desired lift. The idea was to make them more mobile by adding a tracked or wheeled undercarriage and the earliest recognised example of this was the Lidgerwood (Samset 1985). The concept was largely successful as indicated by sales and popularity of models such as the Madill 009 of which there were approximately 900 machines produced (Table 1). By the 1960s, yarders were becoming more commonly employed and they were produced by several manufacturers. Water cooled brakes added smoothness to the rigging movement and controls of a yarder that were far superior to the band brakes. The new types of brakes allowed for faster speeds, higher tensions and longer brake life, all of which helped improve productivity and justify larger and costlier yarders (Rice 1974). Interlock became another important development in winch sets, allowing drums to turn at the same

speed or torque, and improved the effectiveness of running skyline systems, particularly the use of grapples on swing yarders (Carson and Jorgenson 1974). Originally, interlock was mechanical but transition to hydraulic functions started, which allowed for energy recovery from braking and smoother control of functions (Hartsough et al. 1987).

Table 1 An overview of cable yarding developments at Madill (after Heavy Equipment Forum, 2016)

Model	Number built	Basic Description
1960s		
Madill 009	900	2 drum highlead machine, with strawline. Usually 90' tower height
Madill 046	56	3 drum slackline yarder, with straw and taglines. Usually 90' tower height
Madill 052	20	3 drums as 046, but running skyline. Huge, heavy. Usually 90' tower also
»Yarding Crane«	3	Swinging grapple yarder. Huge. Prototype for the 044
1970s		
Madill 071	235	50' Tower, slackline yarder mounted on Terex, tank, or rubber Madill SP
Madill 044	136	Large swing grapple yarder. Smaller, lighter version of the »Yarding Crane«
Madill 084	3	Bigger version yet of the 044. Only 3 were built. Just too big and heavy
1980s		
Madill 121	3	Lightweight and mobile swing yarder, prototype for the 122
Madill 122	47	New and improved 121, very popular and still in use today. Weighs 50 tons
Madill 123	24	Larger, basically bigger version of the 122. Weighs about 70 tons
Madill 144	19	Bigger still version of the 123. Basically huge, swing grapple yarder
Madill 171	29	Bigger version of the 071, with 70 tower, bigger drums, etc. in big tank
1990s		
Madill 120	31	Swing Yarder. Grapple or dropline machine, all hydraulic, 45 tons
Madill 124	56	Swing Yarder. Same as above, much larger, all hydraulic
Madill 172	34	70' slackline machine, hydraulically controlled mobile standing tower

The Madills of the 90s were a mixed design product, closer to the Cypress machine, and some Cypress machines (6280, 7280) were painted orange and called Madills. In the late 90s, the Cypress/Madill joint venture purchased Thunderbird, which had the rights to Skagit designs, and the last Thunderbird 255B machines also took on the orange and white colours.

3. Aging Yarder Workforce, the New Zealand Case

Cable logging, as practiced in New Zealand, differs in several respects from how it is practiced elsewhere. The reasons are various, but the nature of *Pinus radiata*, the value of the wood recovered, features of New Zealand's terrain and climate, and the reliance on plantation forestry, are all factors (Liley 1983). However, New Zealand shares many similarities in cable logging operations with the PNW due to the two regions long history of interactions and trade. When diesel yarders became well established in North America for harvesting such a resource, New Zealand started importing the machines to harvest their plantation forests of the 1950s and became a catalyst for future collaboration. For example, New Zealand joined the Pacific Logging Congress and Setup the Logging Industry Research Association (LIRA) to get up to speed with the technological developments of the machines and find how to most effectively use them (Ellegard 2016). The two regions embarked on a journey that saw a few decades of focused and collaborative research and training efforts; like the Forest Engineering Institute (FEI) of the late 1980s. The financial downturns at the end of the 20th century put an end to a prosperous period of cable logging developments for both regions, until a resurgence in the last decade.

Clear evidence of New Zealand's reliance on yarder developments in the PNW can be found in a comprehensive yarder survey of working machines in 2012 (Visser 2013). There were 68 different »models« of yarders recorded in the survey and 85% were designed and built in the PNW. The survey indicated that 305 yarders were operating, compared to 214 recorded in the 2002 survey and only 82 yarders in 1985 (Finnegan and Faircloth 2002). Of a total of 2012, 67% were tower yarders and 30% were swing yarders and the remaining 3% were identified as excavator-based yarders. The Thunderbird TMY 70 tower yarder is the most common model yarder in New Zealand with 31 machines (Table 2).

By identifying the make and model and ownership, the survey was also able to determine that approximately 130 yarders were introduced into the

Table 2 Ten most popular yarder models operating in NZ as reported in the 2012 yarder survey (from Visser 2013)

Make/Model	No. in operation
Thunderbird TMY 70	31
Madill 071	26
Madill 123	18
Madill 124	17
Madill 171	17
Brightwater BE70LT	13
Madill 009	13
Brightwater BE 85	10
Thunderbird TSY 255	10
Madill 122	9

workforce and that around 40 yarders were decommissioned in the last 10 years. The majority of additions have used machines purchased from the PNW and either put into service directly or reconditioned in New Zealand. With the closure of most North American yarder manufacturers, the reduced availability of used machines on the market and the expected increase in cable harvesting volume, it is unlikely that this trend can continue for much longer. Therefore, New Zealand will likely see an increase in new yarders entering the yarder population over the next few years.

In the survey, carriage information was recorded for only 213 yarders. Of this total, 129 (61%) did not have access to any sort of carriage. Of the 84 yarders that used a carriage in the survey, 17 were simple mechanical grapple carriages (20%), mainly associated with swing yarder machines. While European yarder systems have predominantly used standing skyline configurations, a survey of rigging configurations (Harrill and Visser 2012) showed that cable yarding operations in New Zealand rely heavily on North Bend, running skyline, highlead and gravity return (shotgun) configurations. These configurations, which do not employ a carriage, provide for higher payloads by sharing the payload with the ground (Fig. 2). The disadvantage is that they require greater mainline pull, higher fuel use per unit volume and create more ground-disturbance.

By 2010, New Zealand had already begun to make another transition of harvesting increasing volumes from forests on steep terrain in even greater proportions (Harrill 2014). The last decade has seen many

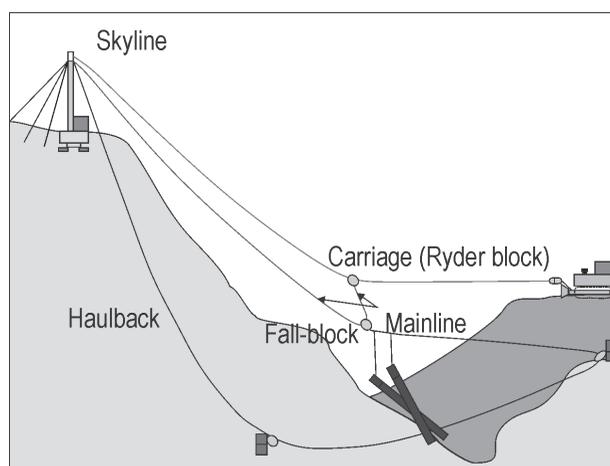


Fig. 2 North Bend rigging configuration, with the mainline going through a fall-block before being attached to the »carriage«. When the mainline is pulled, the stems being pulled balance forward motion with lift so that the payload nearly always remains in contact with the ground

new developments in steep slope harvesting and cable logging technology in New Zealand (Raymond 2012, Visser et al. 2014), some of which have been commercialized and are now being exported back to North America. At the same time the adoption of cable-assisted machines and the aging fleet of yarders in North America is stimulating new developments there.

4. Yarder studies – productivity and safety

System productivity has been extensively researched in logging operations, as increasing productivity typically results in lower logging rate costs (\$/ton or \$/m³) (Cavalli 2011, Visser 2014). An example of studies that provided insight and understanding into production potential of various logging systems and rigging configurations was known as the Pansy Basin Studies carried out in the Pacific Northwest. Production rates and costs for cable, balloon and helicopter yarding systems in old growth stands were established (Dykstra 1975) with a follow up study on the same systems in thinned and clearcut young growth forests, including their delays (Dykstra 1976a and 1976b). There were other research projects carried out at the time such as: running skyline production using a mechanical slack pulling carriage (Mann and Pyles 1988); production of a manual slack pulling carriage in thinned stands (Sinner 1973); comparison of skyline carriages for small wood harvesting (Balcom 1983); production of pendulum balloon logging (Ammeson 1984); production costs and optimal line spacing of

running skyline and standing skyline systems using slack pulling carriages (Rutherford 1996).

Other studies quantified systems production rates, and even compared production rates of different systems and equipment side by side (Kellogg 1987, Forrester 1995) or over the same terrain and stand conditions such as: comparison of Washington 88 and Madill 009 (Bell 1985); cycle time comparison of Timbermaster and Wilhaul yarders (Douglass 1979); shift level comparisons between Ecologger, Bellis, Lotus, and Thunderbird yarders in down-hill logging (Evanston and Kimberly 1992); and a case study of a mobile Madill 009 in mature radiata pine (Murphy 1977). These studies and many other yarder trials, carried out by LIRA/LIRO between 1973–1991, have been summarized in a book by Harper (1992). Some have investigated different rigging systems and their productivities such as: alternative rigging variations for the North Bend configuration to improve productivity by improving control and reducing required line shifts (Bennett and McConchie 1995); and a system evaluation of a Madill 071 using North Bend, Shotgun, Slackline and mechanical slack pulling carriage configurations (McConchie 1987). Stampfer et al. (2010) showed the benefits of using radio-controlled chokers. Visser and Stampfer (1998) showed the increased productivity associated with mechanised felling and processing on subsequent yarder extraction. More recently, Harrill (2014) investigated the productivity and skyline tensions of different rigging configurations in a series of case studies. Cavalli (2012) found that the last 10 years of research by forest engineers interested in cable logging was mainly (45%) directed towards efficiency. According to Cavalli, in the near future, efficiency will continue to be the topic in cable logging research, and efforts in optimization, including computer automation and control of machinery, will aid this focus on efficiency.

Many guide books on cable logging safety and best practices have been produced over the years to educate workers and to reduce accidents. Notably, the Yarding and Loading Handbook by OR-OSHA (1993) and revised (2008) were built on the Cable Yarding Systems Handbook by WorkSafeBC (2006) and subsequent versions. Similar guides exist in New Zealand, like the Approved Code of Practice by the (MBIE 2012) and the Best Practice Guidelines by (FITEC 2000). Unfortunately, worker fatalities occur in the same ways as they did 40 years ago (OR-OSHA 2008). Improving our knowledge of forces and tensions involved with complex cable logging systems, as well as a better understanding of control over the extraction process, can help improve safety. Slappendel and others (1993) in-

vestigated factors affecting work related injury in forest workers in New Zealand. Hartsough (1993) studied the use of remote tension monitors and the benefits they provide to safety. Physical demands of steep terrain workers were quantified by Kirk and Parker (1994), who later investigated heart rate and strain of choker setters (Kirk and Sullman 2001).

Yarder tower collapses became a concern prompting two studies by Fraser (1996) and Fraser and Bennett (1996) on collapses and their potential causes. The New Zealand accident reporting scheme was established to combat increasing rates of accidents (Sullman et al. 1999). Bentley et al. (2002) outlined how the accident reporting scheme data could be used to identify priority areas for ergonomics, safety and health research attention. Social acceptability towards safety has led to many logging contractors and forestry companies taking a more proactive approach to fully mechanising cable logging operations via cable-assisted felling and grapple yarding.

5. Fully mechanised systems

Mechanisation of cable logging operations offers both safety and productivity benefits (Amishev 2012). Most cable logging operations require the use of skilled workers (e.g. fallers and choker-setters) to get the trees on the ground and connect wire ropes to the stems for extraction to a roadside or landing (Kirk and Parker 1994, Harrill and Visser 2012). The task of choker-setting is not only physically demanding but also poses a high risk to workers being struck by logs. Forestry is classified as one of the most dangerous jobs in



Fig. 3 T-Mar Log Champ 650 shown above, like Madill 124, is a very large (70+ tonne) swing yarder designed for larger scale mechanised clear-cut operations

New Zealand and the tasks of tree felling and choker-setting have been identified as the most common to serious harm accidents and deaths (Raymond 2014).

Grapple carriages have been around since the 1960s and most are a mechanical type, where the yarder's wire ropes are used to open and or close the grapple. Using a mechanical type grapple carriage requires a running skyline system, which is most effectively operated with a more modern and expensive interlocked swing yarder (Carson and Jorgenson 1974, Hartsough et al. 1983, Harrill and Visser 2012). New yarders commissioned in the PNW and New Zealand in recent years have mostly been of this type (Fig. 3).

One way to develop the use of grapple carriages onto other yarders was the powered grapple carriage. Powered grapple carriages require a minimum of two wire ropes to be deployed and can operate on a live skyline system as they have an internal power source which opens, closes and sometimes rotates the grapple. Early developments of motorised grapple carriages started in the PNW in the late 60s when labour costs became unfavourable. Some of the first motorised grapple carriages weighed as much as four tonnes and commonly had problems with mechanical reliability, to a point where they never gained wide spread acceptance and almost vanished from the industry until a recent resurgence. The Forestry Falcon Claw (FFC) is a New Zealand built motorised grapple carriage that has gained market popularity since its introduction in 2012. Another example is the Alpine carriage (with hydraulic accumulator), which is lighter weight (Evanson 2014). Both carriages followed two earlier versions produced by Eagle Carriage & Machine Co. in the USA and numerous other attempts, less commercially successful, by different PNW enterprises. The nature of how these carriages operate compared to mechanical grapples differs and has been the focus of many studies (McFadzean and Visser 2013, Evanson 2014, Nuske 2014). McFadzean and Visser (2013) found that »feeding« grapple carriages (i.e. handing bunches of stems to the carriage with an excavator) could nearly double the productivity of yarder extraction. This practice is becoming more common in New Zealand and worldwide and it has been facilitated by cable-assisted machine use.

6. Integrating New Technologies

One disadvantage of the grapple carriage extraction system is that, due to visibility limitations, the operator can have difficulty in picking up stems. Traditionally this limitation is overcome by using a »spotter«. Spotters place themselves along the harvest cor-

ridor, where they are able to see the grapple and the stems to be extracted, and provide feedback to the yarder operators in terms of carriage control commands through a walkie-talkie. Although using a spotter is effective, it does not meet the objective of fully mechanising the system.

Two types of camera systems have been developed to provide the yarder operator with good visual information to assist in the grappling phase. The first is a camera system that is either directly integrated into the carriage such as used on the Falcon Forestry Claw, or towed behind the carriage on a rider block which can then be used on a mechanical grapple carriage as well. The second system places the camera in the cutover (Evanson 2013). While this camera also sends the video image back into the yarder cab, the operator can remotely control both the direction and zoom of the lens so as to focus on the immediate area below the carriage.

New yarders incorporate features designed to optimize both the system controls as well as the ergonomics to reduce operator fatigue. Cabs and systems are now being increasingly retrofitted to older machines with features such as adjustable seats with electronic controls simplified to two joy-sticks. Most utilise Programmable Logic Controllers (PLC) or CANBUS for electric over air or electric over hydraulic controls, which can be programmed to optimise the winch performance by selecting a rigging configuration or mode (e.g. grapple, carriage or scab) (Visser et al. 2014). Other features offered by these new computer-operated control systems are: simplicity of operation including more precise control of machine functions, audible alarms and indicators for distance and tension, ease of maintenance with machine diagnostics displayed on a screen in the cab and troubleshooting using a visual Test Points function. The computer controlled systems also provide the opportunity for autonomous control of certain processes (e.g. carriage outhaul), which have become standard for many of the European manufacturers.

Another example of feedback software is the AC-DAT (active data) system, an on board data storage computer system produced by Active Equipment, which is standard with the company's new yarders or can be retrofitted into older machines (Active Equipment 2016). This system is a one screen, multiple application computer that has four key functions: GPS tracking of choker-setters, live time tension display, modelling of the terrain and operations data recording. For the choker-setter tracking system, the choker-setters wear a special GPS unit that is synced each morning with the yarder. This information is stored by day and data is retained on the computer for a month.

Information categories include: skyline tension, main-line length, skyline length and engine voltage to name a few. There is also the option for the yarder operator to manually enter haul statistics (e.g. number of pieces extracted for each turn) (Visser et al. 2000).

Increasing the operating range of ground-based systems has been significantly aided by the fast development of winch-assist (also known as cable-assist or tethered) harvesting system (Heinimann 1999, Visser and Stampfer 2015). These systems are now being used to operate on slopes up to 100% (45 degrees), and while they potentially complement the cable yarding systems by providing a safe and effective felling system, in many cases the extraction systems are also winch-assist. This will result in a decline for cable yarding services over time. The full extent of this development has not yet reached its potential, but it will challenge the cable yarders for providing cost-effective extraction services.

7. Conclusion

Cable yarders continue to be the backbone of timber extraction on steep terrain. This paper has provided an overview of yarder developments in North America and New Zealand, and identified differences with European developments. While many of these differences can be explained by the forest management requirements, many of the preferences simply reflect regional development. With increases in the cost of labour and fuel, and increasing global market competition, there will be increased focus on operational efficiency. Reduction in energy expenditure and fuel consumption, as well as automated controls for improved safety and worker satisfaction will increase the interest in modern, mainly European designed, yarders. However, in the interim, the continued focus in the PNW and New Zealand will continue to be on robust high production yarders.

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