A STUDY OF CHAIN THROWING ON LOGGING TRUCKS

ENFO410

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Executive Summary

This investigation stood to discover two important parts of the log truck industry that have remained largely unstudied. One of them was to provide a definite time as too how long it takes for chain throwing and securing activity on a log truck to occur, and to break that down elementally. The second goal was to determine how drivers' opinions on a variety of set issues while also giving them the opportunity to illustrate what was currently hindering/bothering them. This study was conducted at Chaney's Plantation, nestled between Christchurch and the Waimakariri River, and it was conducted on a landing which could be described as being an ideal chain throwing setting.

The elements of a chain throwing activity were determined to be "organising and throwing," "repositioning and securing," and "tensioning." Delays were also timed; their size and importance are discussed further within the report. Overall there were nineteen trucks observed with four of those being three-bunk trailer configurations while the rest were two-bunk configurations trucks. Generally, the result for total time for all configurations was five minutes and 12 seconds with a standard deviation of 102 seconds, this result is very vague though as it does not discriminate between trailer configurations. The three-bunk configuration took a total time of seven minutes and 28 seconds with a standard deviation of 55 seconds, "organising and throwing" took three minutes and 15 seconds, "repositioning and securing" took two minutes and 15 seconds while "tensioning" took one minute and 58 seconds. The two-bunk configuration took a total time of four minutes and 36 seconds with a standard deviation of 79 seconds, "organising and throwing" took one minute and 54 seconds, "repositioning and securing" took one minute and 38 seconds while "tensioning" took 65 seconds.

"Have you or others in your line of work had injuries caused by chain throwing?" and "have you ever/how frequently have you experienced a chain coming loose" are two examples out of the seven set questions that were asked to drivers in the survey. Some of the main findings that were discovered from this were that driver injuries were less frequent and less severe than expected, drivers are working through the pain/self-medicating, and that older drivers are pushing through to retirement. Answers became truly interesting when drivers were asked the open-ended question about what was hindering them. One view that was shared by the majority of drivers was that the chain was easier to throw when its placed halfway of the bolster, though it must be looped down to the bottom of the bolster in order to not move from a 6mm chain to a 7mm. Another point cover was how injury could happen from a shock loading if a "D" or hammer shackle was in an unusual position and then was snapped into place through the tightening of a chain.

Table of Contents

Introduction

Chain throwing and log transport is the one sector of the forestry industry that has had little research conducted. This is a real issue for the sector as many injuries are associated with log securement that has been ignored. Areas such as harvesting have received a lot of attention around safety. Over the last decade, mechanization has been pushed forward, keeping people off the ground and, therefore, safer. Given this, the process of log securement has not changed for decades. Drivers still have to get out of their cabs every load, throw heavy chains over the log stack, and then secure them into a ratchet or twitch device to give tension.

Literature Review

Introduction

Log transportation is a vital part of the forestry industry here in New Zealand. Currently, there is little research completed concerning logging trucks and, especially, load securement. According to Mackie and Ashby, 2011, 38% of drivers had recorded injuries while securing a load. Trucking is falling behind compared to other dangerous tasks in the industry, which have significantly changed in the past decade regarding safety. There is a need to improve the log-securing method for NZ to ensure driver safety.

Currently, there are efforts to improve this mechanism through the automation of chain throwing. Many systems have been tested, which are explored later in this text and do not provide the required securement load. Trinder engineering out of Richmond is creating a product that places the load over the logs. They also have a product currently in development that will be researched later in the year.

Chain throwing and twitching are the most common practice for securing a loaded logging truck. This method has become increasingly concerning for the industry due to the large number of injuries occurring. An aging workforce is also a problem due to the considerable physical aspect of this.

Current standards

The ACOP states in section 17.4, “All loads shall be loaded and secured so that no portion of the load can become dislodged or fall from the vehicle.” Failure to comply with these can mean up to $2,000 for drivers and $10,000 for trucking companies.

At least two bolsters and stanchions must be used to secure log loads, and an overhang is beneficial at either end. Logs must overhang, as shown in Figure 2, by at least 300mm on the outside and bottom of the packet. This may be reduced to 150mm if three chains are used to secure the logs. It is preferred that shorter logs be between two bottom logs or on the top of the packet. If not in contact with a stanchion, they must be in contact with the restraint of equal strength (WorkSafe, 2012). As shown below in figure 1, All loads must be crowned at the top to allow the lashing to be in contact with all outside logs during transport.

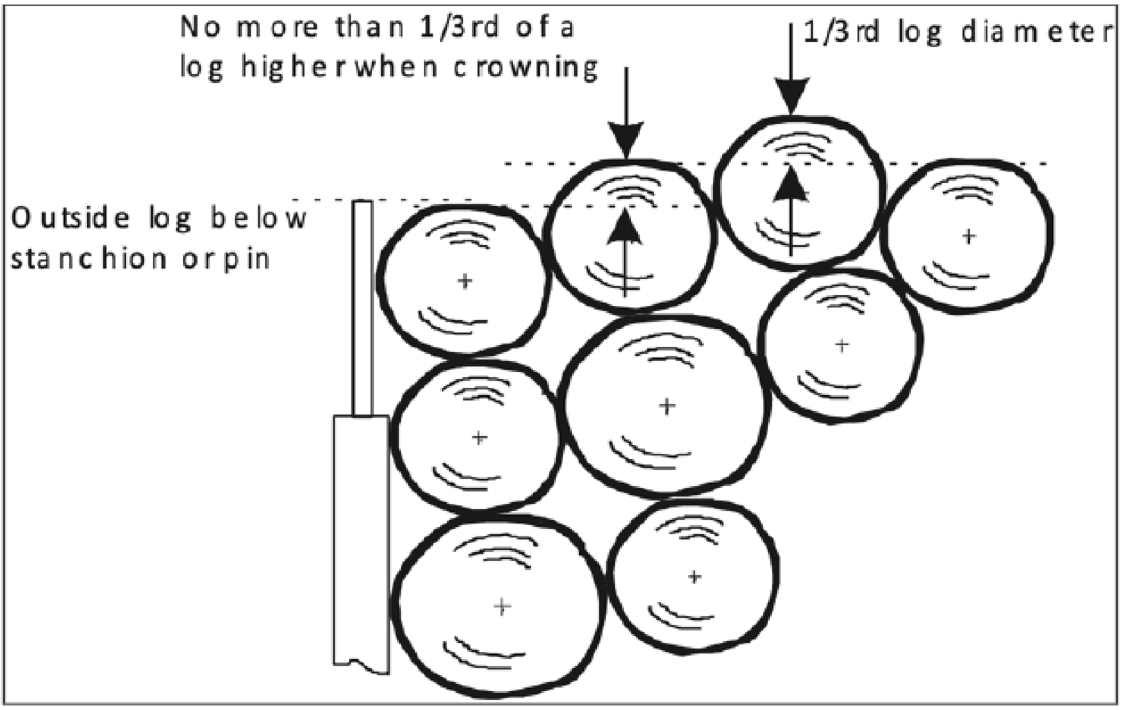

Figure 1 - Crowning of the load (LTSC, 2012)

A report by LTSC, 2020 states that the restraint of logs must be attached to two anchor points which have a capacity of at least ¼ of the log packet weight each. The guidelines state that each packet must be secured by:

- Two 2.3 tonne restraints with one placed forward of the rear bolster and the other as belly restraint attached to the chassis or
- Two 3 tonne restraints, one attached to the rear and the other to the front bolster or adjacent chassis

Injuries

In a study by Mackie and Ashby, 2011, Injuries occur suddenly or over time from repeated motions. The two common injuries from chain throwing are "Struck-by" injuries, which occur when someone is struck by an object, such as a chain or the twitching bar. The second is "stress/strain", also known as musculoskeletal, which occurs through repetitive throwing and twitching motions.

Shoulder injuries are a crucial area of concern to the industry. Although these are not the most severe, they are the most common and cause most drivers to miss work. This paper goes into detail about the mechanisms in the shoulder which cause these injuries. There are four standard techniques that drivers use to throw chains; these are:

- The 'skipping rope' technique
- The 'flick'
- The 'cricket bowl' overhead technique
- Standard chain throw

A study by Mackie and Ashby 2011 recorded that 38% of drivers reported stress-strain injuries from chain throwing, and 35% of drivers reported a mix of stress-strain and 'struck by' injuries from twitching. "While some drivers seem to have no problems with throwing and tensioning chains, a significant proportion of drivers are likely to be affected in some way, especially given the age profile of log truck drivers in NZ. The extent of these issues may widen in the future as the driver workforce ages further."

Interventions to reduce injury

A paper by Mackie and Ashby, 2011, also outlines some possible interventions to reduce injuries. These were aimed at providing ideas for consideration. No single factor will prevent injury, but many improvements can be introduced to help reduce these. These can be found in the table below.

Category	**Intervention description**
Organisational design	1. Plan for and provide specific a chaining up area on skid site 2. Reduce time pressure and working hours 3. Implement an effective maintenance programme 4. Implement an early reporting and injury management system
Physical task design	5. Use loader drivers to place chains over load 6. Reduce chain weights 7. Use auto tensioning devices 8. Use alternative load chain tensioning methods 9. Explore modified twitch design 10. Attach and throw rope (leader rope) to pull chain over 11. Use ramp to reduce throw height 12. Place anchor points at appropriate heights 13. Install winches to replace twitches 14. Limit excessive load heights 15. Use locking device for winches and twitches 16. Provide or develop tension measuring device for drivers
Technique and training	17. Specific task training principles 18. Communicate effectively with loader driver

The key output is making a spacious, flat area on the skid for chaining up activities and reducing chain weight to make throwing easier for the driver. Testing loaders to lift chains over the load. Ensuring training occurs and the possibility of alternate twitching devices.

Previous Surveys

The study conducted involved 42 drivers. From these, 16 drivers reported injuries to the shoulders, neck, back, arms, wrist, and knees. These all involved time off work, with some being up to 7 and a half months. On a scale of 1-5, drivers reported the difficulty of throwing chains as a 2.3.

From biomechanical research, it was found that the whole body was involved in the chain throwing processes. The start of the movement uses the legs and trunk of the driver, with the shoulder doing the final part of the movement. It was calculated that the torque through the shoulder joint throwing a 5kg chain was approximately 60 N.m.

It was found that drivers found twitching a 2 out of 5 when looking at difficulty. These injuries were stress-strain, with some being burses or lacerations.

Possible alternatives

A paper by Patient and Brown, 2021, notes many alternate methods which can be adopted in securing log loads. Synthetic restraints made from ultra-high molecular weight polyethylene (UHMWPE) have been proposed as an alternative to a heavy chain. Synthetic restraints are advantageous as they are lighter, weighing roughly 1/6th – _1/8th of traditional steel cables. This material, such as Dyneema and Spectra ropes, is easier to throw, reducing the risk of injury to the driver. Rotorua Forest Haulage Ltd (RFH) trialled synthetic restraints using UHMWPE rope with a resistant exterior, giving a 6,000kg lashing capacity and 12,000kg breaking capacity. FPInnovations in Canada (Shetty, 2013; Jokai, 2018) tested the durability of syntenic ropes and found that they lost strength and deteriorated too quickly for practical use in the forestry industry.

"Methods to secure logs on trucks to minimize shoulder injuries" by David Adams noted the use of loader-assisted chain throwing. This method is cost-effective, easy, and practical on the skid, significantly reducing shoulder injuries. In this report, studies at the KPP in Rotorua found that wheel loaders do not have the reach to lift the chains over a full, on-highway load.

Timberlands developed a chain lifting device, as shown below in figure 2. Each truck is designed to drive up to the mechanism and attach the chains to the bar, which lifts them over the log packet. This is a modification to a cheery-picker device that exchanges the basket for a bar on which the chains can be hooked. Timberlands designed this mechanism for every skid to reduce driver excursions and injuries.

Figure 2 - Timberlands Chaining Device

ExTe's Comp90 Bunks is an already available autonomous load securement device. This device uses a retro-fitted bolster system that remotely secures the load. It includes a live remote monitoring device in the cab to allow the driver to see the load without getting out of the cab. This device is currently fitted on a truck in NZ, but there have been concerns when securing pine logs when sappy or wet. Chinnery-Brown. (2017) also reviewed the feasibility of this device in NZ. They noted that this is already a standard device in other parts of the world and would be viable when the truck travels less than 50km. The major drawback to this is the cost to install of ~$96,000, which makes nationwide roll out unfeasible.

Cost Benefit Analysis of the Trinder Chain Placer and Tensioner by Ian Brown

On Thursday, the 2nd of June, we met with Ian Brown of Woodhills consulting to discuss the cost-benefit analysis he created for the Trinder chain placers. This was an incredibly insightful meeting, especially concerning some of the metrics he accumulated and not just for use in the excel spreadsheet. Before going into details about the cost-benefit analysis calculations, these will be discussed to provide context, and it should be noted that all the metrics that Ian Brown used as factors and has outputted have been agreed with the Log Truck Safety Council.

According to Brown, the average age for truck drivers is currently 52 years, and then the average age at which they are exiting that role is 58. He also states that it costs approximately $20k to train a driver, suggesting that the longer drivers can be kept on the job, the fewer logging companies will have to "fork out" to induct new drivers. In contrast, Brown also stated that it would be better to bring more female drivers into the force as they are subjective, "more diligent, gentler on machinery and are much better at radio communication." He determined, in agreement with LTSC, that there could be a 20% increase in the workforce with women joining.

The base data that Brown used was three average trips per day, 30 tonnes per trip, 12 hours worked in a day, 229 workdays a year, 4 hours per trip, 20610 tonnes a day, and average revenue of $20/tonne. Finally, the most significant figure from this was revenue lost from having a car parked up for the day, which was an astonishing $1800. The fleet size was calculated based on tonnes/year at 1650.

One section in which Brown emphasised that Trinder's chain placers and tensioners could save considerable amounts of time was in the chain checking stops. This was because the chain tensioners would have an active tension gauge system in the truck's cab, allowing the trucker to constantly monitor it without having to exit the cab apart from the mandatory when exiting the forest roading network onto public roads. He determined that three minutes could be removed from the average time per trip due to the reduction in stops, which could increase the additional volume carted per year by 261 tonnes. The main output gained through the reduction of chain checking stops is an increase in annual revenue of $5218 per truck per year.

The belly stropping process was also put through the same analysis regarding its removal from the system, which led to Brown factoring 9 minutes saved per trip. This, in turn, led to 482 additional tonnes being carted per year and then an additional annual revenue of $9,636 per truck per year.

Injury cost's main factors were derived from a combination of IRIS and LTSC data from 2016 to 2020, which was determined to be 14.9 throwing injuries per year and 21.1 twitching injuries per year. However, Brown did say that there was a high chance that a lot of throwing injuries are not reported as they are deep musculoskeletal injuries that incur over time, whereas twitching injuries are straightforward to report as they are high instant impact loads usually to the face causing externally visible effects such as loss of teeth. The final figure was calculated as the total cost of injuries to the industry, which was $236.96 per truck per year, with the majority of this being a cost to ACC of $123.74 per truck per year, which was calculated by dividing the total cost to ACC divided by the calculated fleet size. Probably of most importance in the cost-benefit analysis was the cost of these injuries to the trucking companies, as they will be the ones implementing these systems. This mainly consisted of lost time which was $100.36 per truck per year, and $12.87 per truck per year, which covers the first week of wages of an injury which ACC does not cover.

Other figures which were calculated were driver demographic (loss of revenue due to trucks being parked up due to various reasons such as no drivers), which was found to be an annual loss of revenue of $4122 per truck per year and driver retention which was a cost of $400 per truck per year. The final figure, which was intriguing as it had not been thought of, was payload loss due to the weight of Trinder's chain placing/tensioning system, which was found to be 0.5 tonnes per truck. The most interesting part of this was the weight of a larger chain as the new system could revert to older larger chains which were essentially made redundant due to the difficulty of throwing them; this made up 120 kg of the new additional figure. Using that 0.5-tonne figure, the annual revenue loss was determined to be $7481 per truck per year.

The next step in Brown's process was to implement these figures calculated into a cost-benefit for the new Trinder system. The primary base data for this was the estimated cost of implementing six placers onto a truck which was $40,000. The cost of a singular placer was $6,666.00, winches $3,000.00, loadcells $1,000 and the monitoring system which was $4,000. The additional cost of upgrading the truck with depreciation and maintenance factored in was $1.17 per tonne. This figure is higher than the figure for benefit; therefore, the net benefit is actual negative: -$0.22 per tonne.

Mechanical Engineering FYP titled “Log Transport Load Securing”

Log Transport Load Securing was the title of a final year report from 2017 by a group of mechanical engineering students from the University of Canterbury led by Aaron Chinnery-Brown. This report was mainly concerned with finding reasoning for how drivers were injuring themselves in a biomechanical sense (for example, with the torques their shoulders were having to generate in order to get the chain over the load), finding a simple, cost-effective solution and then observing how the industry would react to said solution.

A piece of information that stood clear after their stage of consulting physios was that even with improvements made to techniques and materials in using the current system, it was still of incredibly high risk.

This group determined that the best system was using a lead-rope method to pull the chains over the log packet. This trial used a low-cost nylon rope with a monkey-fist ball to add weight to the rope. The nylon is attached to the end of the chain, and the weighted end is thrown over the log packet.

The group's anatomical analysis and biomechanics validation showed that the standard system required a shoulder torque of 210 Nm. This figure is approximately quartered when using the lead rope system, which gave a figure of 52 Nm.

David Adams reviewed this method and found that this method does not reduce injuries. It was found that drivers were over-arm throwing the monkey-fist, which caused injuries. If this device was thrown underarm, injury prevention was likely.

As stated previously, the group wanted to determine how the industry would react to this proposed solution. The main group that was analysed was drivers due to the fact that this was a low-cost solution; therefore, there would not be many financial barriers to implementation. An interesting case study they referenced was one into the introduction of high visibility clothing into New Zealand logging in the mid 1990s. A main output from the case study was that there is a definite hierarchy in a crew of working men and that there would need to be a trickle-down effect from the guys that were respected at the top of this hierarchy in order to get everyone else interested. This was found with regard to their lead rope system, as many truck drivers thought they would be the subject of jokes from other people working on forest skids, such as loader drivers. Also, after delving deeper, the projected ease of a truck driver's chain throw is a massive point of pride among them and their peers. They also stated that they found the lead rope system very slow and cumbersome.

LTSC and Dr Hamish Mackie report titled “The Health and Fitness of Log Truck Drivers” 2008

The health and fitness of log truck drivers wanted to be analysed as they have a relatively sedentary job but often feel fatigued due to the long hours they are required to work and are often injured due to brief periods of physical activities such as throwing and twitching chains. The main part of this study which was found to be incredibly interesting was a questionnaire that had 225 responses which represents approximately 16% of the industry at the time. The mean age of drivers who responded was 43.8 years of age.

A question posed to drivers was, “have any of the following required you to go to an emergency clinic or a hospital? (tick as many boxes as you need to).” The tabulated form of the results was found nowhere in the report, so results have been visually estimated from the bar graphs showing results. 6% ticked the box for “throwing chains”, while 9% ticked the box for “being hit while using twitchers.”

Another interesting question was, "do you have difficulty with any of the following when you are on the job? (tick as many boxes as you need to)." The results showed that 7% ticked the box "throwing chains" while only 2% ticked the box for "securing and tightening chain."

Objectives

Understanding the length of time associated with each process is the end objective goal of this project. Survey data from the truck drivers will be used to understand their opinions on the task at hand, this is the end subjective goal. In order to achieve this a time study will be conducted alongside a survey of the truck drivers.

This information obtained will be allow the forestry industry to understand both methods and be used to inform their decisions in the future.

Problem Statement

The log cartage industry has a current problem with their drivers currently experiencing injuries when securing log loads to their truck trailers, this is what has driven the need for an investigation.

The log cartage industry in New Zealand has long favored chains over alternatives such as strops for their strength in securing the load downwards and ability to apply friction to the load to halt lateral movement. The use of chains has come at a cost though, usually in the form of musculo-skeletal or impact injuries to the log truck drivers who apply and secure the chains themselves.

In order to understand how these problems are going to be fixed, what needs to be assessed is what is currently causing the injuries and what can be done to prevent them.

Methodology

Elemental Time Study

An elemental time study will be used to understand the time associated with chain throwing of logging trucks. To do this, each driver will be timed from when they get out of the cab until all chains are secured around the log stack. To understand this process better, each element in the throwing process is divided up to allow analysis into the whole system. These elements are as follows,

Organising and throwing (O+TR)

Before the driver is able to throw the chains over the log stack, they must be unhooked from the storage mechanism of the trailer. The driver then loops the chain around their hand and throws the chain over the stack. This element is completed once all chains are thrown over the truck

Figure 3. The organising of the chain, the removal from its on-trailer storage position and the coiling of it.

Figure 4. The throwing of the chain in the sidearm technique.

Repositioning and securing (R+S)

once the chains have been thrown over the log packet, they are repositioned to ensure they are on the correct side of the bolster and line up with the tensioning device. They are then secured into the tensioning device; ether being secured into the ratchet system or twitch system.

Figure 5. Repositioning of the chain, usually done through a "whip" action.

Figure 6. The securing of the chain to a ratchet.

Tensioning (TN)

This is the time taken for the tensioning devices to be loaded so the log packet can be secured to the truck.

Figure 7. Tensioning of the belly chain in the traditional twitching method.

Figure 8. The tensioning of the bolster chains using an on-bolster ratchet.

Delay (D)

Delay was purely designated as the time the drivers were out of the cab but not completing any of the chain throwing activities listed above. The types of delay that were encountered will be covered later in the report.

It should be noted that when planning for the time study that there were initially six different sections. It was quickly discovered on the first time study data collection day that many of the different sections we had planned for were actually combined in the real life process as the change from one activity to the other was too quick to differentiate properly or the boundary was "blurred." In particularly these sections were Organising and Throwing which became one as did Repositioning and Securing.

As well as the elemental time study results, they type of truck and system used was also noted. Trucks were ether loaded as 2 bunks with one log packet on the truck and one log stack on the trailer, or as a three-bunk system with one stack on the truck and two stacks on the trailer. This effected the number of chains that had to be thrown and secured into the tensioning device. Another variation was the tensioning system used on the truck and trailer. The trucks were ether fitted with full ratchet tensioning devices and others had ratchets on the bolsters and a twitch bar used to tension the belly chains.

While the trucks were waiting to be loaded, or just after they had been secured, survey questions were asked to the drivers. These questions were delivered to the drivers to get their options and experiences of the chain throwing process over their years of experiences.

Survey Questionnaire

Along with the time study results, a survey questionnaire was asked to the trucking drivers. This questionnaire allowed insight into the driver's history with chain throwing as well as finding their opinion in regard to manual chain throwing and other alternates. For this survey, 7 questions will be asked to the drivers in a casual fashion. These questions are as follows:

1. Have you or others in your line of work had injuries caused by chain throwing?
2. If so, has this caused you financial strain
3. Are you or do you know anyone that has faced early retirement due to chain throwing?
4. Do you think there would be more log truck drivers if chain throwing was eliminated from the process?
5. Have you ever/how frequently have you experienced a chain coming loose
6. Is your ability to chain throw a point of pride for you
7. How long have you been driving for?

These survey questions and conversations around these points will be recorded through voice recording on site.

Site Description and Layout

Figure 9. Location of the landing where all the data collection was conducted.

The site for the study was Chaney's plantation which was 2km south of the Waimakariri River and 2km east of State Highway 1. Access to this site was granted by Hamish McConnon, the Canterbury operations manager for Rayonier Matariki Forests. The logging contractors that were logging and in control of the skid was crew 107 from Brand Logging with "Lunna" as the foreman. The logging truck contractor was Steve Murphy Limited (SML) from nearby Kaiapoi.

The site as a whole could be described as perfect forest harvesting conditions due to how flat it was and its proximity to State Highway 1. This was mirrored with the landing conditions.

Figure 10 - An image of the chaining up area

Figure 11 - An image of the loading area

With regards to the study, the drivers regarded the landing as being almost near perfect for throwing chains over their loads. One factor that was stated was because of how flat it is, therefore meaning the risk of slipping was lowered. Another factor that was touched on was how the areas directly beside the roads were of the same, if not similar, grade to the road which meant that the truck drivers could utilise this area to walk out further and throw their chains over. The one thing that was pointed out that could cause an issue was the proximity of some of the red Brand Logging utes to the chaining down area, a minimal risk as truck drivers only had to be wary of them.

Results

Time Study Results Introduction and Visual Observations of the Study Material

The time study for chain throwing activities took place over three days. In that time nineteen trucks were observed, four of which were three bunk trailers and the other fifteen were two bunk trailers. Included below are example images of each type of trailer configuration taken at the site of SML trucks. A further statistical category that was going to be studied and analysed was the technique used to throw the chain over the truck, as the study progressed it was found that all the drivers studied used the side arm technique (images included below). It was further deduced that this was a good representation of the whole log truck population. The delay section has not been included in the graphs or tables and will be discussed later within the section.

Photographic Breakdown of the Sidearm Throwing Technique

Figure 12. Step 1 of the Sidearm technique: the removal of the chain from its storage position and the subsequent attachment of it.

Figure 13. Step 2 of the Sidearm technique: Coiling/reeling of the chain in order to focus its mass in order to throw it all over.

Figure 14. Step 3 of the Sidearm technique: The "loading" of the throwers arm, the start point in the throw where the throwers arm and shoulder are both at full extension.

Figure 15. Step 4 of the Sidearm technique: the final point in the throw of the chain, the release of the mass.

Photographic Examples of the Different Trailer Configurations Studied

Figure 16. An example of a two-bunk trailer configuration.

Figure 17. An example of a three-bunk trailer configuration.

With reference to the images above, the quantity and location of the chains on the truck will now be explained. On a two-bunk trailer configuration there are a total of four bolster chains and two belly chains to be thrown while on a three-bunk trailer configuration there are a total of six bolster chains and three belly chains that are to be thrown. One aspect that was observed and then subsequently deduced as being a result of the landing configuration and characteristics was that after having their trailers loaded the truck drivers did not bother throwing a belly chain over the load (to secure it in the transition from the loading area to the chaining up area). The reasons that were deduced for this were that the whole landing area has virtually no gradient and secondly the distant the trucks had to travel to arrive at the chaining up area was less than 50 metres.

All Trailer Configurations

Included below is an image and table summary of the main statistical points of all nineteen trucks studied throughout the course of the time study. As the result section of the time study is progressed through further there will be more in-depth analysis and breakdowns with respect to the different configurations. This initial section will be used to provide overview as to why certain graphs and numbers were chosen to represent the data.

The clustered column (as shown below) was chosen as it allowed for easy visual comparison of all the different data points split up into their categories while retaining the same colour through each category. A light view of the variance and general range of the values can also be visually extracted from these graphs.

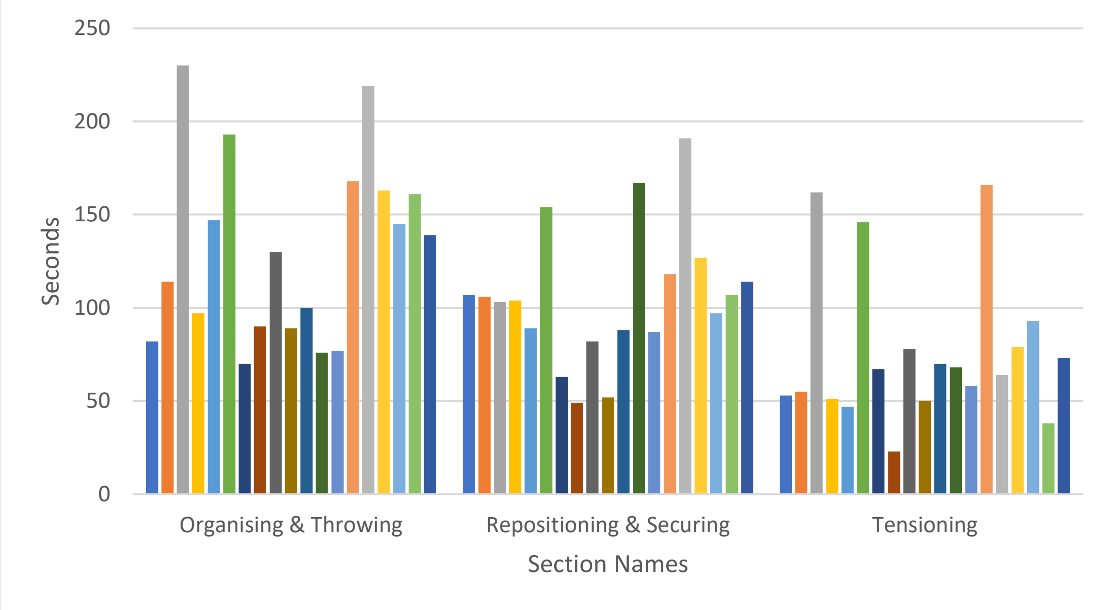

Figure 18. Clustered column graph representing all the trucks observed, regardless of number of trailer bunks.

There were four main statistical data points that were chosen to provide representation of each of the categories. The mean was used for its usual function, providing a centre point of the data and the standard deviation was much the same, showing the how dispersed the data was with relation to the mean. Fastest time, slowest time and their difference, the range, were also included to illustrate the extremities of the data points. As can be seen on Table 1 the three main elements of the time study were included as well as the total of these three elements, as mentioned earlier the "Delay" element will be discussed later in this report section.

Table 1. The main statistical data for all nineteen trucks regardless of trailer configuration. Units are in seconds.

	ORGANISING & THROWING	REPOSITIONING & SECURING	TENSIONING	TOTAL
MEAN	131.05	105.52	75.84	312.42
STANDARD DEVIATION	48.94	36.18	39.95	102.20
FASTEST TIME	70	49	23	162
SLOWEST TIME	230	191	166	495
RANGE	260	140	143	333

Table 1 shows that for all nineteen trucks observed (regardless of trailer configuration), the average total time was 312.42 seconds and that figure had a standard deviation of 102.20 seconds. The fastest time taken to chain up a load was 162 seconds while the slowest was 495 seconds. The "Organising and Throwing" element generally took the longest out of all the elements to complete with an average figure of 131.05 seconds and the same element also had the most variation with 48.94 seconds. The variance is also indicated by the range of this element which was 260 seconds, a figure which is closer to the total's range figure than that of the other time study elements.

The stacked column illustrates an image similar to that of the clustered column but from a different "angle." Here the data points have their own individual columns which give their total time shown on the y-axis, these are then split up further to show a visual composition of that total time by element. Figure 19 includes all trailer configurations but provides discrimination by having the two different configurations appear in two different colour schemes, with the fifteen two bunk trailer configurations being grey, orange, and blue, and the four three bunk trailer configurations being green, light blue, and yellow.

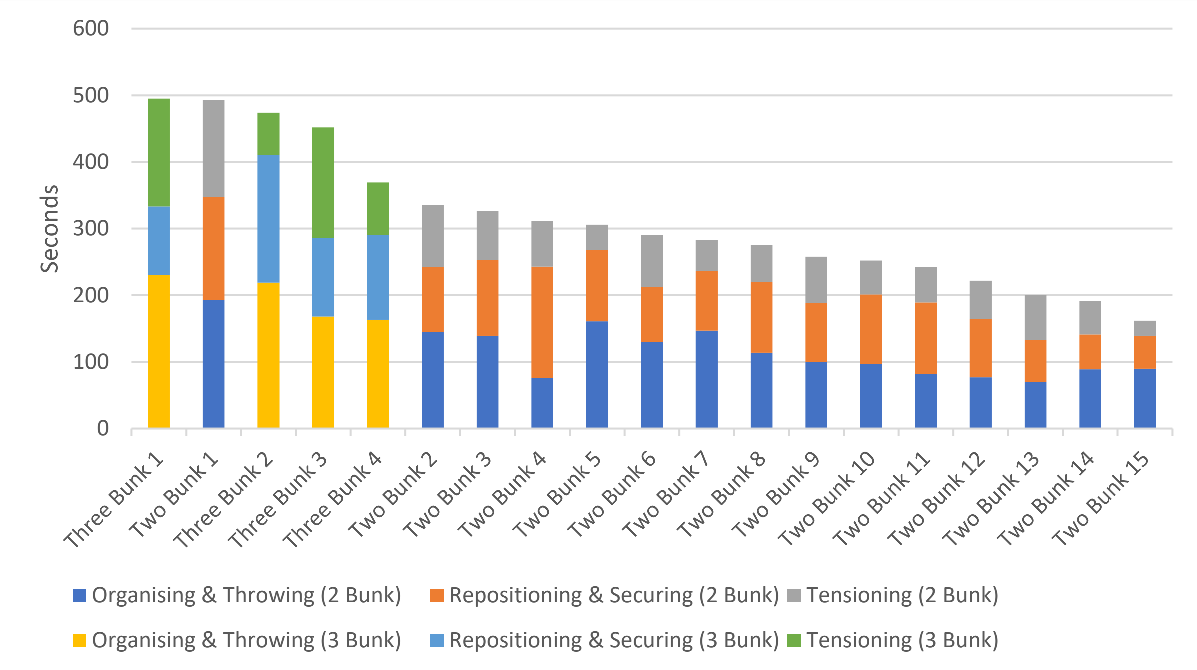

Figure 19. Stacked column graph representation of all the trucks studied.

From Figure 19 it can be seen that three bunk trailer configurations fit with the logical assumption that they take longer to chain up with the one anomaly to this observation being truck "Two Bunk 1" which takes the second longest out of any truck at 493 seconds total.

Three Bunk Trailer Configuration

The three tables/graphs used to illustrate the data points for the three-bunk trailer configuration were a stacked column, clustered column and a table outlining the main statistical points. Unlike the two-bunk results section, no box and whisker plot was used as the sample size was deemed to be too low to provide an illustration of any real use.

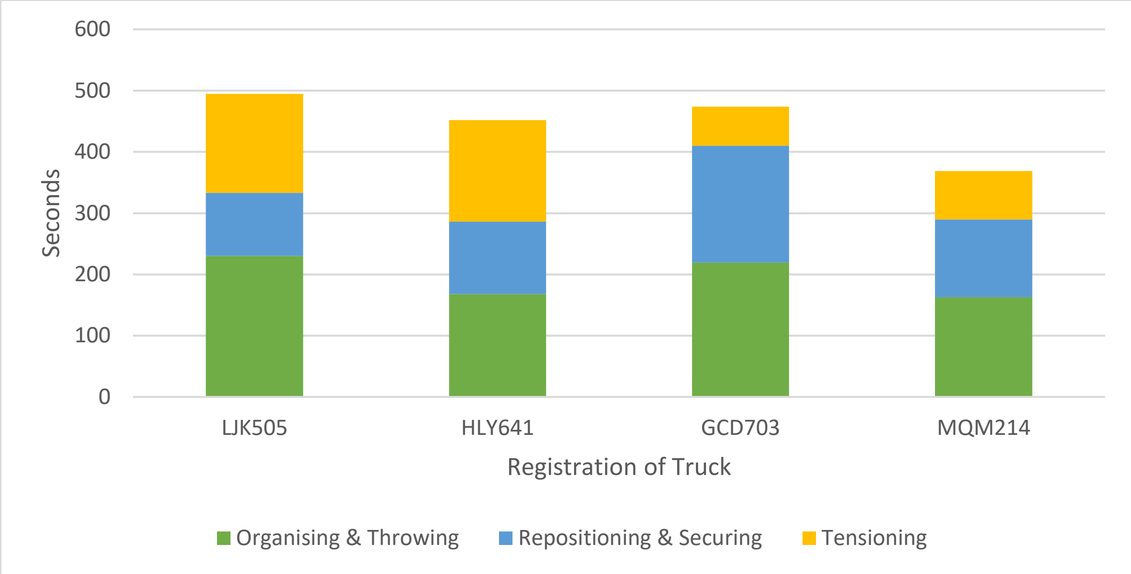

Figure 20. Stacked column representation of the four three bunk trailer configurations observed.

Table 2. The main statistical data for the four three bunk trailer configurations observed. Units are in seconds.

	ORGANISING & THROWING	REPOSITIONING & SECURING	TENSIONING	TOTAL
MEAN	195.00	134.75	117.75	447.50
STANDARD DEVIATION	34.42	38.78	53.78	55.20
FASTEST TIME	163	103	64	369
SLOWEST TIME	230	191	166	495
RANGE	57	88	102	126

Table 2 shows how three bunk trailer configurations have an average figure of 447.50 seconds for total time taken with a standard deviation of 55.20 seconds. “Organising and Throwing” stayed in line with the whole sample illustration of taking the longest time of all the elements though in this case the “Tensioning” element had the highest standard deviation.

Two Bunk Trailer Configuration

Due to the number of two bunk trailer configuration trucks observed, especially when compared to three bunk trailer configuration trucks, it has been decided to display the column graphs of each time study element individually as opposed to having all the elements next to each other in the clustered column graph format as it was in the “Three Bunk Trailer Configuration” section.

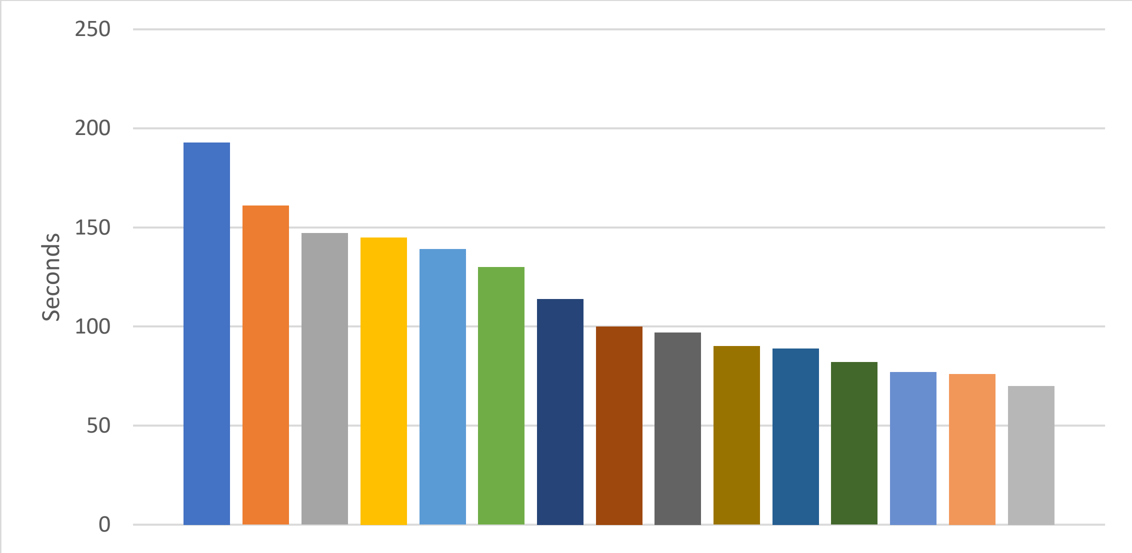

Figure 21. Clustered column graph representation of the "Organising and Throwing" element of all two bunk trailer configuration trucks.

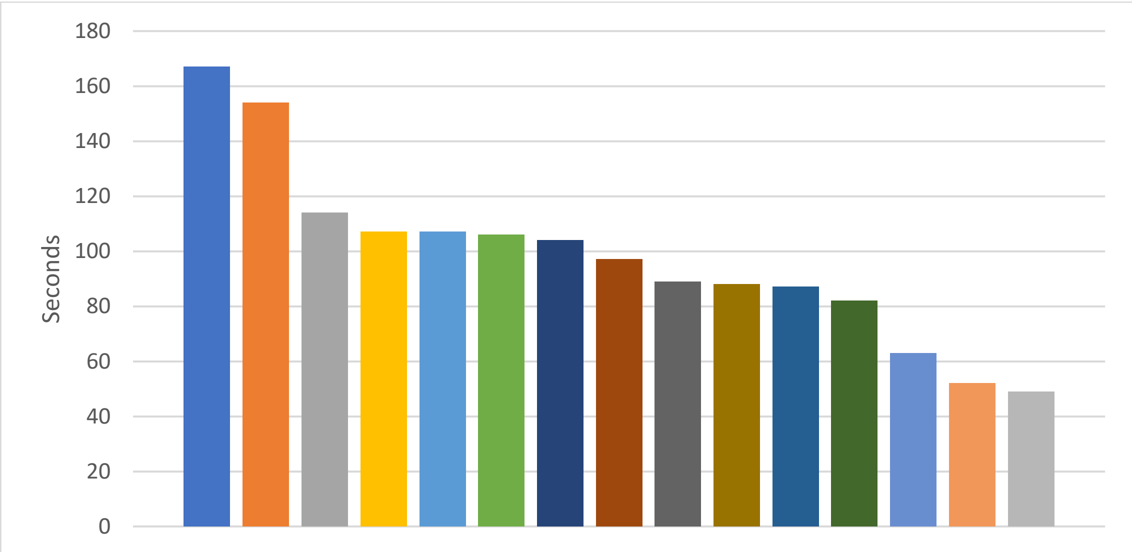

Figure 22. Clustered column graph representation of the "Repositioning and Securing" element of all two bunk trailer configuration trucks.

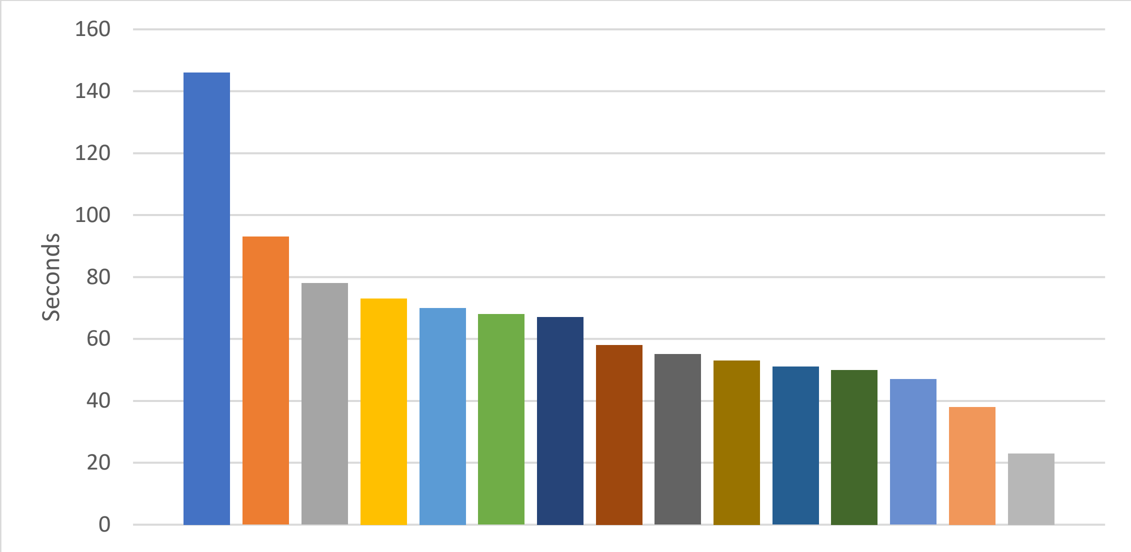

Figure 23. Clustered column graph representation of the "Tensioning" element of all two bunk trailer configuration trucks.

The separated data is illustrated in clustered column graphs in Figure 21, Figure 22 and Figure 23. There are outliers, such as the highest figure in the “Tensioning” clustered column. Due to the relatively large amount of samples, the following box and whisker plot illustrates the range of samples better.

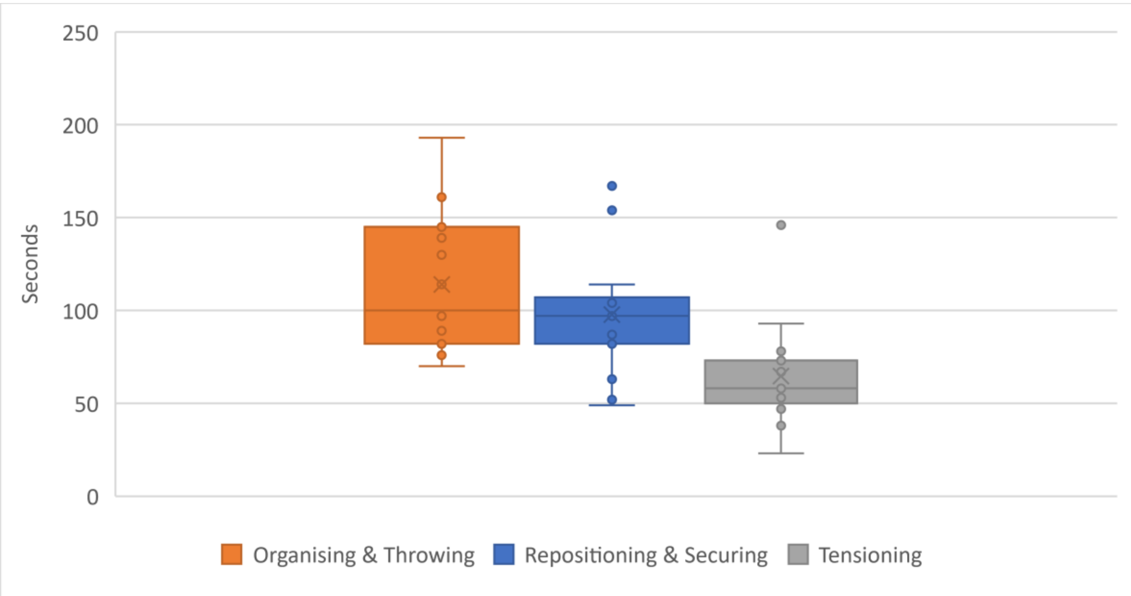

Figure 24. Box and whisker plot representation of all elements of all two bunk trailer configuration trucks

Figure 24 is a box and whisker plot which illustrates the variation by element. The “Repositioning and Securing” and “Tensioning” elements have two and one outlier respectively. Both of them have an interquartile range of 25 seconds or lower which suggest that the middle values cluster tighter. “Repositioning and Securing” has a slight negative skew while “Tensioning” has a slight positive skew.

“Organising and Throwing” has an interquartile range of 63 which suggest the middle data for that element is more spread out than its counterparts. The data is definitely positively skewed. The element has no outliers.

Table 3. The main statistical data for the fifteen two bunk trailer configurations observed. Units are in seconds.

	ORGANISING & THROWING	REPOSITIONING & SECURING	TENSIONING	TOTAL
MEAN	114.00	97.73	64.67	276.40
STANDARD DEVIATION	36.68	32.42	28.22	78.56
FASTEST TIME	70	49	23	162
SLOWEST TIME	193	167	146	493
RANGE	123	118	123	331

Table 3 shows that two-bunk trailer configurations averagely take 276.40 seconds to complete while having a standard deviation of 78.56 seconds. As covered earlier, the fastest and slowest data points for all trailer configurations are both two-bunk trailer configurations. Once again, the "Organising and Throwing" element had the highest mean and the largest standard deviation with figures of 114 and 36.68 seconds respectively.

Delays

Delays were not chosen to be added to the graphs due to the extreme variation experienced in that element and common lack of data throughout the samples as a direct resultant of there being no delay. To provide an illustration of the variance, the average figure for delay was 177.83 seconds while its standard deviation was almost double the mean at a figure 329.82 seconds. The highest figure gained for delay was 1166 seconds which is approximately nineteen and a half minutes, this occurred as the truck driver and the processer operator had a lengthy conversation around what appeared to be the log grades or the crowning of the logs on the truck. Other reasons listed as reasons for delays were for example, as the driver reentered his cab so the processor could continue loading on his three bunk trailer configuration truck, reorganizing the chain after a poor throw, and on one throw what seemed like an extremely rare event of the thrown chain ending up caught on a small hook at the top of the bolster.

Survey Data

Literature reviews and meetings with the industry found that implementing a new system will be difficult if the drivers do not want to adopt it. Because of this, drivers' opinions and experiences must be noted. As stated above, the drivers were asked a survey questionnaire after they had chained down their trucks. During data collection, eight truck drivers were surveyed. These conversations gained valuable information for our project and gave us insight into chain throwing that we were unaware of. One of the drivers interviewed was typically the dispatcher for SML. This provided great information for us due to his vast knowledge of the 36 drivers that work for the company.

The following are responses to the log truck drivers' survey questions over the four days of data collection.

- Have you or others in your line of work had injuries caused by chain throwing?

This question led to several different responses from the truck drivers. Out of the nine drivers, five recorded having no injuries, while the remaining four recorded having injuries over their careers. Out of these, four injuries were all musculoskeletal shoulder injuries, mainly due to wear and tear over time, with one injury coming from being struck by the twitch bar. Four of these five drivers noted that they did not have any time off work and just worked through the sourness in their shoulders and facial injury. Painkillers were used to reduce the pain thorough out the day, which was only required for a few days until the pain disappeared. This was a common practice for the drivers, who were almost too proud to have the day off. One driver noted that his shoulder pain was so severe that he did have time off work on ACC. One driver noted an injury from chain throwing. One day he just woke up and was in pain. He took a few days off work on ACC and went to the physio to get some assistance. He said the physio was no help and just dealt with the pain through painkillers. This soreness also went away after a week or so. The driver stated that as he has gotten older, his technique for chain throwing has changed. He has done this to ensure that injuries do not happen. Nowadays, he focuses on flicking the chain over the log stack instead of using force.

The dispatcher said that injuries are not a big problem for the trucking contractor. He stated that injuries happen once in a blue moon, but that happens no matter what industry you operate in. Sprained ankles and crushing injuries to the hands of drivers were the most common for SML. He said that some drivers might have bad technique, but their bodies will tell them due to pain after a while.

The primary trend in the data was that some drivers noted that they sometimes had sore shoulders from chain throwing. This was due to the repetitive motion of throwing the chains over the log stacks. However, this did not hold them back as they continued to work, and the sourness passed within a few days. The summary from the drivers was that with good technique, injuries are preventable. When the drivers have poor technique and try too hard to throw the chains over the log stack, they come unstuck. Another driver noted that technique is the most critical factor in chain throwing, and with good technique, minimal effort is required to get the chain over the log stack.

One of the drivers knew a log truck driver who had a shoulder injury from the repetitive nature of chain throwing. Because of this, he was given a rope to throw over the log stack. This rope was attached to the chain, so it was easier for the driver to throw the lighter rope than the heavy chain. This driver used so much force in his throw that he injured his bicep. This never got better, so he gave up on log truck driving.

Out of the four drivers who noted never having injuries from chain throwing, they all noted that chain throwing was simply technique. They said that with good technique, a low effort is required to get the chain over the log stack, reducing their risk of injuries.

One of the drivers noted that chain throwing is very repetitive and can see how people injure themselves. He said the sourness in his shoulder had been removed after the trucks were fitted with 6mm chains instead of the larger gauge chains. 6mm chains are much lighter than the old, larger gauge chains, so they are significantly easier to throw over the logs.

Another one of the drivers surveyed knew of two drivers with severe shoulder injuries from twitching. Because of these injuries, they both had surgery to fix themselves. This was due to the shock loading of the chain jerking their shoulders. Another driver noted having a shoulder injury from the securing aspect of chain throwing. This injury was not severe and came about due to having a worn ratchet system. This worn cog made the chain slip when he was trying to gain tension in the chain and caused a shock load. It was found that this shock load was the leading cause of injury from securing. He noted that he knew some other drivers who had been injured in the past from this shock loading. When the chain slips, it can load the driver's back and shoulders, which can cause musculoskeletal injuries. He also noted that crushing injuries can occur here where your hand gets crushed against the truck's bolster. Another driver noted that he had been struck in the face during twitching before.

Overall, most of the drivers' injuries came from the throwing action compared to twitching of the chains, with limited time off work from the whole sample.

- If so, has this caused you financial strain

Half of the drivers surveyed had been injured from chain throwing, and only one had to take time off work. This was an insignificant period and was covered by ACC. Because of this, the financial strain incurred was not a problem for the drivers. The remaining three injuries noted that they did not take any time off work, so they got paid as usual.

One driver said he had enough time off work to “wipe the blood off his face”. From these nine drivers, there was only a matter of days off from chain-throwing injuries.

- Are you or do you know anyone that has faced early retirement due to chain throwing?

None of the nine drivers surveyed considered an early retirement from log truck driving due to the chain throwing process. This was a surprising result, mainly because of the drivers' age and years of experience. A driver, who had been driving for the last 47 years, was already at retirement age and said he had no plans to stop soon. Stu said he loves log truck driving and had no reason to retire, as it was not a difficult job for him. This is because of the excellent technique he has gained and refined over the last 47 years.

Only one driver stated that he knew someone that faced early retirement from chain throwing. This driver asked for a few weeks off on ACC after he had injured his shoulder. The company he worked for then said to him that he should not come back. This driver was able to continue driving trucks, just not in the logging industry.

Another driver also stated that early retirement is a thing in the industry but does not occur frequently. Drivers learn how to throw chains efficiently and train their bodies to the action after years of experience.

- Do you think there would be more log truck drivers if chain throwing was eliminated from the process?

All drivers interviewed stated that no more drivers would enter the industry if chain throwing were eliminated. All drivers said that chain throwing is not a difficult task and requires the correct technique to complete. Stu noted that the log truck industry is not for everyone. Some people stick around for 2-5 years and do not enjoy it. Log truck driving is not for everyone, which has nothing to do with the chain throwing processes.

One of the drivers stated that they had a 5”3 female driver working for the company in previous years. He said that after a week of training, she could easily throw the 6mm chain over the log load.

- Have you ever/how frequently have you experienced a chain coming loose

Three out of the nine drivers surveyed noted that they have had logs slip out of the packets in the past. Although these logs did not fall off the truck, they moved a meter or so. One driver noted that when logs come loose, the centre logs slip and move a meter or so while the outside logs touching the chain or bolster remain in place. A driver noted that one time in spring, he did not attach a belly chain to one of the log packets. Because of this, the centre logs slipped out and hit the headboard of the truck.

All of the drivers stated that logs do come loose from time to time. This was due to the slippery nature of debarked Radiata Pine. Although these logs do come loose, they said they are unlikely to move out of the packet and to remedy this, they need to re-tension the chains.

The drivers noted that Radiata pine was difficult to cart in New Zealand conditions. Especially in the winter when it rains regularly. Two drivers also noted that the grade of the log also affects if the logs slip. He said that saw grade logs do not come loose very often. This is due to the regular nature of the logs, making them easy to stack onto the truck and gain significant tension. He said that carting pulp-grade logs is significantly more challenging. This grade is very irregular in shape, which makes stacking hard. Poor stacking leaves significant gaps within the stack, which decreases the holding capacity of the chains. He said pulp logs come loose more often than the other grades.

- Is your ability to chain throw a point of pride for you

None of the nine drivers said that chain throwing is a point of pride for them. They all expressed that chain throwing is just a part of the job which they are required to do.

- How long have you been driving for?

The survey revealed an extensive range of driving experience among the nine drivers. The dispatcher had less than a year of experience with log truck driving. Another driver had the most experience out of the surveyed drivers having 47 years of experience in the logging industry.

- Miscellaneous remarks from outside the set-out questions

There were numerous remarks made by the log truck drivers about the attachment systems in place on the trailers for the chains. Several drivers discussed two types of shackles at length: the "hammer" and "D" shackles.

Figure 25. A Hammer Shackle on Magpie's Trailer.

Figure 26. A D Shackle on Magpie's Trailer.

Five of the nine drivers surveyed went into depth about the importance of these shackle systems. It was noted that these shackles are a significant cause of injury for the drivers from the shock loading, which can occur when these are not orientated in the correct position. As shown below, the D shackle is in an unintended attaching position. It was explained that the D-shackle could slip when this chain gets loaded with tension. This slipping motion gives slack to the chain and allows a few inches of movement. While trying to gain tension in the chain through the twitch bar or ratchet system, it was explained how dangerous this extra slack could be. A driver explained that when this slips, there is a lack of tension force opposing his downward tensioning action. This causes the tensioning bar to jump down, causing a jolt that his whole body could feel.

Figure 27. D-Shackle in its unintended attaching position.

These five drivers explained the impact this jolt causes on their bodies, shoulders, arms and back. These drivers said that this only happens once or twice in your career until you make an effort every time to ensure the shackles are in the correct position before tensioning. One of the drivers even explained how you could crush your hand against the truck if there is enough slack in the chain.

Another driver explained that currently, systems could be adapted to the bolsters to minimize this effect. As shown below, the chain is looped through a hook below the D-shackle before it goes over the log stack. Another driver stated that this is good for two reasons. One is so the shackle cannot be incorrectly positioned before tensioning, and the second is the lower attachment point of the chain on the bolster.

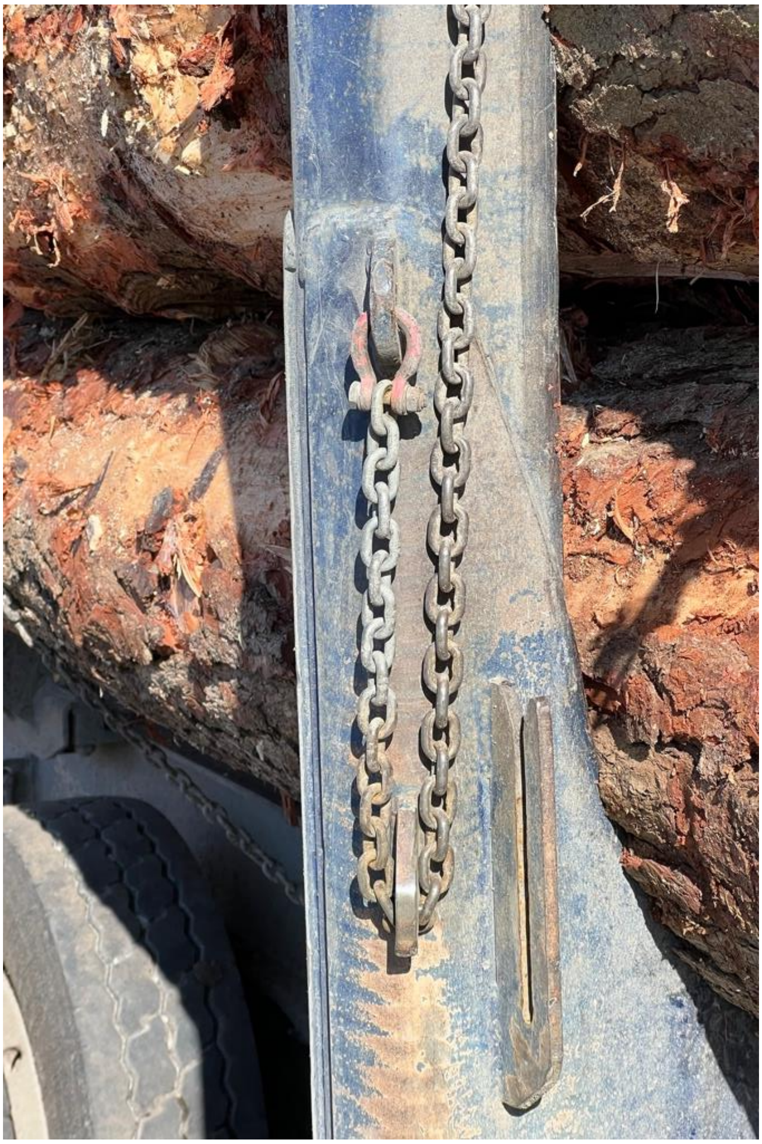

Figure 28 - D-shackle with chained hook

This chain attachment position was another factor that was explained by some of the drivers. Four of the drivers went into depth about this positioning of the chain on the bolster. One driver explained that having the attachment point halfway up the bolster made the chain easier to throw over the log stack. However, this incurred a problem with some of the shorter drivers as they found it harder to reach the attachment point. He stated that this position provides less securement of the log packet due to the chain's rating. It was noted that a lower attachment point provided better securement of the logs. As shown above, in Figure 28, having the lower hook to hold the chain increases its rating.

All nine drivers surveyed stated that the chain throwing process has become significantly more manageable since adopting lighter chains. All of the trucks surveyed were running a 6mm gauge chain. They all stated that this lighter chain was significantly easier to get over the log stack with minimal effort compared to the 8mm chain previously used. This was due to the weight difference between these two chain gauges.

One of the other major sections of the processes explained by the drivers was the ratchet mechanism attached to all but one of the trucks. All of these drivers said that the ratchet system has made the tensioning process much easier than the twitch bars, which used to be standard on logging trucks. All but one truck had ratchet systems on all bolsters. Twitch bars were still standard for tensioning the belly chain. This is due to the difficult position these would be in. A driver said that the belly chain ratchets get clogged up with mud as they are situated behind the wheel with no mudguards. This causes excess wear and tear on the cogs. Five drivers talked about parts of the ratchet system that must be maintained to keep the system and drivers safe. These ratchet systems are shown in the figure below.

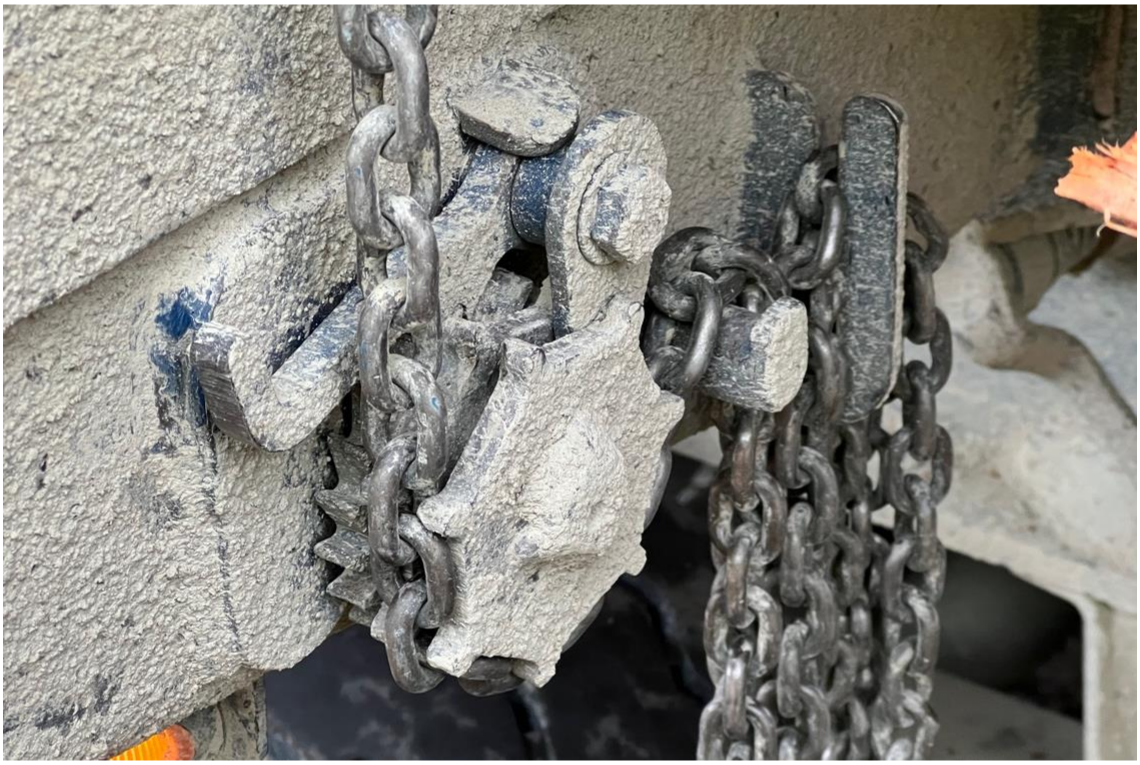

Figure 29 - Ratchet system on the logging truck

One driver noted that these systems are much safer than the twitching system as the twitch bar has lower tension and cant fling back up and hit the operator in the face. The downside for this system was noted that they can fill up with mud and dirt from the wheels which can clog them, making them difficult to use. He noted that drivers must be careful around the maintenance of these as wear and tear can cause injuries. If the teeth on the cog become worn, the chain may slip when trying to tension them. This can cause shock loading to the driver and injury. He noted that these are easy and relatively cheap to replace. One option was to rotate the cog which will give the teeth more life. Magpie, who was the only owner-operator surveyed, didn’t liken the addition of ratchet devices. He said that he was annoyed with the economic impact it had on him.

To operate these ratchet devices, the company created a power bar that could be used both on the ratchet and the twitch system. The drivers all noted that these were a good addition to the truck as it improved the driver safety. He said having the right tools for the right job is vital and helps the company keep their drivers safe. These bars are shown below.

Figure 30 – Power bar

The drivers stated that the end attachment to the power bar was a good idea. This bar locks onto the end of the twitch bar, ensuring it does not slip off the bar when trying to gain tension. One driver talked about the previous system being a length of pipe, which in some cases slipped, which caused the twitching bar to fling back towards the operator's head. It was stated that having one bar for both mechanisms saved the drivers time, which benefited the operation. One of the drivers stated that one day he let go of the bar while tensioning the belly chain. This caused the bar to go flying in the air. This driver claimed that the bar went 30m into the air.

Another note from the drivers was that the position of the driver's body over the bar impacted safety. Not being directly over the bar while trying to twitch was the best practice as if something was to happen, the twitch bar would not fling up and hit the operator. Another driver said that the drivers do not need to put too much pressure on the bar and bounce on it. This causes issues as the power bar could slip and strike the operator.

The new systems proposed were also discussed by some of the drivers. Six of the drivers had heard of new systems for chain throwing but did not know enough to talk about them. The other three drivers said that new systems would be "just another thing to destroy". A driver said the forestry industry is rough, with many large machines. He said bolsters always get bent, which is easy enough to replace. This comes from the grapple of the loader banging into them or logs hitting them. He said that different mechanisms on the bolster would be prone to damage and expensive to replace.

Discussion

The primary logical conclusion, satisfied by the time studies results, was that three bunk trailers would take longer to load than two bunk trailers; the following question after this statement is by what proportion? The mean value for the entire chain throwing process for three-bunk and two-bunk trailer configurations were 447 and 276 seconds, respectively, which was a percentage increase of 62%. This figure did not match across the elements, though, and essentially there was no consistent growth in time across the different chain throwing activities. Tensioning had the most significant growth from two-bunk to three-bunk at 81%, while Organising and Throwing, Repositioning and Securing experienced 71% and 39% growth, respectively.

This is different from expected, as repositioning and securing takes longer than tensioning, regardless of trailer configuration. Therefore the expected finding would be that the growth experienced from two-bunk to three-bunk would reflect this.

It is fair to say that the three-bunk trailer configuration time study did not draw definite conclusions due to the small sample size. However, the Organising and Throwing and Repositioning and Securing sections did yield standard deviation figures under forty seconds which could be regarded, in the context of the figures gained from the study, as being standardly clustered around their mean figures (195 and 134.75 seconds, respectively). Tensioning element and the total time had more significant standard deviations, with figures of 53.78 and 55.20 seconds, respectively. One aspect of the Tensioning element that should be noted is that the four figures were both at two extremes, with the high figures being 162 and 166 seconds and the low figures being 64 and 79 seconds. This is undoubtedly a massive factor in the large magnitude of the standard deviation result for that segment. Ultimately definitive results would only come with a larger sample size for the three-bunk trailer configuration.

Regarding the deviation seen in the two-bunk trailer configuration time study, which had a larger sample size of fifteen trucks, all of the elements had standard deviation figures lower than 36.68 seconds (for the Organising and Throwing element, the mean value of 114 seconds). Repositioning and Securing (mean value of 97.73 seconds) had a range of 118 but only had a standard deviation of 32.42 seconds, the subsequent use of a box and whisker plot (as seen in Figure 24) highlighted the two outliers for that element which had an interquartile range of 25 seconds. A similar analysis process was used for the Tensioning section (mean value of 64.67 seconds), which had an even more extensive range of 123 seconds but a standard deviation of 28.22 seconds. The interquartile range of this element was 23 seconds, and the box a whisker plot revealed an outlier at the extreme time of 146 seconds.

If the total time taken for the two-bunk trailer configuration were to be processed into a box and whisker plot, the interquartile range would be 91 seconds, and the box would be relatively evenly distributed on each side of the median, therefore, giving the appearance of symmetrical data. It should be noted that the total time had a mean value of 276.40 seconds and a subsequent standard deviation of 78.56 seconds.

The main conclusion that can be drawn for the two-bunk trailer configuration is that the shorter time the element usually takes to be completed, the easier it could be predicted as both standard deviation and interquartile range decreased as the mean value for the time taken for specific elements decreased. As for the total time taken for the whole chaining process, this would be much harder to predict due to extremities in results indicated by the large standard deviation and interquartile range.

In the planning for this project, as can be examined earlier in the report, there was some discussion around throwing techniques with options such as "the flick" and "the skipping rope" touted. None of these options were encountered throughout the project, except when an operator asked if he could show us the skipping rope (this was counted as a delay in the time study). After attempting it twice, he could not succeed in doing it and reverted to the sidearm. The sidearm arm had a 100% hit rate in use across all the operators encountered in the study. When asked about the lead rope technique, operators said it was sometimes used by trainees/new employees for about two weeks before they succumbed to the cumbersome nature of it and moved to the standard sidearm. From what was gathered in meetings with the operators, it seemed as though using different techniques was anecdotal at best, and sidearm is the preferred method across the industry in New Zealand.

When the general movements of the landing were examined in a "big picture" style, it was assessed that the chaining down did not contribute to the bottlenecking of a landing. This view is somewhat skewed as this was purely assessed with regard to the specific study area, which, as mentioned, has ideal logging conditions. At one point in the study, there were three trucks on the skid at one time so in that instance, there was a need for the processer to move one of the truck's trailers into its ideal reversing position but other than that there was not much else required to get the operation running again. It is unlikely that a change in the chaining up area would change this as the time to load the trucks was much greater than that to chain the loads to the trucks.

The responses given by the drivers during our questionnaire gave valuable insight into the chain throwing process. Many small details made the process easier and decreased the possibility of injury for the drivers. Overall, it was found that driver injuries were less frequent than expected and were less severe. Out of the nine drivers, only one faced time off work because of the injury. The injuries the rest of the drivers obtained were far less severe than expected, with the drivers just working through the pain. It was interesting to find that only one of the drivers was injured from the twitching process, where he was hit by the twitching bar. This was due to the drivers using the correct technique while twitching and having the power bar, which made this step of the process safer. Shoulder injuries via the repeated motion of throwing were the most common injury here, which was expected.

The frequency of these injuries seems to be reduced, though, due to the adoption of the lighter 6mm chains. Although none of the drivers surveyed had any severe injuries in their careers, it was found that they do know of people who have been severally injured. These severe accidents were uncommon but do happen. These gains were due to the repetitive motion of throwing chains causing shoulder injuries.

Due to the low severity of the injuries, limited time off work was required to resolve these. Only one of the drivers noted having time off work as he could not work through the pain. ACC also covered this, only having to have a few weeks off work until he was fit enough to come back. Because of this, no financial strain was found by any of the drivers surveyed. When questioned about the time off work injuries and the strategies they individually had in place for dealing with pain, the drivers retained a very typical "Kiwi-centric" viewpoint of their respective situations. At the very core of their answers were strategies not to target the cause of the pain; instead, they were merely trying to deal with the pain daily through self-medication of over-the-counter painkillers. For some of the older drivers, it seemed like they were trying to push through the final years of their careers, as it would be infeasible to retrain at this point. One story that stood out from the others was that of a Blenheim driver who was just told not to come back after having consecutive ACC time off periods. This seemed to be the worst-case scenario for a driver late in their careers.

All of the drivers surveyed said that early retirement was not likely for them at the end of their careers. Chain throwing was explained as a simple task that requires minimal effort. Although some drivers explained how the repetitive motion of chain throwing had damaged their shoulders, they could still complete their jobs day in and day out. Unless they were forced out of work or physically could not complete their jobs anymore, these drivers would continue to drive. One driver was a prime example here, having driven for 47 years and is currently at retirement age. We asked him why he continues to drive, and was quickly explained how he loves driving. This driver has never had an injury and wants to continue to drive logging trucks until he physically cannot anymore. Truck driving was a passion rather than a job for these drivers, as they expressed that they loved the job.

It was interesting to hear from the driver's experience that chain throwing is not as complex as it once thought. Because of this, the drivers did not believe there would be more drivers if the chain throwing process were removed. It was explained that log truck driving is not for everyone. The chain throwing process is not what keeps people out of the log truck industry. If a new system gets adopted by the log truck industry, no more drivers are expected to drive.

Throughout the interviews, the topic of logs slipping was talked about in-depth. All the drivers stated that logs do come loose as they settle. The trucks travel from the skid site to the forest gate over the rough forest roads. As the truck and logs bounce around, they settle into a tighter orientation which can cause the chains to lose tension. This is why the drivers stop at the forest gate to re-tension the chains to ensure they do not move on public roads. Although chains come loose in this process, logs slipping out of the stack are not common. The drivers stated that Radiata Pine is especially prone to slippage due to the slippery surface when the processing machine removes the bark. This is why synthetic restraints have not been adopted in New Zealand, as they do not have the holding capacity on these slippery logs. Chains must bite and dig into the logs to ensure a sufficient hold.

Another factor in logs coming loose was the grade of timber being carted. Saw-grade timber was explained to be much easier to cart as it can be stacked tight. These grades of timber are straight and uniform, allowing many points of contact between individual logs and the bolsters. This allowed an excellent crown to be formed, which gave the chain sufficient holding force and tension to keep the logs from moving within the stack. It was found that carting pulp logs were far more difficult than saw logs. Pulp logs are irregular in size, with lots of sweep. This makes stacking the logs more difficult while having less contact between the logs and the bolsters. Getting adequate tension on the log stack is more difficult, especially using the twitch bar. When tensioning, logs deform and bend within the stack before they can be forced into the bolsters. As twitch bars only have a limited range of movement, sufficient holding force into the bolsters can be hard to achieve. This leads to problems and can cause more log slippage than other grades. This problem can be solved by using the ratchet tensioning device. This has a greater range of movement than a twitch bar, allowing the uneven logs to bend and be forced into the bolsters.

From the survey, the drivers explained many other vital points that affect the chain throwing process.

Chain points halfway up bolster. One of these factors explained was having the chain attachment point halfway up the bolster. This position made the chain significantly easier to throw over the logs. This position is easier as there is less length of chain, which is required to get over the logs, therefore reducing the weight of the chain. It was found that this position was not standard on the truck and trailer units, with each truck and bolster having a different arrangement. Going forward, this would be beneficial to study and adopt throughout the industry. Having a lighter chain length to throw over the log will reduce the force required by the drivers, reducing injury risk to the drivers. Although this placement allowed less force from the drivers to throw the chain, it had some downsides. It was found that some of the chain placements were so high up that some of the shorter drivers found it difficult to reach. This is important when the shackle is not positioned correctly and needs to be moved to eliminate shock loading during tensioning. The other factor which this effect is the holding strength of the chains. The other orientation standard on the company’s trucks was having a chain point attached to the bottom of the bolster or even the truck/trailer. This position was down low, making throwing harder but allowing better chains' geometry. A lower attachment point gives the chain a greater rating and more holding force than a higher attachment point. As half of the company’s trucks were running attachment points halfway up the bolsters with a low attached belly chain, it is proven that sufficient holding force can be achieved. Standardised attachment points halfway up the bolster could be implemented nationwide to help reduce injuries to drivers.

The reasoning for the chain attachment being at the base of a bolster or being able to be looped to the base of the bolster was outlined in a phone call with Patchell Trailer's design manager. He stated that the main event it is designed for is the event of heavy braking. When heavy braking occurs at the chain attachment begins at the bottom of the bolster, the angle of the chain in heavy braking is less steep than it would be halfway up the bolster, therefore lowering the load on the chain. If the driver were to elect to use the attachment halfway up the bolster (and not loop it down to the base), they would need to use a 7mm diameter chain rather than the standard 6mm chain. Using a 6mm chain compared to a 7mm chain halfway up the bolster would be highly beneficial for the drivers as it would mean chain throwing is less physically demanding. With the lower loop, such as in Figure 28, this would be the optimal configuration for driver safety. In the future, this would be something to consider for the entire New Zealand fleet to adapt to ensure their drivers are safe.

The use of ratchets has proven to be a positive advancement in the log truck industry, though it has come at a small cost, especially for owner-operators. With the incremental nature of ratchets, the operators prefer how they can continuously keep latching down on even "fiddly" log grades such as pulps. This is as opposed to the readjustment required for the traditional twitches. One aspect that has proven to be a slight worry is when the teeth on the ratchet start to wear out, it can create a gap in lack of resistive force against the operator causing them and the bar to move a larger tangential distance than they were expecting.

Another point of interest discovered through the study was the partial unpredictability of attachment shackles joining the chains and the bolsters, namely D and hammer shackles. Sometimes in the Repositioning and Securing part of the chain throwing/securing process, the shackles can be caught at bizarre, often 45° angles, as seen in Figure 27. Much like a ratchet with worn down teeth, if the operator tries to tighten a chain with a shackle in this position, they also experience a "jump" due to the momentary lapse in resistive force.

The design and implementation of the power bars attached to the companies trucks were also found to improve the safety of twitching. An engineered couple to attach to the twitch bar ensured it would not slip. This minimised the risk to the driver as the bar could not slip and strike them in the face causing severe injury. It was also beneficial that this power bar could operate the ratchet mechanism. It allowed efficient operation and sped up the tensioning process.

While this mechanism helps the operator, sufficient training should also be conducted to ensure they have good technique. It was found that companies puts each driver through a week of in-house training before they operate their own truck. This helps the drivers learn the correct technique while throwing and twitching. Currently, there is no unit standard for chain throwing, which should be considered in the future. Teaching basic skills and techniques would significantly reduce injuries in the trucking industry. While talking to the drivers, it was found that there are right and wrong ways of chain throwing which would be great for new operators to know before they start instead of learning by hurting themselves. This course would involve teaching drivers the correct technique for throwing chains, using the side arm technique, which was found to be adopted by all drivers. The drivers should be taught that chain throwing is not about just strength and should be shown how to use the momentum of the chain to assist in getting it over the log packet. Twitching would also be a big focus point for this course, teaching the drivers not to stand directly over the bar when tensioning the chain and making sure they are not bouncing on the power bar. It would also be essential to show the drivers things to watch out for on their trucks, such as D-shackle orientation and ratchet wear signs. Teaching these points would ensure the new operators understand the best practices and know some of the risks of chain throwing before they learn the hard way.

Conclusion

In conclusion, for the time study aspect of this report, there were 19 separate chain throwing activities observed which had a general mean time figure of five minutes and 12 seconds. Four of these chain throwing activities were completed on two-bunk trailer configuration trucks while the remainder were on three-bunk trailer configurations. The two-bunk configuration had an average figure of four minutes and 34 seconds while the three-bunk configuration had a figure of seven minutes and 28 seconds.

The report's survey aspect also gave valuable insight into the chain throwing process. It was found that injuries were far less severe than expected. Over half of the drivers surveyed stated that they had had injuries in the past which caused no time off work. The discussions outside the question set also provided valuable information about the small details, making the chain throwing process safer. Small details which improve the drivers' operations are smaller 6mm chains, using a ratchet tensioner and having a power bar. These takeaways are vital for driver safety and should be looked into for the industry as a whole.

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