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Skyshifter
Twin Winch Tail Hold Carriage:
Field Trials

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Primary Growth Partnership (PGP) Steepland Harvesting programme included a project to develop an innovative yarding system to reduce log extraction cost from steepland and to improve safety of the steepland extraction process.

An idea generation process was undertaken in 2012 across the New Zealand logging industry, whereby more than 70 ideas were generated. Through the subsequent rigorous feasibility assessment many ideas did not meet the project criteria to be innovative, technically feasible and reduce cable harvesting costs significantly.

One innovative yarding system idea was later proposed by Awdon Technologies Ltd. The system incorporated a low-cost yarder, a self-propelled grapple carriage, a lateral yarding carriage, and a tail hold carriage to move the skyline (Skyshifter). The Skyshifter tail hold carriage concept was taken forward to the next stage of development, to design and build the prototype.

On completion of the prototype build, the Skyshifter was tested at three sites to see how well it met the original design specifications. Not all specifications were met, but the most important parameter (winch line pull) was exceeded. This report provides a summary of the Skyshifter performance against the original design specification. As part of the trials, different application methods were also tested. On completion of the field trials the economic analysis was updated.

During the trials, it became evident that the Skyshifter and or the winch ropes should not touch the ground or any obstacle during moving, and thus the winch ropes would need to be tied off to tail trees making setup time longer than first expected. The updated economic analysis showed the Skyshifter could improve on-truck log cost by about 9.4%. This was lower than the original economic analysis of 12% improvement due to the requirement for the winch ropes to be tied off to tail trees.

INTRODUCTION

The Innovative Yarding System project aimed to develop a new alternative yarding system to increase harvesting productivity and reduce the cost of cable yarding. An idea generation process was undertaken in 2012 across the New Zealand logging industry.

To generate ideas for an innovative yarding system, four workshops were held across New Zealand which resulted in many innovative and general improvement ideas being put forward by the participants [1 & 2]. Of the 72 ideas generated during the workshops only 22% were deemed innovative by an independent selection committee. Further technical and economic analysis showed that many of the ideas either were not feasible or did not improve harvesting cost significantly (a key project objective). Of the 72 ideas generated during the workshops, 8% were about improving rope shifting time.

One innovative yarding system idea was later proposed by Awdon Technologies Ltd, a design and development company from Gisborne, New Zealand. Awdon's system incorporated a low-cost yarder, a self-propelled grapple carriage, a lateral yarding carriage (to put a bight in the skyline), and a tail hold carriage to take the place of a mobile tail hold to move the working ropes across the cutover to aid and improve grapple extraction productivity[4].

Due to constraints in time and project resources, only the Skyshifter tail hold carriage concept was taken forward to the next stage of development, to design and build the prototype. On analysis, the tail hold carriage showed the most advantage for improving grapple extraction productivity and reducing on-truck log cost. It was also seen that this concept could be retrofitted to yarding systems already operating across New Zealand, and as such was considered to have the best commercial application.

The concept was that the skyline from the cable yarder would be anchored to the tail-hold carriage which would contain two winch lines that are separately anchored 60m to 70m apart at the back line of the cable setting. Letting one winch rope out while winding in the other would allow the tail-hold carriage and skyline to be moved sideways.

Several tail hold carriage designs were developed by Awdon and the pros and cons of each design were carefully assessed. To help with the assessment, small models (1/20 scale) of each design were developed to further test each theory prior to the final carriage design selection. Additionally, experts from the University of Canterbury determined the theoretical impact of having the additional weight of the tail hold carriage at the back of the skyline, and calculated what affect that would have on payload.

An alpha prototype ($^{1}/_{8}$ scale model) of the selected design was built to demonstrate (including the installation process) how the concept would work, and was tested in front of a selection of industry people in Gisborne. On positive feedback from industry the Skyshifter carriage underwent full design, peer review and construction.

The completed Skyshifter carriage was first tested in a contractor's workshop yard in Gisborne in February 2016, where the Skyshifter was suspended between three excavators. Further field tests were conducted in Kererutahi Forest in the Bay of Plenty in conjunction with a TMY90 tower yarder running a Falcon Forestry Claw grapple carriage, and a third field test was conducted in Gammons Forest, also in the Bay of Plenty, on a Thunderbird 6355 swing yarder running an Alpine grapple carriage.

This report summarises the three field tests and the learnings from those tests, and how the Skyshifter might be incorporated into an operation. An updated economic analysis is provided.

DESIGN SPECIFICATIONS

The design team (which included Don Scott of Awdon Technologies Ltd, Maurice Signal of Signal Electronics and Mike Grooby of Eaton Hydraulics Ltd) were provided with the following specifications as a guideline for development:

1. One or two small winch drums capable of carrying 100 metres of 26mm to 28mm diameter rope
2. The winch drums to have pulling power of at least 4 tonnes
3. Have walk over guy capability
4. Carriage to weigh <1.2 tonnes
5. The winch drums to have rope spooling capability
6. The carriage to be remote controlled from the yarder
7. On-board camera system to monitor operation of the winch drums
8. The carriage to withstand 30 tonnes of skyline tension

SELECTED DESIGN

The chosen design is shown in Figure 1 and was selected as it met more of the design parameters than the other designs [6]. On actual design though, the carriage was going to weigh more than double the specified weight parameter, and roll over winch ropes were not going to be an option. To further complicate the design, an independent engineer showed the system needed to be interlocked to have any level of efficiency in terms of power requirements.

In general, the Skyshifter is the result of a very detailed design which was discussed in an earlier report, and while it is not practical to report on all this detail it is worth mentioning the process undertaken to design just the winch drums. The European Federation of Material Handling standard for Tower Cranes (ISO/TC 96) was used as the initial design guide. The standard required the winch drums to be almost solid steel (heavy) for this application, which didn't seem right given that no hauler drums used in New Zealand would have met the EFMH standard. Awdon Technologies engaged SGS New Zealand Ltd (certification service providers) who came to Gisborne and tested a 171 Madill winch set for metal type, dimensioning and assembly, and along with the Madill 171 manufacturer's specifications sent this information to Motivated Design and Analysis Ltd who then calculated the minimum requirements for the twin winch setup.

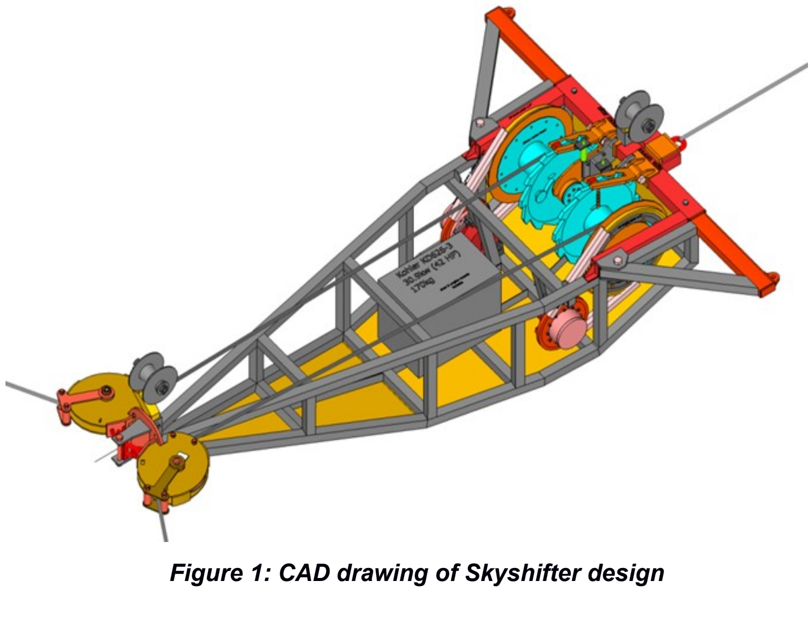


Figure 1: CAD drawing of Skyshifter design

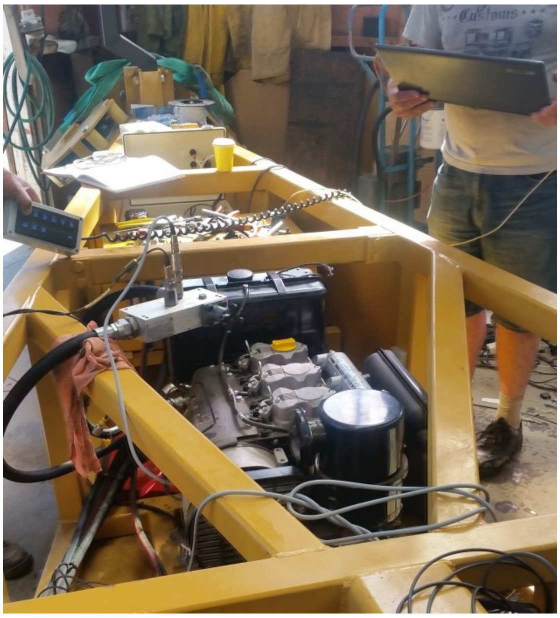
In comparison to the original design parameters, the Skyshifter design met drum capacity requirements, on-board cameras, remote control and can withstand 30 tonnes of skyline tension. Due to the length of the carriage, the winch drums did not need a rope spooling mechanism. The winch drums have a 7-tonne line pull, almost double the design parameter. The selected design did allow the use of synthetic winch ropes, which weren't a design parameter, but it became evident early in the design process that synthetic winch ropes were going to be a key requirement to aid quick and easy setup.

Figure 2: Skyshifter winch assembly

THE BUILD PROCESS

The carriage frame, sheaves and winch drums were built by Hancock Engineering Ltd in their Mosgiel workshop. The frame is 100 x 100 box section mild steel, the floor is 5mm mild steel and the side panels are 3mm mild steel.

Figure 3: Skyshifter frame during construction



The engine, hydraulic componentry and electronic system were fitted by Signal Electronics and Eaton Hydraulics Ltd.

The hydraulic system and the Kohler 35kW engine have in-built safety management systems to avoid major breakdowns and damage. These include but not limited to:

- low engine oil pressure – engine stops
- low hydraulic pressure - warning
- Low hydraulic pump charge pressure – engine stops
- Engine temperature - warning
- Low battery charging – warning.

Figure 4: Programming the hydraulics and engine management system

FIELD TEST ONE

The first field test was carried out in a flat paddock. The Skyshifter was suspended between three excavators, and a series of tests was completed, including;

- Line tension and winch pulling power
- Over tensioning
- Travel speed
- Rope fleeting
- Rope angle calculation
- Video performance
- The skyline balancing system
- Training of operator.

Figure 5: Skyshifter Field Test 1 setup

Figure 5 shows the setup for Field Test 1. In this setup (poor deflection, skyline = 15^0, guy 1 = 5^0 and guy 2 = 5^0), 7 tonnes of tension were required to lift the Skyshifter off the ground, and therefore operation of the Skyshifter was on the upper tension limit where the brakes could not release. The highest tension recorded was just on 10 tonnes, at which point the winch would stall.

The maximum tension applied during this test was 20 tonnes and during and after this test no adverse effects were recorded either to the structure of the Skyshifter or to the synthetic winch ropes.

Travel speed was recorded from several passes backward and forwards, and averaged 6 seconds per metre – that is, the skyline would move across the cutover 1 metre every 6 seconds.

Figure 6: Skyline balancing mechanism to keep Skyshifter level with varying winch rope tensions

Rope fleeting worked very well if each layer of synthetic rope was tight (wound on with 4 to 5 tonnes of pressure). If the rope was loose on the drum, the top layer would bite down through lower layers and become jammed. The on-board camera system allowed the operator to keep a close check on the rope fleeting.

To ensure that the tension in the winch ropes of the Skyshifter does not exceed the tension in the skyline, the angle between the two synthetic winch ropes must be 120^0 or less. The angle calculation is based on the amount of line out for each winch and the distance between the two anchor points (an input). The line out is calculated from the winch drum revolutions, but this is dependent on how many wraps of line are on the drums. The rope angle calculation was inaccurate.

The video performance was good with a very clear view of the winch drums. The video link had to be line of sight. If the sun was directly on the camera this did cause issues with glare.

The Skyshifter has a skyline balancing mechanism which keeps the Skyshifter level as the tension in the winch ropes change. This mechanism was tested and worked well. To operate the mechanism the tension in the skyline had to be < 5 tonnes.

Operator training was relatively simple as the system is easy to use if the carriage is clear of the ground. During the first test, the carriage could touch the ground and each time it did it would almost roll.

On completion of the first field test adjustments were made to the programme to try and better predict the distance of line out.

FIELD TEST TWO

The second field test was undertaken at an operation with a 22m TMY90 tower yarder running a Falcon Forestry Claw grapple carriage in Kererutahi Forest in the eastern Bay of Plenty. The setting was considered ideal as the back face slope was steep, with a deep gully.

Figure 7: Setting used during Skyshifter Field Test 2.

Figure 8: Skyshifter in position just prior to being lifted into working position with the skyline

For this test, the Skyshifter was carried to the backline so that setup wouldn't interfere with production too much.

The Skyshifter winch lines were set up on stumps about 40m apart. Two additional lines were set up on the back of the Skyshifter and tied down to stumps for added safety, particularly when checking the Skyshifter or turning it off and on. These safety lines would be necessary to hold the Skyshifter in place while anchoring the Skyshifter winch lines in the first setup (refer to the manual setup procedure in Appendix One).

Figure 9: Skyshifter setup on a 32mm skyline

This field test was a repeat of the first field test, but in a working situation. The results were the same as the first field test in terms of movement speed, line out calculations, and rope fleeting if the Skyshifter was clear of the ground and obstructions. During test two the winch ropes were moved to new stumps, and this operation was easy from a human workload perspective.

The time to shift to new stumps included securing the Skyshifter so it didn't move while slacking the winch ropes, moving the winch ropes and then releasing the Skyshifter to allow operation. The new stumps had been pre-rigged. This move took less than 15 minutes with one person. During the trial, a few difficulties were experienced which had not been identified in the first field test.

The difficulties included;

1. A lack of deflection at the carriage (critical point) meant that high tension was necessary to lift Skyshifter clear of the ground to move.
2. The hauler operator had difficulty seeing the Skyshifter, and therefore shifting the Skyshifter required a spotter. If the Skyshifter tilted 30^0 to the side or 45^0 length ways the oil pressure in the engine would drop and the engine would automatically switch off.
3. Anchoring to stumps did not provide enough height, and therefore the blue synthetic winch lines were on the ground.
4. When the synthetic ropes left the sheave on the back of the Skyshifter at an acute angle, the rope could rub on a sharp edge which could easily cause damage to the synthetic rope.
5. Mechanical issues during the test included a hydraulic hose coming off dropping all the hydraulic oil, and the engine throttle coming loose, both causing the engine to stop automatically. In both cases the Skyshifter was in a very difficult spot to fix.
6. The electronic system in the Skyshifter would switch off overnight which meant someone would need to visit the Skyshifter in the morning to switch it back on, which, depending on how the Skyshifter was sitting, could be dangerous.

Several changes were made to Skyshifter to overcome the difficulties experienced during Field Test 2. These included:

1. A rotary oil pickup was installed in the engine so that the Skyshifter would work on acute angles, 60^0 length ways and 75^0 to the side.
2. All hydraulic lines were tightened.
3. A locking mechanism was installed on the throttle.
4. It was apparent that the anchoring points for the synthetic winch lines had to be elevated to ensure the synthetic winch lines would never touch the ground, Figure 10.
5. All sharp angles at the front sheave were removed, Figure 11.
6. Changes were made to the electrical system to ensure the system did not power down, and a new sleep function was added to the electronic system to ensure good battery life.
7. Programming changes were made so that the rope out record would improve the angle calculation between the two synthetic winch ropes.

Figure 10: Poor deflection at the backline made shifting the Skyshifter very difficult.

Figure 11: Sharp angles anywhere synthetic rope can touch must be avoided (both on the carriage and when the winch lines are extended, including stumps).

ELEVATING THE SKYSHIFTER ANCHOR POINTS

Elevating the anchor points in tail trees would help ensure the synthetic winch ropes are clear of obstacles to reduce abrasion[(5)], and more importantly improve the change in angle between the skyline and the synthetic winch ropes (deflection at the Skyshifter). The greater the change in angle at the Skyshifter, the lower the tension in all ropes, and this allows better control of the Skyshifter during movement. However rigging tail trees requires more effort than tying off to stumps. Tail trees are required to be topped by a certified tree rigger; and a second certified tree rigger capable of performing a rescue must also be present.

Figure 12: Elevated anchors ensure Skyshifter and winch ropes can be lifted clear of the ground.

The Skyshifter operates through an arc of 75^0 to 80^0 in a single setup (refer Figure 13), this would require at least three support guys for each tail tree. It is likely that the same tail tree would be used when logging the next chord, and therefore each tail tree would require at least 5 support guys. It is reasonable to expect each tail tree will take two to three hours to rig with two people.

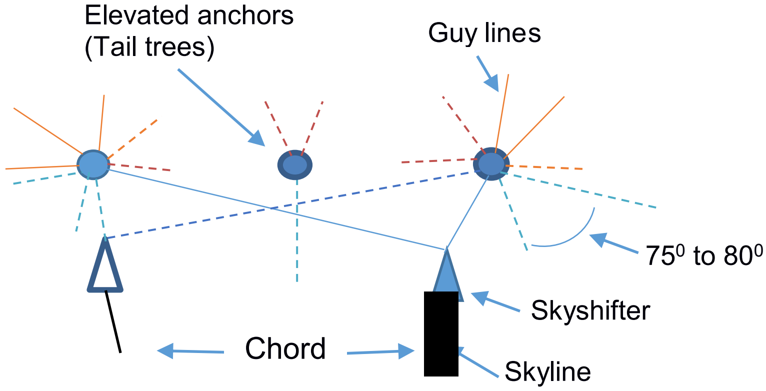


Figure 13: Tail trees will require five support guys.

Figure 13 shows a third tail tree sited in the middle. This elevated anchor would be necessary to log the triangle behind the Skyshifter when the Skyshifter is positioned in the middle of the two main tail trees. Ideally, in addition to what is shown in figure 16, a fourth elevated anchor would be pre-rigged to reduce shifting time between chords. That would mean 17 guy ropes would be required in total. Shifting this quantity of steel guy ropes would not be feasible, and therefore adjustable synthetic guy ropes would be key to this setup.

FIELD TEST THREE

The third field test was undertaken at a Thunderbird 6355 swing yarder operation running an Alpine grapple carriage in Gammons Forest in the Bay of Plenty. While the Skyshifter was designed more to enhance grapple extraction with tower operations, this test was aimed at proving whether it could also work with a grapple swing yarder.

The main learnings from the previous two field tests were that the Skyshifter or the winch ropes should not touch the ground or any obstacles at any time during Skyshifter movement, and that a good understanding of expected rope tensions prior to setup would be crucial. Ensuring the tail trees were available in the correct locations would take careful planning, and the height of those anchors would require calculations to be done. Prior to the third field test, expected rope tensions were calculated from a force diagram of the expected setup. The calculation was used to check if tail trees were required, and if so how tall these needed to be.

This field test mirrored the previous two tests in terms of the metrics collected. The Skyshifter performed the same on the swing yarder setup as the previous two tests. An observation during this test was that the Skyshifter sat on the ground during grapple extraction and was very stable in that position. The original design weight specification was 1.2 tonnes with the final weight being 3 tonnes; the extra weight may have helped with stability of the Skyshifter during extraction. A lighter Skyshifter may not be as stable during the extraction phase.

Figure 14: Elevated anchors guyed with adjustable synthetic rope

Figure 15: Tightening the adjustable synthetic guy ropes with a light weight “cumalong”.

The inputs required for the calculation included;

1. The angle between the Skyshifter winch ropes (refer to Figure 17)
2. The angle from the Skyshifter to the top of the hauler pole/boom, assuming the Skyshifter is 1m off the ground.
3. The angle and length of the Skyshifter winch lines to the anchor points, assuming the Skyshifter is 1m off the ground.

Figure 16: Field Test 3 setup.

In this setup, the distance from the tail tree to the Skyshifter was 20m, the distance between tail trees was 32m, the distance the Skyshifter was below the bottom of the tail tree was 1m and the winch ropes were secured 7m up the tail tree. The angle to the top of the hauler was 25^0 and the angles of the winch ropes were 20^0. The angle between the winch ropes was 110^0. Calculation of this setup showed the tension would be less than 3 tonnes. This meant the tail tree could have been reduced in height and still worked satisfactorily.

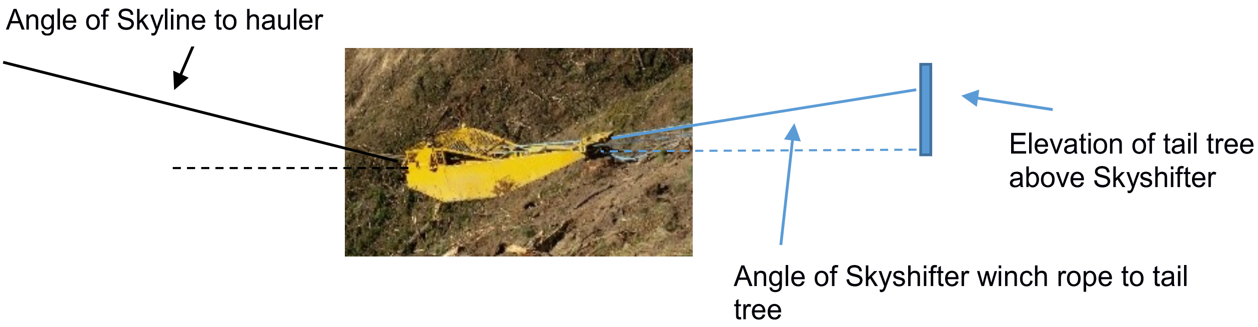


Figure 17: Important rope angles

Table 1: Relationship between skyline and winch rope angles to rope tension and corresponding height of tail tree anchor above the Skyshifter.

Angle of Skyline to hauler	Angle of Skyshifter Winch Rope to Tail tree	Tension in Skyline	Tension in Winch ropes	Elevation of Tailtree above Skyshifter Including Ground Slope
10	5	8.6	8.5	2.18
10	10	5.7	5.7	4.36
10	15	4.2	4.3	6.54
10	20	3.3	3.5	8.73
15	5	7	6.7	2.18
15	10	5	4.9	4.36
15	15	3.8	3.8	6.54
15	20	3.1	3.2	8.73
20	5	5.9	5.6	2.18
20	10	4.4	4.2	4.36
20	15	3.5	3.4	6.54
20	20	2.9	2.9	8.73
25	5	5.1	4.7	2.18
25	10	4	3.7	4.36
25	15	3.3	3.1	6.54
25	**20**	**2.7**	**2.6**	**8.73**

In Table 1, the last line of the table (highlighted) indicates the setup for Field Test 3. The height of the tail tree could have been reduced to 4m without over-tensioning the winch ropes.

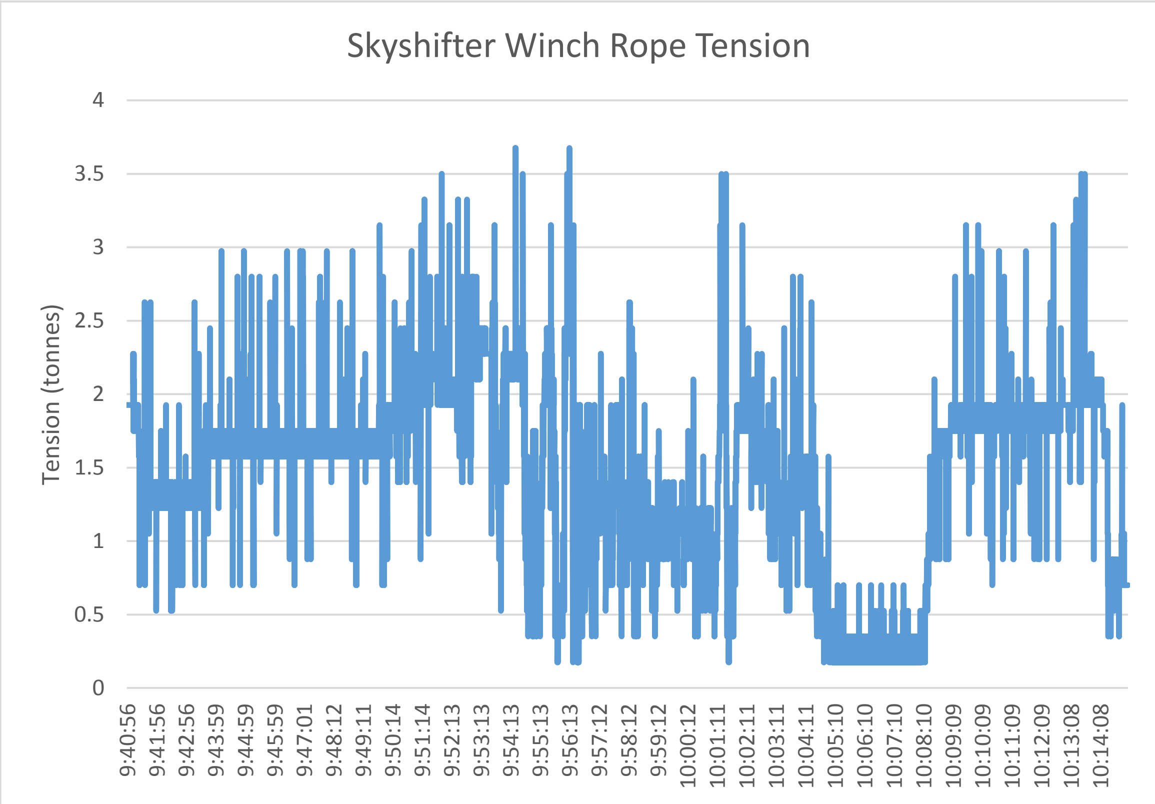


Figure 18: Actual tension monitor readings of right hand winch rope during movement of the Skyshifter

POSITIONING SKYSHIFTER ON BACKLINE

For all three field tests the Skyshifter was carried to the backline and into position with an excavator. In normal operation, the Skyshifter would be "flown out" on the skyline. Part of the project included developing a method to do this. This method is outlined in Appendix One.

UPDATE TO THE ECONOMIC ANALYSIS

Prior to the development of the Skyshifter prototype, an economic feasibility analysis showed an 11.92% improvement in on-truck log cost. At that time it was assumed that the winch ropes could be secured to stumps. As a result of the production field trials of the Skyshifter this assumption proved to be the exception rather than normal practice (due to terrain limitations). The economic analysis was updated to include the rigging of tail trees and updated information regarding shifting times. This amended the expected improvement in on-truck log cost to be around 9-10% (Table 2).

The updated economic analysis shows the expected difference between a tower operation running a grapple and manual line shifting compared to the same operation using a Skyshifter for line shifting to be **$4.28 per tonne** in favour of using a Skyshifter.

Table 2: Updated economic assessment of the likely improvements of on-truck log cost using Skyshifter.

Comparison of Harvesting Systems		
Elements	**Current Standard Tower Operation with Grapple Carriage - No Twin Winch Tail Hold Carriage**	**Current Standard Tower Operation with Grapple Carriage - with a Twin Winch Tail Hold Carriage**
Piece size (tonne)	**2**	**2**
Minutes per day available to work	**480**	**480**
Haul distance (m)	**280**	**280**
Out Haul (sec's)	47	47
Position Grapple (sec's)	30	20
In Haul (sec's)	93	93
Drop Load (sec's)	5	5
Un-hook (sec's)	40	30
Lift Ropes (sec's)	20	20
Cycle Time (minutes)	**3.92**	**3.58**
Contingincy 10% (minutes)	**0.39**	**0.36**
Time Per Cycle (minutes)	**4.31**	**3.94**
Move backline minutes per day	45	8
Reposition Hauler minutes per day	8	8
Rig up minutes per day	11	24
Rig down minutes per day	11	19
Mechanical Delay minutes per day	8	8
Operational Delay minutes per day	15	15
Cycles per day	**89**	**101**
Tonnes per cycle	**2.40**	**2.40**
Trees per cycle	1.2	1.2
Production per Day (tonnes)	**213**	**243**
Day Cost of Operation ($)	**9,702**	**10,006**
Unit Rate ($)	**45.47**	**41.19**
% Improvement	**9.43%**	

Assumptions in developing this economic analysis included:

- Out-haul speed of 6 m/s (original analysis was 9 m/s, now considered to be too fast [7]).
- A slightly longer grapple time in the manual operation due to larger shifts, resulting in a mixture of butt pull, gut hook and head pull extraction.
- In-haul speed of 3 m/s (original analysis was 3.5 m/s, now considered to be too fast).
- Unhook time was slightly slower in the manual operation due to gut hooks and head pulls taking longer to unhook.
- Move backline in manual operation includes moving the skyline and tail rope 12m, taking 45 minutes. Moving the Skyshifter the same distance takes 1.3 minutes, plus every third day having to shift both winch ropes taking 20 minutes (average 6.7 minutes per day)
- Rigging up is expected to be slower for the Skyshifter operation (24 minutes vs. 11 minutes) based on the assumption that the Skyshifter is flown out on the ropes and set up for the first time. Likewise, down-rigging returning the Skyshifter to the landing for a hauler move would take longer than standard practice (19 minutes vs. 11 minutes).

CONCLUSION

The development project and the subsequent field trials of the Skyshifter showed the new technology product to be a success, even though the target reduction in on-truck logging cost was not achieved. The Skyshifter performed or in some cases out-performed, the original design specifications with the exception of carriage weight. The final weight (3 tonnes) was more than double the design specification and this made shifting the Skyshifter between harvest areas more difficult. However it was observed during the trials that the Skyshifter was reasonably stable during extraction, particularly when used with the running skyline system.

The winch line-pull of 7 tonnes exceeded the design specification of 4 tonnes. The additional line pull was required for ease of operation. More line pull could be gained if the winch ropes were double purchased (out to the tail tree and back to the Skyshifter), and this would enable the Skyshifter to work in low deflection areas where there was less opportunity to reduce skyline tension. The travel speed of the Skyshifter was more than adequate at 6 sec/m. At this speed it took 30 seconds to shift the carriage laterally by 5 metres.

During the trials, it was observed that the Skyshifter and winch ropes had to be clear of the ground and any obstacles during moving laterally. Any obstruction made moving the Skyshifter difficult. If the hauler operator was to control the Skyshifter move without the aid of a spotter, an additional vision system (such as the CutoverCam) would be advantageous.

The updated economic analysis showed a 9.4% improvement in on-truck logging cost (approximately $4.28 per tonne) could be expected when using the Skyshifter to improve skyline shifting time.

For ease of setup a tension calculator app would be crucial to ensure the setup was done within working limits. This app would also calculate the height of the tail trees.

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APPENDIX ONE

Using Skyline for Installation

Setup of Skyshifter for a slackline skyline system with the tail rope connected to the Skyshifter for a three drum hauler if there is no access to backline:

1. Layout straw line for a line shift (as per standard practice) including around a side block at the landing prior to sending to a single stump near where the Skyshifter will begin operation.

2. Pull out tail rope as per normal with straw line with short piece of skyline attached to the tail rope eye (with an eye at each end and approximately 5m long) which can be synthetic or wire. This short piece of skyline is only for setup purposes and must be used so that the skyline can be transferred from the stump to the front of the Skyshifter. At the backline, detach the short piece of skyline and attach to a stump. Pull tail rope back to hauler with straw line.

3. Once tail rope is back at hauler attach both skyline and straw line to tail rope. Pull out the skyline and straw line with the tail rope. Attach the skyline to the short piece of skyline already set up at the backline. Slacken tail rope so that the skyline pulls up tight on stump. The tail rope will be tight at this point, so get slack in straw line and attach to a pass chain around tail rope. Tighten straw line to get enough slack in tail rope to undo shackle from skyline. Reattach straw line to tail rope.

4. Pull the tail rope in and return the straw line to the hauler so that the straw line remains laid out in the cutover.

5. Lift the Skyshifter into position at the hauler.

6. Feed the tail rope around the two spreader sheaves on the front of the carriage, either sheave first. Ensure the straw line remains on the outside of the tail rope. Connect the tail rope eye to the base of the tower; this will be connected to the back of the grapple carriage.

7. Lift the carriage onto the skyline but ensure the carriage is still firmly on the ground by allowing enough slack in the skyline.

8. Connect a short piece of skyline to the front of the carriage about a metre long at the position where the skyline will be attached and wrap up out of the way of the tail rope.

9. Attach the straw line to the back of the carriage.

10. The carriage is ready to send out. Take up all slack in the tail rope.

11. Lift the skyline while braking the tail rope, and once high enough off the ground take up the slack in the straw line. Reduce pressure in the tail rope brake and pull carriage slowly out using the straw line.

12. Pull carriage out so both sheaves ride over the joining link in the skyline and skyline extension.

13. Connect the carriage transfer link to the skyline connect ring.

14. Pullout right hand Skyshifter winch rope (or the winch rope opposite to the direction of harvesting) and connect to stump or tail tree.
15. Pullout the left hand tail hold winch rope and connect to stump of tail tree.
16. Unhook the straw line and pull back to the hauler.
17. Position grapple carriage under the skyline.
18. Connect the mainline to the front of the grapple carriage.
19. Connect grapple carriage to the skyline ensuring the carriage stays firmly on the ground.
20. Connect the tail rope to the back of the carriage.
21. The grapple carriage is now ready to go.
22. Take up slack in the main rope and lift skyline.
23. Ease off the mainline brake and pull grapple out with the tail rope.
24. Lower grapple to the ground to collect trees.
25. Lift skyline and pull grapple back to hauler with main rope.
26. Use Skyshifter remotes to shift Skyshifter to next line.
27. Perform procedure in reverse to de-rig.

Using Running Skyline for Installation

1. Layout straw line as per normal but around a side block at the landing prior to sending to a single stump near to where the Skyshifter will begin.
2. Pull out main rope with straw line with short piece of mainline attached, which can be synthetic or wire. This short piece of mainline is only for setup purposes and must be used so that the mainline can be transferred from the stump to the front of the Skyshifter where it will be joined to the tail rope. At the backline, detach the short piece of mainline and attach to a stump and connect to the end of the mainline.
3. Manually pull straw line back to hauler.
4. Once straw line is back at hauler position Skyshifter under the main rope.
5. Feed the tail rope around the two spreader sheaves on the front of the carriage, either sheave first. Ensure the straw line remains on the outside of the tail rope. Pull the tail rope about 10m through the second sheave and secure with rope clamp or pass chain so that the 10m of extra tail rope is available to connect to the mainline once the carriage is sitting at the backline. Wrap up the excess tail rope and secure on the carriage. Apply tail rope brakes.

6. Connect Skyshifter to the mainline and attach the straw line to the back of the carriage. The carriage is now ready to send out.

7. Lift mainline.

8. Release brake on tail rope slightly and pull in straw line and pull carriage to the backline and past the connect point by 8m.

9. Pull out the Skyshifter winch lines and attach to stumps or tail hold trees. Tighten tail hold winch lines but ensure Skyshifter is still firmly on the ground.

10. Connect the tail rope to the mainline connection where the mainline extension is connected to the mainline (at the 'D' swivel).

11. Once connected, pull in the tail rope to create slack in the short mainline extension.

12. Remove extension.

13. If need be pull in the tail hold winch lines to create slack in mainline extension.

14. Pull mainline connected to tail rope back to hauler.

15. Hold tail rope at hauler with excavator and disconnect mainline from tail rope and connect up butt rigging and rider block.

16. Release hold on tail rope. System now ready to start logging with running skyline system (scab) with grapple capable of being run on a two line system.

17. Perform procedure in reverse to de-rig.