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International Grapple/Carriage Developments: A Review of the Literature

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EXECUTIVE SUMMARY

A literature review of skyline grapples and carriages concluded that larger capacity grapples and carriages are manufactured only in North America. Recent innovations included multi-speed transmissions and hydraulic powered slack pulling carriages and the use of cameras to help the yarder operator spot the carriage or grapple.

Smaller capacity carriages (but no grapples) were used in European operations, and the yarder-carriage control systems for Processor-Tower-Yarder (PTY) systems were found to be well advanced.

Combinations of these developments may have application in New Zealand clearfell cable yarding operations to enable wider haul corridors to be logged, reducing the number of rope shifts, and to exploit the possibility of extracting drags of bunched stems. They could aid grapple yarder or tower yarder-grapple operators to grapple a load more efficiently and enable spotters or breaker outs more control over positioning of rigging and activation of grapples.

The end result of such innovations may be faster work cycle times, and consequently increased productivity of cable logging systems used in New Zealand.

INTRODUCTION

A series of projects was initiated by Future Forests Research (FFR) with the aim of enabling the New Zealand forest Industry to achieve productivity gains and cost reduction through the use of improved harvesting technologies. Two of these projects, involving the development of an improved grapple/carriage control system and an advanced hauler vision system, have the specific aim of improving the productivity of the extraction phase of cable logging. A review of existing literature contributed to the problem definition phase of these two projects.

Although many of the basic principles and technology of carriages remain the same, in the past 20 years there have been significant improvements in some of the operating systems and technology. This review identifies some of the latest developments from North America and Europe. Skyline carriage design and construction has evolved over the years to include features that reduce cycle times and increase the width of the swath extracted with each line shift (skyline corridor). For the purposes of this report, the different types of carriages have been given a type number to help with identification (Figure 1).

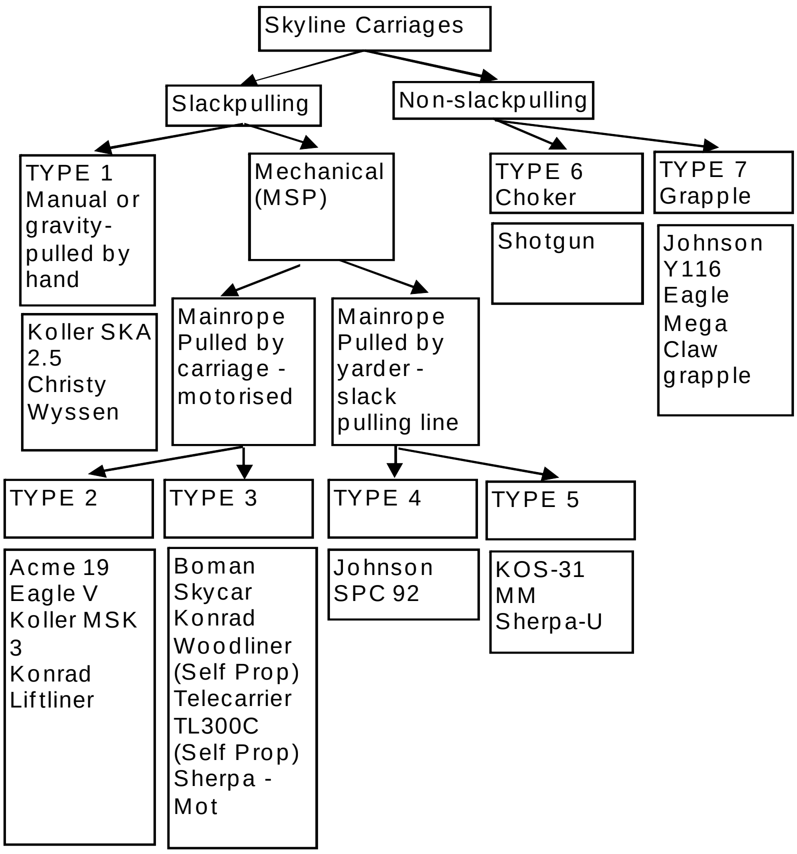

Figure 1. Skyline carriage schematic (with examples) (after Studier, and FIT)[1].

Examples of the different carriages are provided as a guide. This convention has been followed throughout this literature review.

The importance of lateral hauling (and consequently the development of slack pulling carriages which enable lateral hauling), relates to two issues: the hook-on time element of the cable logging productive cycle is frequently the longest, and the number of trees hooked on is often affected by the amount of slack available to the breaker outs[2]. Some rigging systems such as high lead, shotgun and slackline have no slack pulling capacity (the width of the skyline corridor or swath taken out between line shifts is limited to the length of the chokers). The North Bend system has the capacity to bridle the fall block away from the skyline, but an extra block is required. Width of the skyline corridor is still restricted to the location of the block, and slack is still limited to the length of the chokers.

All carriages (including grapples and shotgun carriages) are described as skyline carriages[3]. These carriages have been used in both tower or pole yarders as well as swing yarders. Slack pulling carriages have attracted significant interest because they enable the chokers to be pulled out either side of the skyline.

The chief advantage of slack pulling carriages is that they have the potential to increase the productivity of cable logging operations by reducing the number of line shifts. One review noted that motorised slack pulling carriages and Skycars are suitable for 2-, 3- and 4-drum yarders.[4].

PREVIOUS RESEARCH

Mechanical and Motorised slack pulling carriages

In 1985, Hemphill[5] carried out a survey, identifying skyline carriages suitable for New Zealand logging conditions. New Zealand conditions were defined as having large tree sizes, both up and downhill logging, and a hauler fleet equipped with between two and four drums.

Of the 18 different manufacturers identified in that survey, at least seven are still making carriages (such as Koller, Johnson and Maki). New manufacturers have entered the market since the 1985 survey was done, including Eagle, Boman and Acme.

Six different skyline carriages with the best potential for use in New Zealand were described:

- Type 1: Manual or gravity slack pulling (e.g. Koller clamping carriage SKA 2.5,).
- Type 1: Movable carriage stop (e.g. Christy carriage – still made, but not by Christy)
- Type 1: Traction drum carriage – drop line type (e.g. Steyr – no longer made)
- Type 4: Skidding system carriages (e.g. Danebo MSP, Young YCC13 – both no longer made).
- Type 4: Three drum carriage (e.g. Danebo S35 – no longer made)
- Type 6: Shotgun or gravity return carriage.

Studier[3] later compiled a review of skyline carriages in 1993, which is summarised in Table 1. This review formed the basis for the classification in Figure 1.

Table 1. A summary of the skyline carriage review (Studier 1993).

Skyline carriage type	No. Makers	Number of models (detail)
Type 1: Manual slack pulling	10	18 (mostly uphill use, live skyline, weight range – 72 to 4536 kg)
Type 2: Mechanical slack pulling – by carriage.	5	11 (all uphill use, radio-controlled skyline clamp, weight range – 544 to 2177 kg)
Type 3: Mechanical slack pulling – by carriage – drop line	6	10 (uphill and downhill use, weight range – 1723 to 4082 kg)
Type 4: Mechanical slack pulling – by yarder	4	10 (mainly uphill and downhill use, weight range 258 to 1360 kg)
Type 5: Mechanical slack pulling – by yarder – skid drum in carriage	8	12 (mainly uphill and downhill use, weight range – 453 to 2358 kg)
Type 6: Non-slack pulling – chokers	7	16 (weight range – 408 kg to 2358 kg, 3 radio controlled clamp models)
Type 7: Non-slack pulling – grapple	6	10 (most on a running skyline, one radio-controlled rotation, weight range – 544 to 4082 kg) Note: Power-opening type grapples for large logs.

The trend in New Zealand since 1985 has been towards the use of motorised rather than manual or mechanical slack pulling carriages.

Recognising the potential for improvement with the use of carriages, the NZ Logging Industry Research Association (later LIRO) initiated a number of studies between 1989 and 1998 designed to illustrate the advantages using slack pulling carriages.

An early report into the Koller 2.5 self-clamping manual slack pulling carriage working with an Ecologger 1 hauler showed that a promising production rate could be achieved in a relatively small piece size – 106 m^3/day was achieved in a mean piece size of 0.7 m^3. One of the advantages of the Koller carriage was that the skyline did not have to be lowered at the landing for unhooking[6].

Research into mechanical and motorised MSP (Mechanical Slack Pulling) carriages in New Zealand included an evaluation of an Interstate I-DLC 36S 3-drum drop line carriage (similar to a Danebo S35 Drumlock model) working with a Madill 071[2]. This carriage relied on the hauler having a tag line or slack pulling rope that mechanically powered out slack to the breaker outs. The author recorded a high production rate (236 m^3/day in 1.0 m^3 mean piece size) despite the setting not being ideally suited to drop line operation because of limited deflection. The perceived disadvantages of carriage weight and set up times were offset by easier breaking out, increased lateral pulling capacity and faster cycle times.

Further research evaluated an Eagle II motorised slack pulling carriage working with a Thunderbird TMY70 hauler[7]. In this operation, the motor in the carriage powered out the hauler main rope through the carriage and out to the breaker outs. This system provided unlimited slack within the bounds of the main rope capacity and the capability of the breaker outs to physically pull the slack required. Productivity in this operation was again limited by poor deflection and restricted load size.

Another study was undertaken of a Boman Mark III-H Skycar working with a Bellis BE85 hauler using a gravity return system[8]. The Skycar carriage has the advantage of an internal drop line drum which is independently powered by a large diesel engine mounted within the carriage. The authors noted that there were five contractors using Boman Skycars in New Zealand and comments included:

- Lighter winch rope and strops enabled faster hook on and break out times.
- Inhaul speed could be increased by concurrent inhaul on the drop line as well as the hauler main line.
- Drop line slack could be paid out on outhaul if the terrain allowed.
- This carriage is best used in trees smaller than 2 tonnes and at high stocking rates which will enable the use of pre-set chokers.
- Cost of a Boman Skycar 111 H was $148000 (in 1998).

A LIRO review of the use of motorised slack pulling and Skycar carriages[4] included findings that:
- The ability to pull slack to breaker outs means a wider corridor or skyline road and hence fewer rope shifts.
- The use of these carriages makes pre-stropping attractive
- Carriages offer good control of the drag.
- Bridling is possible over long distances by pulling the main rope laterally with the tail rope (not usually done with a Skycar because of possible mechanical problems).
- The Skycar is suited to smaller average piece sizes and high stockings (drop line size 14 to 16 mm) and an MSP carriage to larger piece sizes (main rope 19 to 25 mm).
- There were positive comments received from operators about the mechanical and electronic reliability of the carriages.
- Some of the sheaves in slack pulling carriages have the potential to damage the end of the main rope by either crushing the rope as it passes through the sheaves or the sheaves skidding on the rope as they try to propel the rope through the carriage. A wire rope supplier suggested the use of swaged rope to counter this problem.

With the adoption of carriages by some contractors, additional investigation was carried out into the safe use of carriage systems. Tuor *et al*[9] examined the effects of carriage use on the skyline tension, and the possibility of rope failure when the skyline clamp is released. The authors also analysed the effects of three different carriage positions during breakout:
- carriage at right angles to the drag
- carriage in front of the drag
- carriage behind the drag.

Operational techniques to minimise the tension between different parts of the skyline included releasing the skyline clamp once the chokers are set but before breakout. This allows the carriage to move freely along the skyline. Then the carriage is clamped again for breakout. Alternatively, a tail rope can be attached to the carriage and tensioned before breakout to counteract the main rope pull.

A 2002 unpublished survey (Finnegan, pers.com.) reported on motorised carriages only. Of the non-slack pulling carriages (grapples and shotgun carriages) surveyed, there was no information on shotgun carriage use found in the literature examined for this report. It was believed that many contractors with swing yarders used grapples, but some also used chokers when conditions were not suitable for grapples. Tree size, terrain, haul distance, and whether trees were bunched or not, were some of the factors that determined grapple use.

In terms of present day use of slack pulling carriages, the 2002 informal survey noted that there were 162 haulers and 49 swing yarders working in New Zealand. There were also 19 motorised slack pulling (MSP) carriages owned by contractors, two of which were located in the South Island. Recent information about new purchases suggests that at least 12 Acme MSP carriages are now in use in New Zealand (Finnegan, pers.com).

Self Propelled Carriages

A variation of the Skycar design is a “self-propelled” Skycar, of which there are two main types: carriages using the skyline for suspension and propulsion, and those that use a second, smaller diameter cable as a “driveline” to pull the carriage along.

Self-propelled carriages (Konrad Woodliner and FUX SK2000) were investigated and productivity levels of the carriages in thinning operations overseas were reported[10]. Both carriages had similar payload limits of 2 tonnes but had differing drive systems. The carriage weights of the FUX SK2000 and Woodliner were 900 kg and 810 kg respectively. The application of these carriages in NZ was predicted to be in the downhill extraction of cut-to-length timber over haul distances of up to 400 m. Other reported advantages included:

- Lower system costs
- Simpler rigging up
- Smaller crew required
- Reduced capital investment

Another self-propelled MSP carriage is the TLD Gauthier (Teleforest) Telecarrier[11, 12]. In one report this carriage (TL 3000C) was assessed working in both thinning operations and clearfell. Although able to offer significant cost savings (it typically operates with a two-man crew), its load capacity of only 2.7 tonnes and limited ability to yard uphill were seen as disadvantages.

Skyline Carriage Control Systems

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 is an integrated boom, with processor attachment, mounted on a tower yarder and operated by the yarder operator (Figure 2).

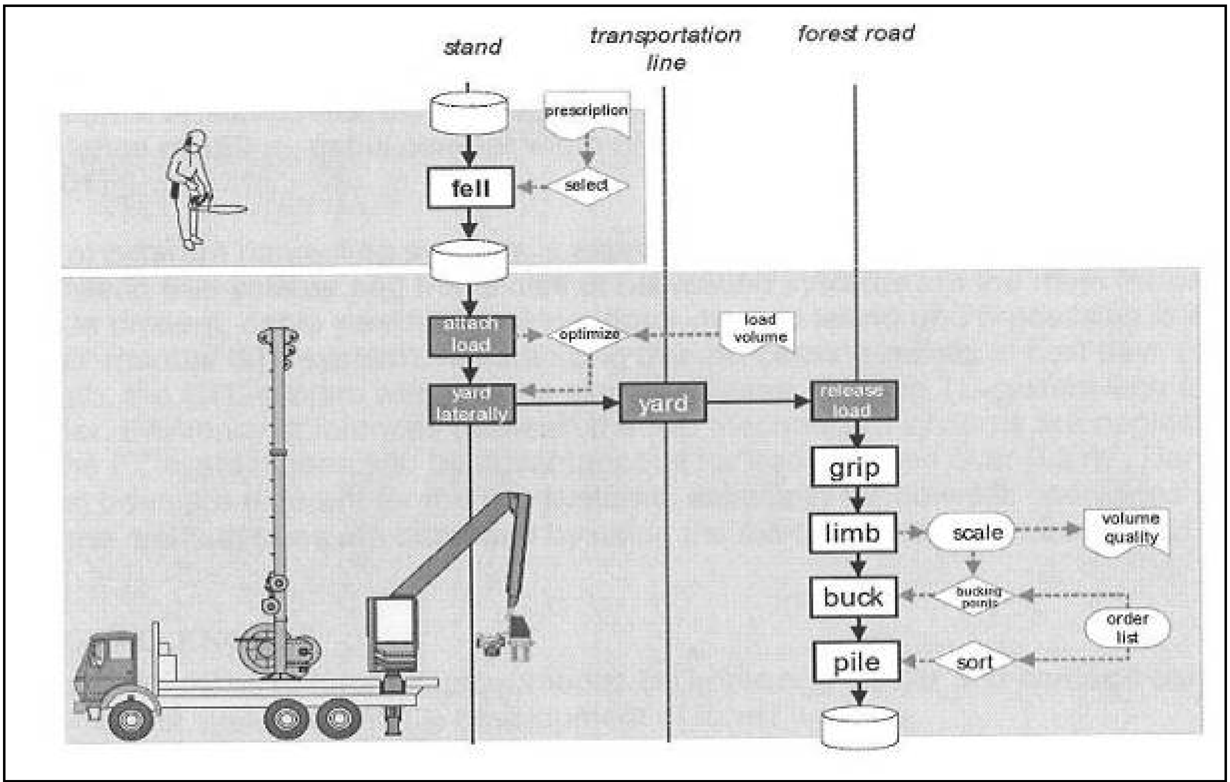

Figure 2. A tree-length PTY system[13]

An example of this system working in a Syncrofalke hauler was described in a LIRO technical note[14]. The distance from tower to carriage and carriage speed are derived from an encoder in the main rope sheave on the tower. Information is displayed in the cab. In addition to the manual controls in the cab, the breaker out can control both the carriage and yarder functions. There is also an automated carriage return function. Systems now include range programming which tells the drum control computer at what point carriage speed should change. Such systems are now well established for processor-tower yarders (PTY) in Central Europe[13].

The use of cameras to assist a yarder operator in hooking on or grappling a load could be regarded as a kind of control system. An early study by MacMillan Bloedel[15] of a fixed, cutover-based video camera (radio link to operator TV display) found that in a "steep canyon" environment, a grapple yarder's production rate was nearly doubled. There was no information indicating continued use of this technology.

Communication systems in yarding have traditionally involved hand-held radios and Talkie Tooter systems. These enable communication between the breaker outs and the yarder operator. Some systems, e.g. Talkie Tooter, can send audible signals either way but have voice communication only from the breaker outs to the yarder operator. Communication and activation of skyline carriage functions have been achieved in three ways:

- Yarder ropes.
- Timer delays.
- Radio controls.

Figure 3. The Koller MultiMatik system.

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. In several European PTY developments (e.g. Mayr-Melnhof Forsttechnik, Koller Forsttechnik), the breaker out has control (via radio-control) of the yarder drums as well as the functioning of a skyline carriage (Figure 3).

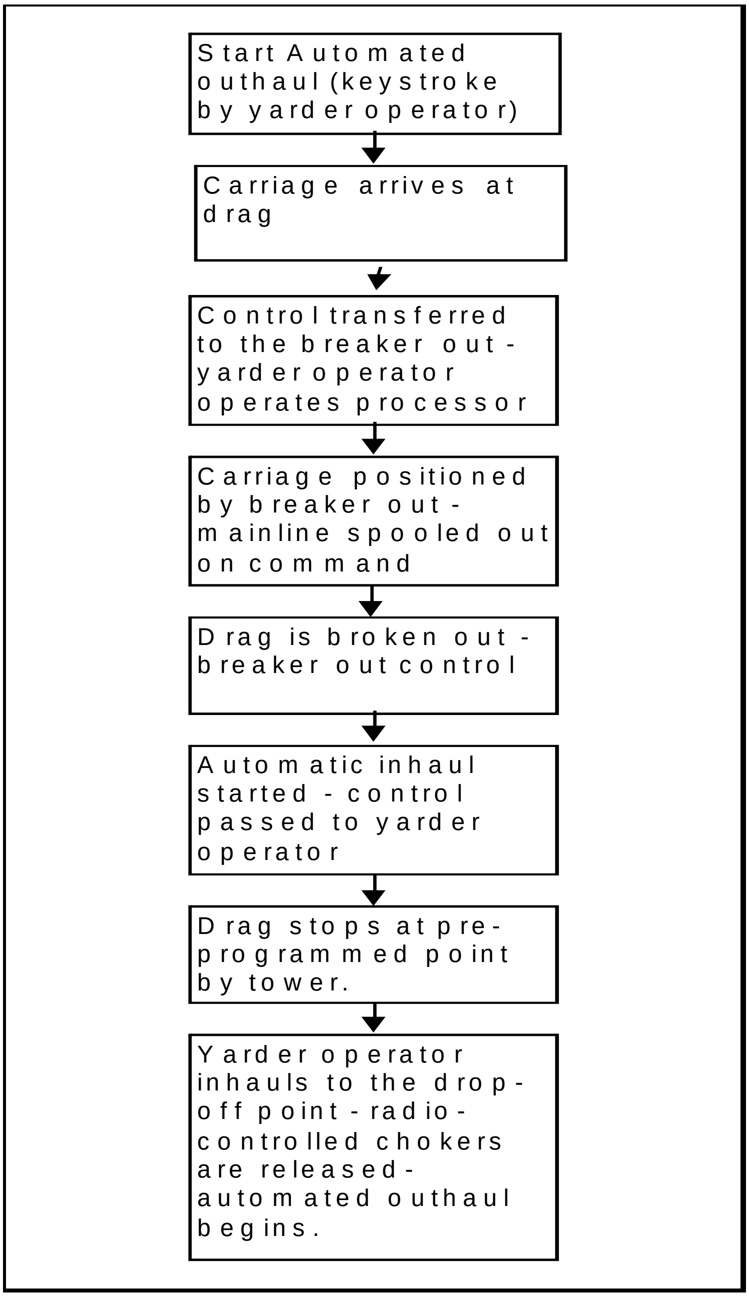

Figure 4. Sequence of operation with a PTY system[14].

Figure 4 shows the sequence of operation in a PTY system. The system enables the yarder operator to perform another function, namely that of processing with a harvester head. The yarder has an integral boom and stick with harvester head fitted.

Tower Yarders and Grapples

Tower yarders have the potential to run a grapple carriage. An early report[16] described one technique used with a J78 (modified Madill 009 yarder with an extra main line drum). The report also noted that fast line shifts and enhanced positioning of the grapple was achieved by the use of a moving tail block system, the tail block being moved by the use of a "corridor change drum and line" while configured as a high lead system. More recently, tower-grapple systems have also been used in New Zealand, with a Madill 071 (Wooster, pers.com).

Recent Grapple Carriage Developments

An innovative grapple carriage has been developed by Eagle Carriages (Figure 5.)

Figure 5. Mega Claw grapple carriage (Eagle carriage website)

Two variants, the Mega-Claw, and the lighter Yoder-Claw feature:

- Radio control.
- Hydraulic operation of grapple tines and rotation of the grapple.
- A video camera and cab display to aid the operator in the grappling process.
- Removal of grapples to allow the unit to be used as a slack pulling carriage.

The carriages are designed to operate on a live skyline rigging system in an uphill logging/gravity return situation.

A novel grapple carriage (ground-based) is the Konrad Pully[17] (Figure 6), which is not skyline supported but uses a single cable and capstan unit. A diesel motor and hydraulic pump supply power to the wheeled unit which also has a telescoping boom and grapple. The Pully is remote controlled.

Figure 6. Konrad Pully (Konrad website)

Helicopter Grapples

Grapples feature in other forestry operations such as helicopter logging. Some helicopter grapples require hydraulic control of the grapple tines[18]. Others such as the Fandrich[19] aerial grapple and Helihawk[20] grapple (Figure 7) use the lifting action or contact with the ground to open and close the grapple so no control lines are required.

Figure 7. Helihawk helicopter grapple (Helihawk website)

These kinds of grapple could have application with drop line carriages, in conjunction with a camera system.

Turn Back Yarding System

One method of reducing the hauler work cycle time (and hence improving productivity) is to reduce inhaul and outhaul time. A Japanese concept[21] which has been taken to a working scale model stage involves the use of two carriages that "hand over" or transfer the drag at the halfway point, thus halving the effective haul distance (Figure 8). As the one carriage is in inhaul mode, the other completes the outhaul. There may be other similar developments in Japan, but accessing information was difficult and internet searches were not very productive.

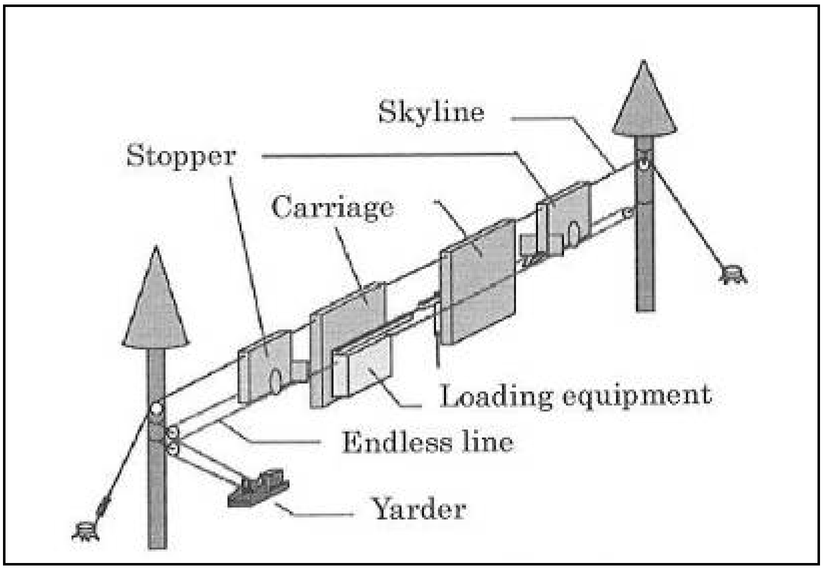

Figure 8. Turn back yarding system (Aruga* et al*, 2008)

A further development of the turn back system has been proposed and modelled by simulation[22]. It includes an independent lateral yarding carriage handing over to a gondola cable system. This was compared to two scenarios using a conventional gravity yarding system. At haul distances from 120 to 300 m both new systems showed productivity advantages.

STUDY METHOD

This review was compiled through reference to various reports, patents, papers and manufacturers' sites on the internet as well as interviews and discussions with cable logging experts.

Patents

The following patents (Table 8) were identified through internet searching, but may not include all currently applicable patents.

Table 2. Grapple carriages - Patents identified using search term "grapple carriage patents".

Inventor	US Patent No.	Pub. Date	Description
H.C. Hornsby	3572515	1971	Line operated grapple
S. Baker	7246712 B2	2007	Carriage and Grapple unit, Main rope operated Grapple, Remote control of grapple rotation, and carriage position on skyline.
L. Torgerson	7234605B1	2007	Remote controlled grapple with self-contained power supply
W. Maki	5653350	1997	Remote controlled, motorised grapple carriage on a skyline, grapple on a knuckle boom for lateral grappling of logs.

The following patents (Table 9) were identified when searching for "Slack pulling carriage patents":

Table 3. Slack Pulling Carriages - Patents identified using search term "slack pulling carriage patents".

Inventor	US Patent No.	Pub. Date	Description
S.L. Kuehn	4454951	1984	Remote controlled slack pulling carriage, integral hydraulic motor operated by an accumulator – mechanically charged.
J.C. Carlile	5975319	1999	Driving drum configuration in a slack pulling carriage
S. Baker	7213714	2007	Radio controlled, integral motor, hydraulically driven skidding line sheave, skidding line and skyline clamps. Novel pump control.
Davis	4687109	1987	Radio controlled electric slack puller, brake and battery recharging system

Interviews and Discussions

Comments and feedback were sought from two prominent cable logging consultants in the Pacific North-West (Brian Tuor, and Dallas Hemphill) regarding the most significant recent developments in cable logging carriages. Their comments are summarised below:

- Limited new developments and no significant innovations in recent years.
- Boman carriages have minor improvements in weight and performance.
- Acme slack pulling carriages appear to be leading the market.

- Use of carriages in NZ (relative to the US) may be related to heavier pine and fewer downhill logging operations.
- One interesting development is the Eagle carriage, which has a mounted camera. The carriage also allows a rapid change from grapple to chokers to suit stand conditions.
- Another interesting development is the inclusion of two- or three-speed transmissions in Acme carriages.

RESULTS

Skyline Carriages

Specifications of the following types of skyline carriages are described in the following tables:

(following the schematic in Figure 1):

- ***Type 1: Manual or gravity slack pulling***
- ***Type 2: Motorised Slack Pulling – Main rope pulled by carriage***
- ***Type 3: Motorised Slack Pulling – drop line (integral skidding drum)***
- ***Type 4: Mechanical Slack Pulling – Main rope pulled by yarder - slack pulling line***
- ***Type 5: Mechanical Slack Pulling – Main rope pulled by yarder – drop line (integral skidding drum)***
- ***Type 7: Non-slack pulling – grapple***

Table 4. Type 1: Skyline carriage – Manual or gravity slack pulling

Carriage	Model	Weight (kg)	Capacity (kg)	Max. skyline size (mm)	Lateral yarding	Yarding direction[2]	System[1]	Comments
Koller[23]	SKA 2.5	260	2500	28	Clamp by cycle, radio, timing	U	S	
Koller[23]	SKA 1	150	1500	24	Clamp by cycle, radio, timing	U	S	
Koller[23]	USKA 2.5	360	2500	28	Clamp by radio	U, D	S	
Koller[23]	USKA 1.5	285	1500	22	Clamp by radio	U, D	S	
Wyssen[24]	HY 7	630	7000	45	Clamping by radio	U	S	
Wyssen[24]	HY 3	-	3000	-	Clamping by radio	U	S	
Wyssen[24]	HY 2	350	3000	32	Clamping by radio	U	S	Hydraulic accumulator
Mayr Melnhof[25]	Sherpa SBA	150	1500	20	Clamping by radio	U	S	
Gantner[26]	BK 25		3000	26	Clamping by radio	U, (D)	S	Can also be rigged as 3 rope system, yarder slack pulling
Gantner[26]	BK 50		5000	36	Clamping by radio	U, (D)	S	Can also be rigged as 3 rope system, yarder slack pulling

[1] *System = S for skyline, = L for live skyline, = R for running skyline*

[2] *Yarding direction = U for uphill, D for downhill, F for flat*

Table 5. Type 2:Skyline carriage – MSP – Motorised - main rope pulled by carriage

Carriage	Model	Weight (kg)	Capacity (kg)	Max. skyline size (mm)	Motor rating (kW)	Yarding direction	System	Comments
Koller[23]	MSK 3	690	3039	-	5.6	U, D, F	S	Radio controlled
Acme[27]	Model 8	317	5443	22	6	U, D, F	S	All Acme carriages are radio controlled
Acme[27]	Model 10	453	5443	28	7.5	U, D, F	S	
Acme[27]	Model 19	725	6804	28	14	U, D, F	S	With 8 or 10 in skyline sheaves
Acme[27]	Model 23	725	6804	35	17	U, D, F	S	With 8 or 10 inch skyline sheaves
Acme[27]	Model 28	997	11, 340	35	21	U, D, F	S	With 10 or 16 inch skyline sheaves
Eagle[28]	Eagle IV	1043	6804	35	16.5	U, D, F	S	16 inch skyline sheaves
Eagle[28]	Eagle VI	1202	11,340	35	21	U, D, F	S	Hydrostatic drive slackpuller
Eagle[28]	Eaglet	719	6804	28	16.5	U, D, F	S	
Eagle	Super Eaglet	719	6804	28	16.5	U, D, F	S	Hydrostatic drive slackpuller

[1] *System = S for skyline, = L for live skyline, = R for running skyline*

[2] *Yarding direction = U for uphill, D for downhill, F for flat*

Table 6. Type 3: Skyline carriage – MSP – Motorised - drop line (integral skidding drum)

Carriage	Model	Weight (kg)	Capacity (kg)	Max. skyline size (mm)	Motor capacity (kW)	Yarding direction	Capacity of skidding drum (m)	Comments
Konrad[17]	Woodliner	-	25 – 30 kN (3000 kg)	22	73.5	D, F (U)	80 m of 12 mm	Self propelled, can be tail rope rigged
Konrad[17]	Liftliner	850	4000	22	-	U	100 m of 12 mm	
Mayr Melnhof[25]	Sherpa Mot II	480	4000	26	7.3	U	57 m of 11 mm	
Eagle[28]	Eagle V	1950	14,515	38	-	U, D	122 m of 14 mm	
Boman[29]	LT 9100 Sky car	997		28	45	U, D	61 m of 14 mm	Line pull 8,165 kg at mid drum
Boman[29]	Mark V H Magnum	1474		32	79	U, D	122 m of 14 mm	Line pull 11,794 kg at mid drum
Boman[29]	Mark IV Magnum	1808		32	97	U, D	122 m of 14 mm	Line pull 11,794 kg at mid drum
Boman[29]	Z 7900 Sky car	1950		35	119	U, D	152 m of 14 mm	Line pull 18,144 kg at mid drum
Teleforest[11]	TL 3000	1320	2700	22	53	F, D	76 m of 16 mm	Line pull 2,722 kg Self propelled carriage, fastest travel speed 6.1 m/sec

[2]*Yarding direction = U for uphill, D for downhill, F for flat*

Table 7. Type 4: Skyline carriage – MSP – Main rope pulled by yarder - slack pulling line

Carriage	Model	Weight (kg)	Capacity (kg)	Max. skyline size	Lateral yarding	Yarding direction	System	Comments
Johnson[30]	SPC092	254	-	-	-		L, R	Main line max. 22 mm Combination carriage or grapple
Johnson[30]	SPC102	399	-	-	-		L, R	Main line max. 22 mm Combination carriage or grapple

[1] *System = S for skyline, = L for live skyline, = R for running skyline*

[2] *Yarding direction = U for uphill, D for downhill, F for flat*

Table 8. Type 5: Skyline carriage – MSP – Main rope pulled by yarder - slack pulling line – drop line (integral skidding drum)

Carriage	Model	Weight (kg)	Capacity (kg)	Max. skyline size	Lateral yarding	Yarding direction	Skidding drum capacity (m)	Comments
Mayr Melnhof[25]	Sherpa U	250	1500	20 mm		U, D	57 m of 11 mm	
Mayr Melnhof[25]	Sherpa U 3	380	3000	24 mm		U, D	57 m of 11 mm	
Mayr Melnhof[25]	Sherpa U 4	490	4000	26 mm		U, D	57 m of 11 mm	
SLP Kritiny[31]	KOS 31	245	3000					Used with an endless line system

[1] *System = S for skyline, = L for live skyline, = R for running skyline*

[2] *Yarding direction = U for uphill, D for downhill, F for flat*

Table 9. Type 7: Skyline carriage – Non-slack pulling - grapple

Carriage	Model	Weight (kg)	Capacity (kg)/Opening dimension (cm)	Max. skyline size (mm)	Max. cable size (mm)	Yarding direction	System	Comments
Eagle[28]	Yoder Claw	816	213	19		U	L	Accumulator charged off skyline, grapple has powered rotation, Agcam camera system
Eagle[28]	Mega Claw	1270	-	28		U	L	Accumulator charged off skyline, grapple has powered rotation, Agcam camera system
Johnson[30]	SPC092G	413[3]	-	-	-	U, D	L, R	Combination carriage, used with Johnson Y76,86,88 grapples.
Johnson[30]	SPC102G	562[3]				U, D	L, R	Combination carriage, used with Johnson Y 96, 106, 108 grapples
Johnson[30]	Y 116	1,383	295		28	U, D	R	H models have thicker tines
Johnson[30]	Y 106H	1,306	269		25	U, D	R	
Johnson[30]	Y 106	1,161	269		25	U, D	R	
Johnson[30]	Y 96H	1.066	244		25	U, D	R	
Johnson[30]	Y 96	971	244		25	U, D	R	
Johnson[30]	Y 88H/86	884	223		22	U, D	R	
Johnson[30]	Y 88/86	835	223		22	U, D	R	
Johnson[30]	Y 76H	789	193		22	U, D	R	
Johnson[30]	Y 76	735	193		22	U, D	R	
Johnson[30]	Y 56	658	142		19	U, D	R	

[1] *System = S for skyline, = L for live skyline, = R for running skyline*

[2] *Yarding direction = U for uphill, D for downhill, F for flat*

[3] *Excludes weight of grapple*

CONCLUSION

A wide range of slack pulling carriages were found to be available (motorised and otherwise). Some US and Canadian carriage manufacturers identified in the 1980s and 1990s were no longer in the business or could not be contacted (e.g. Skagit, Danebo). European-sourced slack pulling carriages tended to have smaller capacities than their US counterparts and were often suited to downhill logging of log-length material. Acme slack pulling carriages were identified as innovative in their use of two- and three-speed transmissions.

There were no grapple carriages found to be manufactured or used in Europe. The most innovative grapple carriage identified was that made by Eagle Skyline Carriages with its remote-controlled, camera assisted, hydraulic actuation of the grapple and grapple rotation. No operational reports of the carriage's use were found.

The most advanced carriage control systems found were the PTY systems developed and used by Koller Forsttechnik (MultiMatik) and Mayr-Melnhof Forsttechnik (Syncrofalke yarder).

If there is the potential for adaptation of other designs of carriage or grapple, two examples might be the Konrad Pully, and the Helihawk. The Helihawk helicopter grapple may have application with a tower yarder-based drop line carriage, especially if a camera could be mounted on the carriage, and a method of providing lateral movement of the skyline developed.

Another development, the Japanese Turn back yarding system, has the potential to significantly reduce yarder work-cycle time by effectively halving the haul distance for any given load location.

Some combination of these technology advances may have application in New Zealand clearfell cable yarding operations to:

- Enable wider haul corridors to be logged (reducing the number of rope shifts) and possibly exploiting bunched drags.
- Aid grapple yarder or tower yarder grapple operators to more efficiently grapple a load.
- Allow spotters or breaker outs more control over positioning of rigging and positioning and activation of grapples.

The end goal is to reduce work cycle times, and consequently increase productivity of cable logging systems used in New Zealand.

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REFERENCES

1. Forest Industries Training, Best practice guidelines for cable logging. FIT: Rotorua, New Zealand. (2000).
2. Prebble, R., Drop line carriage on Madill 071. LIRA Report, Vol. 15 (7). N.Z Logging Industry Research Association Inc.: Rotorua, New Zealand. (1990).
3. Studier, D., Carriages for skylines. Research Contribution, No. 3. College of Forestry, Forest Research Laboratary, Oregon State University: Oregon. (1993).
4. Palmer, W., Robinson, P., The use of motorised slackpulling and Skycar carriages in cable operations. LIRO Technical Note, No. 45. New Zealand Logging Industry Research Organisation: Rotorua, New Zealand. (1998).
5. Hemphill, D.C., Skyline carriage survey. New Zealand Logging Industry Research Association. (1985).
6. Duggan, M., The Koller 2.5 self-clamping carriage. LIRA Report, Vol. 14 (22). Logging Industry Research Association Inc.: Rotorua, New Zealand. (1989).
7. Palmer, D., Eagle II motorised slackpulling carriage. LIRO Report, Vol. 20 (25). Logging Industry Research Organisation: Rotorua, New Zealand. (1995).
8. Palmer, W., Robinson, P., Boman Mk III-H Skycar: A case study. LIRO Technical Note, No. 44. New Zealand Logging Industry Research Organisation: Rotorua, New Zealand. (1998).
9. Tuor, B., Palmer, D., and McMahon, S., Clamping carriages and skyline tensions. LIRO Report, No. 23 (9). New Zealand Logging Industry Research Organisation: Rotorua, New Zealand. (1998).
10. Stampfer, K., Daxner, P., and Visser, R., An alternative cable system: Self-propelled carriages. LIRO Technical Note, No. 46. New Zealand Logging Industry Research Organisation: Rotorua, New Zealand. (1998).
11. Teleforest, Telecarrier. 2010]; Available from: www.teleforest.com.
12. Foronomics Consulting Ltd, Assessment of the TLD Gauthier Telecarrier TL 3000C and its suitability for North Island applications. Community Futures Development Corporation of Mt Waddington, Canada (1998).
13. Heinimann, H.R., Stampfer, K., Loschek, K., and Caminada, L., Perspectives on Central European cable yarding systems. In (Eds.), The International Mountain Logging and 11th Pacific Northwest Skyline symposium 2001; Proceedings of Seattle, Washington, (2001).
14. Visser, R., and Pertlik, E., Syncrofalke automated skyline hauler. LIRA Technical Note, No. 24. New Zealand Logging Industry Research Association Inc: Rotorua, New Zealand. (1996).
15. MacMillan Bloedel, MB's video yarding system increases productivity. Logging and Sawmilling Journal 14 (2), pp. (1983).
16. MacMillan Bloedel, Grapple yarding: New technique. Forest Industries (NZ), 14 (2), pp. (1982).
17. Konrad Forsttechnik, Carriages: Pully. Available from: www.forsttechnik.at.
18. Isolair Inc, Isolair logging grapple. Available from: www.isolairinc.com.
19. Fandrich Inc, Fandrich aerial grapple. Available from: www.coneharvesters.com.
20. Putaruru Welding Ltd, Helihawk grapple. Available from: www.helihawk.co.nz.
21. Aruga, K., Development of a new operation system with carriages for turn back yarding system. In (Eds.), Proceedings of COFE 2009; King's Beach, California, (2009).

22. Yoshimura, T., and Hartsough, B., Simulation-based validation of new conceptual cable harvesting systems. In (Eds.), Proceedings of Formec 2010 Forest Engineering: Meeting the needs of the society and the environment; Padova, Italy, (2010).
23. Koller Forsttechnik, Carriages, Yarders. Available from: www.kollerna.com. (2010)
24. Wyssen Seilbahnen Ag, Carriages. Available from: www.wyssen.com.
25. Mayr Melnhof Forsttechnik, Carriages, Yarders. Available from: www.mm-forsttechnik.at.
26. Gantner Seilbahnbau, Carriages, /winches. Available from: www.gantner-cableways.com.
27. Acme Manufacturing Inc, Carriages. 2010]; Available from: www.acmecarriages.com.
28. Eagle Carriage & Machine Inc., 12 December]; Available from: www.eaglecarriage.com.
29. Boman Industries Inc; Available from: www.smith-boman.com.
30. Johnson Industries Ltd, Grapple carriages. Available from: www.jlogging.com.
31. SLP Krtiny, Carriages, Yarders. Available from: www.slpkrtiny.cz.