PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email:
forestgrowersresearch@fgr.nz
Web: www.fgr.nz

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Automated truck load securing: a review of the literature

Robyn Patient, FGR

and

Ian Brown, Woodhill Consulting Ltd.

Research Provider:

Forest Growers Research Ltd. (FGR)

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EXECUTIVE SUMMARY

This review of literature related to log truck load securing covered published information as well as unpublished industry trials in New Zealand and personal observations and opinions from New Zealand forest industry members.

Issues driving increased interest in improved load security include:

- Health and safety concerns around current operating practices.
- Additional load security concerns with the industry potentially moving to a greater percentage of debarked logs, given the increased usage of mechanised processors removing a greater proportion of bark, and increase in debarking as a phytosanitary risk reduction treatment due to the reduction in use of methyl bromide.

Aspects of the development of improved log load securing include:

- Reducing musculoskeletal injuries associated with throwing chains over the loads.
- Impact and strain injuries associated with use of load tensioning devices.
- Load security given the settling and movement of logs in transit.
- Load security given the reduced friction between debarked, or partially debarked logs.

Given the interrelated nature of these aspects, ideally the solution, or combination of solutions, should mitigate all of them simultaneously.

The literature search suggests that chains are the best restraint for logs, especially slippery logs. If continued use of chains is envisaged, it is necessary to find a solution for safely getting the chains over the load, and constantly tensioned to a specific force that will prevent the load from shifting in transit.

INTRODUCTION

New Zealand's forestry sector employs approximately 35,000 people and contributes roughly 1.6% towards the national GDP. In 2019 it was reported that 35.9 million tonnes of harvested volume were produced, with most of this being exported to overseas markets as logs. Transportation is an essential link in the supply chain, responsible for moving products from the forest to international ports and domestic markets (NZFOA 2019/20).

It is common practice in New Zealand for truck drivers to secure log loads by throwing chains manually over log packets in several arrangements. These chains must have a minimum 2.3 tonne restraining capacity and are tensioned using either winches or twitches (Mackie and Ashby, 2011; Adams, n.d.). Figure 1 visually demonstrates typical chain throwing and twitch tensioning methods used by drivers for load securement.

Figure 1. Forces involved in chain throwing and twitching to secure log loads (LTSC, 2020)

What has become apparent is the need for improvement in current methods of log load securing through innovative technology. In terms of ergonomics, current load securing practices can be considered problematic as they can promote excessive fatigue and increased risk of injury. Mackie and Ashby (2011) detailed a survey of driver and management employees which revealed that over one-third of participants had experienced injuries from throwing chains. Many drivers felt that twitches required more exertion and are not safe to use in tensioning loads. Blunt force injuries were found to be especially common when tensioning using this method (Chinnery-Brown, *et al.,* 2017).

In a quarterly report of the Incident Recording Information System (IRIS) between the period of 1 July 2019 and 30 September 2019, five of the 34 reported strain/sprain injuries originated from log securing with chains. Of the six head lacerations recorded, two were caused by twitches. Additionally, 11 near misses were attributed to incorrect log securement (IRIS, 2019).

While David Adams was working for Rotorua Forest Haulage Limited (RFH), a local New Zealand logging transport fleet operator in the Central North Island of New Zealand, he wrote a report which stated that 91% of shoulder related injuries and 33% of back injuries were attributed to chain throwing. Twitching was also highlighted as causing 66% of back injuries and 9% of shoulder injuries amongst employees. RFH reported that roughly 4000 days of work had been lost from the year 2000 till the time of writing (approx. 2018) because of load securing.

The physicality and strenuous nature of current load securement may be limiting drivers from entering and staying in the workforce. RFH attributes long-term or permanent shoulder damage as the most common reason for drivers to drop from the workforce (Adams, n.d.). One cause for concern is that drivers in the industry are aging and there are insufficient replacements to fill their positions when they leave the workforce. This is only worsened by the physical requirements of the position which becomes increasingly difficult as drivers age (Mackie and Ashby, 2011). In an interview in 2018, the former Road Transport Forum chief executive Ken Shirley stated that truck driving "…is a skilled labour job and there's a chronic shortage (of drivers)." He described how the average age of drivers was 54 and that many were nearing retirement (Stuff, 2018). If load securing could be changed to be less strenuous ergonomically, it may open up employment opportunities to a wider demographic range of individuals and fill gaps in employment.

When the bark is removed from *P. radiata* logs they are notoriously slippery, creating the need for more secure and effective load securement measures. Reducing log movement will have a greater urgency as New Zealand is set to increase the amount of log debarking undertaken, as an alternative to the use of methyl bromide during export log fumigation to meet phytosanitary requirements. As an alternative to methyl bromide fumigation, debarking export logs is increasing as a risk reduction treatment and this debarking may also occur in the forest in future, increasing the transport of debarked logs. A drawback with this change is that debarked, fresh and sappy logs are very slippery and provide very low friction between logs in a load. Undoubtedly, incidents of securement failure will likely increase in frequency if the current securement practices are not improved.

Load checking is frequently carried out by logging truck drivers throughout their trip. Retightening of restraints may have to occur and is often required especially after travelling over uneven road aggregate or following periods of abrupt acceleration and deceleration. Drivers have a low confidence in the tensioning of their loads and feel that stopping to check would be necessary even if load securing were automated. A tension monitoring system that feeds back in real-time to the drivers may be an effective method of improving driver's confidence and contribute to an overall safer means of transporting logs (Chinnery-Brown, *et al.,* 2017).

Objectives

This study aims to review the methods of load securing currently implemented in New Zealand and other nations across the globe. The following objectives were paramount to this research:

- Define the load security requirements adhered to by New Zealand log transportation
- Inform on current load securing practices utilised internationally
- Inform on alternative technologies for improved load security in New Zealand

Literature used in this review have been accessed primarily through FGR records or academic search engines like Research Gate and Science Direct.

Note the term "restraint" is used generically in this review to designate the object used to bind the load to the truck e.g., strap, chain, rope etc. Specific terms are used to designate actual objects under discussion e.g., chain.

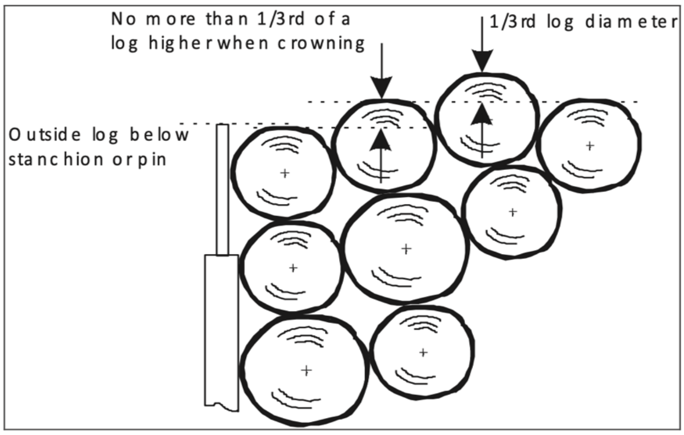
OVERVIEW OF CURRENT NZ LOAD RESTRAINT GUIDELINES

The Log Transport Safety Council (LTSC) log load securing guideline (2012) outlines how drivers can meet New Zealand requirements as per the 1998 Land Transport Act section 134(4)(a). Load securing in log hauling operations must satisfy these regulations. The Approved Code of Practice for Safety and Health in Forest Operations (2012) states under section 17.4 that; "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 requirements may warrant fines of up to $2,000 for individuals and up to $10,000 for companies.

At least two bolsters and stanchions must be used to secure log loads and overhang is beneficial at either end. Logs must overhang as shown in Figure 2. By at least 300mm on 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 a restraint of equal strength (WorkSafe, 2012).

Figure 2. Photos of overhang required when loading 3.1m logs Source: David Adams

As demonstrated in Figure 3, logs are loaded to form a rounded or “crowned” shape as long as they do not rise higher than the stanchion by 1/3rd of the log’s diameter. Crowning is necessary with current securement methods as it ensures that the lashings are all in contact with the top logs to apply tension and pack the logs tight.



Maximum permitted log heights with crowning

Figure 3. Crowning the load (LTSC, 2012)

The log’s natural taper may also be used strategically to maximise load security. The Drivers’ Manual (2018) produced by Rotorua Forest Haulage Ltd (RFH) requires that drivers ensure export logs particularly are stacked with the tapered small diameter end facing outwards. When using two packet trailers this would mean that the small diameter ends would be facing both front and rear of the trailer. In doing this, any movement by the logs with three chains would effectively ‘choke’ the logs, restricting movement using the logs’ natural taper. Export logs need to be loaded in this fashion to facilitate scaling of the logs when they arrive at the scaling station.

Drivers may restrain logs using restraints attached to two anchor points each and these must have a lashing capacity of at least ¼ of the log packet weight. At least two restraints and two bolsters are required per packet. The guidelines state that each packet must be secured by:

- “two 2.3 tonne restraints with one placed forward of the real bolster and the other as a 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.”

As seen in Figure 4, the risk of securement failure is significantly dependent on log friction, depending on factors such as overhang, load height, restraint capacity, restraint tension, and blocking structures. Higher log friction, overhang, restraint capacity and restraint tension can decrease the risk of inadequate load securement. A lower load height and the presence of block structures like headboards can increase the security of log loads when transporting. To develop a safer securement system, these factors will be important to consider (ForestWorks, 2014).

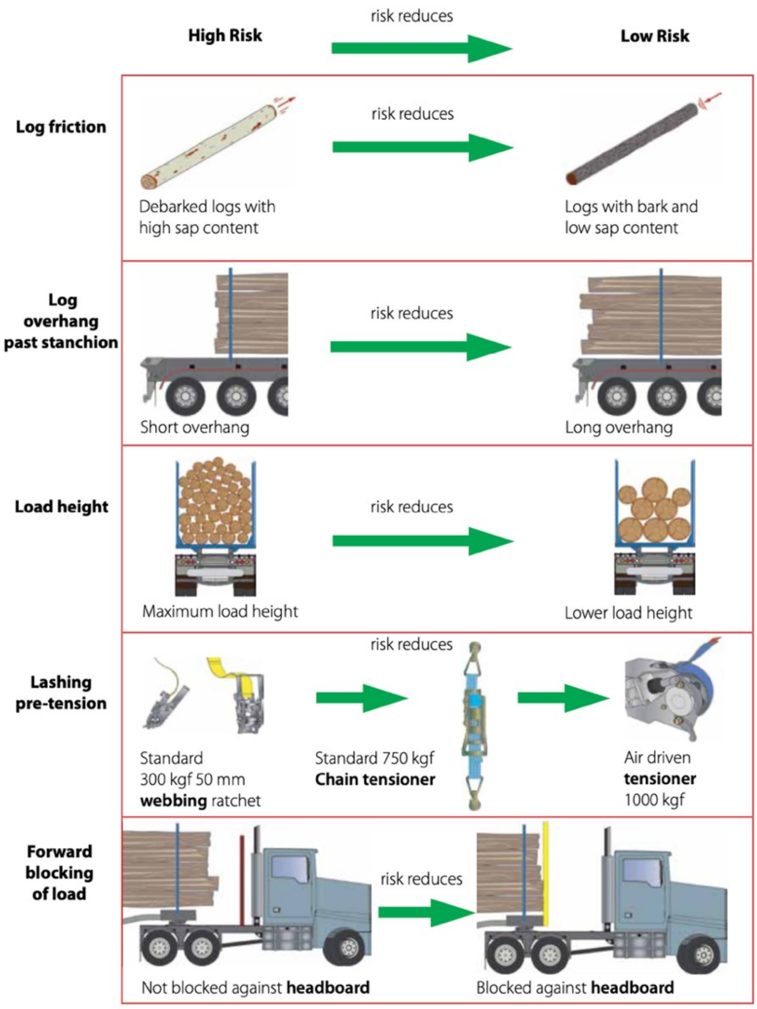


Figure 4. Factors that impact the risk of log load securement failure (ForestWorks, 2014)

INTERNATIONAL LOAD RESTRAINT STRATEGIES

ForestWorks is an industry owned not-for-profit organisation in Australia offering services to support the skills development of the forest and wood industries. Australian log load securement is comparable to New Zealand methods. Bolsters and stanchions are used to hold logs which are crowned to the same standards. Logs are secured by a minimum of two restraints commonly either chain or webbing, to apply clamping force over the packets. Recently, there has been a greater push for the use of chains when securing logs as they bite into logs and are not flexible as webbing is (WorkSafe Victoria, 2015). In Australia it is preferred that these are tensioned by turnbuckles or ratchets rather than 'dogs' which are described as over-centre lever style load binders (i.e., twitches in NZ terminology). Primarily, this is because 'dogs' can be hazardous, and many feel they aren't as effective at tensioning. Headboards to support a weight of at least 50% of the load mass and tailboards to support a weight of at least 20% of the load mass may also be used when transporting logs in Australia (ForestWorks, 2014; Safe Work, 2014). It must be noted here that the NZ load restraint requirements differ from those in Australia. In NZ loads need to restrain a forward force of

1.0g but in Australia the requirement is 0.8g. This obviously places more demands on the performance of restraints in New Zealand.

The British Columbia Forest Safety Council (BCFSC) has identified through injury data that load securement is a significant cause for concern within the Canadian province. Reported injuries are unreasonably high in British Columbia log drivers due to a combination of restraint securement methods and an aging workforce. From 2008 – 2013, 55 related load securement injuries were reported in British Colombia alone at a cost to WorkSafeBC of CAD800,000. This has prompted the creation of a new focused research group within the council called the Load Securement Working Group (BC Forest Safety, 2020; Shetty, 2013). Logs must be crowned and secured appropriately by throwing and tensioning restraints. A unique practice in Canada is alternating the tapered and butt flared ends of logs particularly in Aspen logs where smooth and often frosty bark make them naturally more slippery. In alternating the ends when loading the logs, voids are minimised, and this creates an overall greater compaction (CANFOR, 2006).

In December 2020, FPInnovations (the leading forest research organisation in Canada) commenced a project on behalf of the BC Forest Industry Load Securement Working Group aimed at reducing injuries associated with load securing practices. FGR has a reciprocal information sharing arrangement with FPInnovations, so the New Zealand forest industry will have access to this work and can monitor FPInnovations' progress.

Guidelines from Ireland suggest that logs are loaded onto trucks with stanchions similar to New Zealand transportation. Lashing straps are used to secure logs, however, these need to be the correct length to avoid becoming a hazard. Chains are recommended as a restraint alternative for Irish drivers particularly when hauling slippery debarked logs. Nonetheless, the same drawbacks with chain throwing have been identified in Ireland, their suggested solution is to throw a light rope to pull the chains over the log packet. Similar to Australia, headboards may also be used to stop forward movement into the cab. Unique to Ireland is that when a headboard is attached, a minimum of one restraint is required when transporting bark-on logs of up to 3.3 m in length. With a headboard, logs that have been debarked or are longer than 3.3 m require two restraints per packet. Without a headboard, logs up to 3.3 m long require two restraints, logs up to 5 m require three restraints, and logs longer than 5 m require four restraints. Figure 5 demonstrates these regulations outlined in the Irish guidelines (Forest Industry Transport Group, 2017).

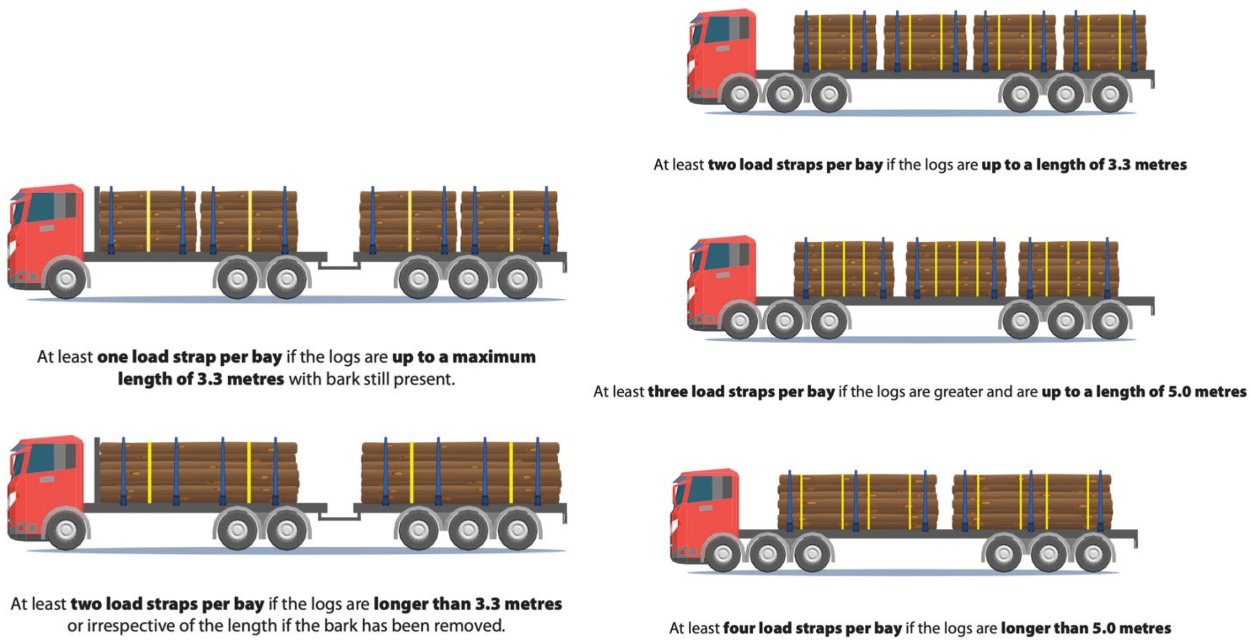


Figure 5. Minimum restraint requirements when a headboard is present (left) and when absent (right) (Ref: Forest Industry Transport Group, 2017)

CHAIN THROWING ALTERNATIVES

Synthetic restraints

Synthetic restraints made from ultra-high molecular weight polyethylene (UHMWPE) have been proposed as an alternative to heavy chain. Synthetic restraints are advantageous as they are lighter, weighing roughly 1/6th – 1/8th of traditional steel cables. Varieties of UHMWPE exist presently in the market such as the Dyneema and Spectra ropes. This material is substantially easier to throw which in turn reduces physical strain and the risk of injury when throwing (Adams, n.d.; Jokai, 2018).

FPInnovations in Canada has investigated the use of synthetic restraints for securing loads. Their 2006 trial concluded that currently available synthetic restraints lose strength and deteriorate too quickly for practical long-time use. Causes of this loss of strength include knots, broken strands, abrasions, and dirt. FPInnovations proposed that increasing rope size or creating a protective polyester sleeve (at a higher cost) may reduce wear and lengthen the durability of these products (Shetty, 2013; Jokai, 2018).

Rotorua Forest Haulage Ltd (RFH) has trialled the use of synthetic restraints using UHMWPE rope with a resistant exterior, giving a 6,000kg lashing capacity and 12,000kg breaking capacity. With the rope on the first trailer packet and chains on the second, drivers identified a marked difference, remarking on its light weight. Wear was not a concern in the early stages of this trial (Adams, n.d.).

Excavator assisted chain throwing.

The report “Methods to secure logs on trucks to minimise shoulder injury” by David Adams discussed the use of loader-assisted chain throwing. It suggested that this method may be a practical, fast, and low-cost alternative to chain throwing. Presently, drivers in New Zealand use this method informally by either throwing chains onto the grapple of an excavator loader or by extending chains out from the truck to be picked up and placed over the load by the loader. FPInnovations has developed a training video to instruct on the recommended practices when using loader-assisted chain throwing (Figure 6). Approximately a third of the chain is thrown through the closed grapple which is then lifted over the log load for the driver to secure (FPInnovations, 2021).

Figure 6. Excavator assisted chain throwing using a grapple loader (FPInnovations, 2021)

Trials at the Kaingaroa Processing Plant (KPP) revealed that the wheeled loaders used there are incapable of reaching across the top of full on-highway or off-highway loads. Alternatively, the tracked excavator loaders present at the KPP were able to successfully reach across the various truck configurations (Adams, n.d.).

Chinnery-Brown *et al.* (2017) described how the spring-loaded lever device shown in Figure 7 may be a useful device to improve New Zealand log load securement. Created by Daryl Hutton of ANC Logging in Victoria, Australia, this system attaches to the side of the bolster and allows drivers to hook chains up in a manner that enables an excavator to lift them over the log packet. Each hook weighs approximately 1kg and come at a cost of $600-900 to fit to a two-bay trailer combination. The response from this device has been generally positive, many companies throughout Australia have incorporated the device in their load securement practices. Reportedly, this system takes around 40 seconds to operate, making it both safer and faster in comparison to hand throwing chains.

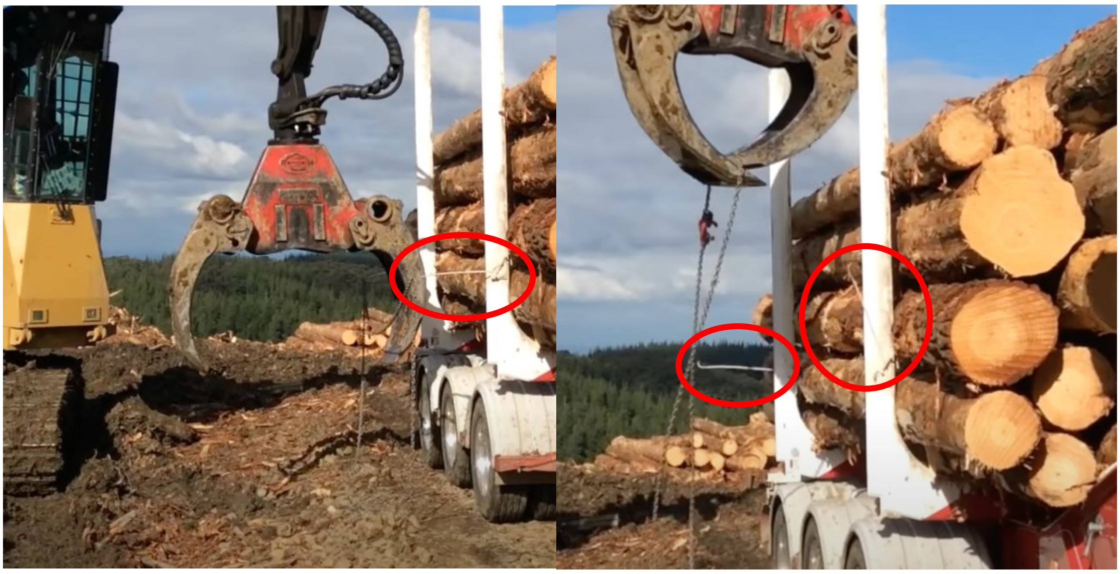


Figure 7. Spring-Loaded Lever Mechanism (WorkSafe Victoria, 2015)

As seen in Figures 8 and 9, a similar device by the Swedish company ExTe called the “Long Life Accessory” has been created, although it is considered not robust enough for New Zealand operations (Adams, n.d.; ExTe n.d.).

Figure 8. ExTe Long Life System

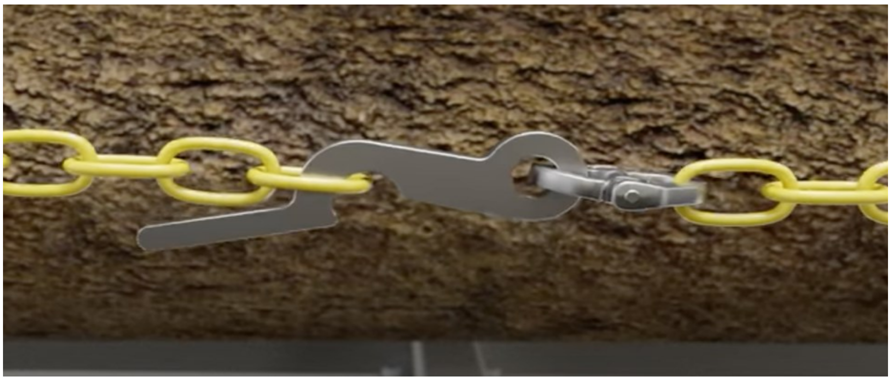


Figure 9. ExTe Link (ExTe, 2017)

Trials run by the Holmes Group in New Zealand, tested, and reviewed four different designs for excavator assisted chain throwing. Design 1 was a bar which the driver would thread chains over in the centre between the bar and the lifting handle to be hooked securely. The bar is then lifted over the log packet and chains are unhooked by the driver. This design was slow and increased risk for driver safety as unhooking was done out of the loader's line of sight.

Design 2 used a pipe and was much faster since chains were threaded over the pipe much like in Design 1 and released themselves when dropped by the loader. Following this was Design 3 which trialled the same design but with a grapple only. This design was problematic as the chains had difficulty releasing themselves. Lastly, Design 4 incorporated welding a pipe to the inside of the grapple where the chains could thread through and release themselves easier. This system was much simpler than the previous three and may be a promising substitute to current load securement practices (Dixon and Mason, n.d.).

A trial run in 2014 at the KPP tested assisted chain throwing by joining three chains with magnetized hooks which would attach to a grapple. As the chains crossed the packet, pulling on the hook would release it and the chains would fall. Numerous issues arose from this trial since finding the appropriate chain length and magnet strength was difficult, the chains would often tangle, and this method has a higher risk as it requires a high human and machine interaction. (Adams, n.d.).

As seen in Figure 10, the log strapping securement device may be an innovative option to implement in New Zealand load securement. This device is designed to fit in place of the inspection plate covering the inspection cavity of a log grapple. A chain link is inserted into the slot and locked to be lifted over the logs. The chain link is then released, and this process is managed remotely by the loader (Heckenberg, 2020).

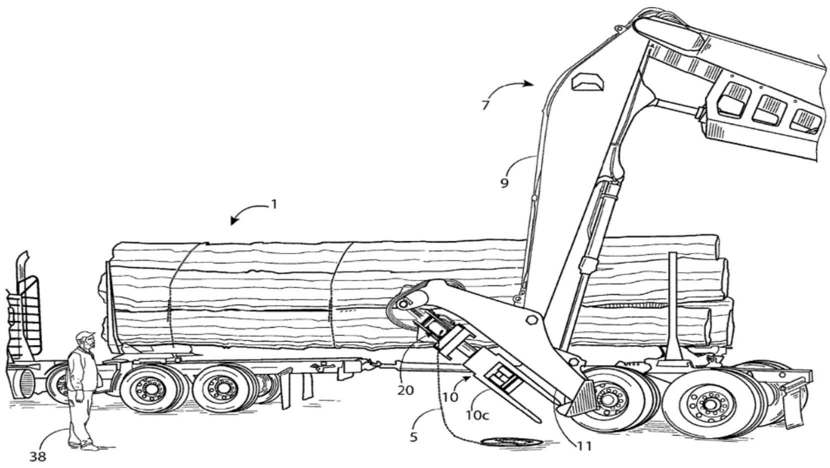


Figure 10. Patent Diagram for Log “Wrapper” Securement Device

Chinnery-Brown *et al.* (2017) proposed the use of a lifting arm system to lift chains over the log packet using an extended arm made from lightweight material. A similar design that they came up with was the T-bar concept. A long bar with hooks would be hinged at the chassis and extended out, the chains would be hooked on this bar, and it would be lifted over the log packet by an excavator loader. The RFH report comments on this concept, stating that simpler alternative solutions like the bars from Holmes’ trials exist (Adams, n.d.).

Chain Lifting Device

As a refinement to using the loader to lift the chains over the load, Timberlands Ltd have developed a modified cherry-picker type machine to place the chains over the load. The cherry picker does not have a platform on the end of the boom. The platform has been replaced with an attachment to enable it to lift a long bar, which is long enough to lift all the chains to secure a trailer load of logs in one movement (Figure 11).

Figure 11. Timberlands Ltd.’s Chain Lifting Device

The idea here is that this machine will be placed in a safe area either on the log landing or in close proximity to it, the driver will pull the truck up next to the machine and connect all the chains to the long bar. The idea is for this process to be remotely-controlled so the driver is only required to press a button to start and finish the process. The machine will then lift the bar and chains over the load and the chains slide off on the far side of the load. Timberlands' idea is for each harvesting crew to have one of these machines on the log landing. The truck will still require the chains to be thrown over manually in this process.

Lead rope

Chinnery-Brown *et al.* (2017) proposed the use of a 'lead rope method' to pull chains over log loads. Their trial was low cost, using 10m of 8mm nylon rope at $0.50 per metre, a $4 carabiner and a 156g monkey's fist ball like a cricket ball ($13). The typical throwing force of 2,943 kgf with chain throwing was reduced to 100 kgf using their lead rope design. This method is effective as a chain throwing alternative and is reportedly already utilised informally in some New Zealand operations. Throwing the lead rope reduces shoulder torque by a factor of 4, greatly reducing the risk of injury and strain. There was a slight snagging issue, however, simple modifications to things like mud guards and chain hooks can be made to reduce opportunities for catching (Chinnery-Brown, *et al.,* 2017).

David Adams (RFH) reviewed the trial detailed in Chinnery-Brown *et al.* He concluded that the monkey fist ball will likely be unsuitable as it causes injuries when throwing overarm. Underarm throwing of a self-made weighted rope was found to be much more effective. Additionally, a toss and tie option is preferred by RFH like the Toss N Tie from Ancra International pictured in Figure 12 (Adams, n.d.).

Figure 12. The Toss N Tie from Incra International Source: https://www.overdriveonline.com/gear/product/14868783/ancras-load-securement-tool

Soper and Soper (2015) designed a triangle hook which uses a small steel triangle with three hooks welded along one edge (Figure 13). Soper and Soper (2015) published a video showing the operation of the system. The triangle is attached to a lightweight rope. The triangle is thrown over the load, the two or three chains attached to the hooks, and the triangle is retrieved from the opposite side of the load by the driver by pulling on the rope, thus drawing the chains with it.

Figure 13. The triangle Hook and Throw Rope developed by Grant Soper

Head and Tail Nets

The use of Head and Tail Nets in combination with lightweight webbing is a unique concept. Webbing is lightweight, so it can be thrown with relatively low physical strain on the driver. The material has been a popular restraint choice internationally, however, it has not been adopted in New Zealand logging. Testing in 2003 by Log Transport Safety Council (LTSA) revealed that web restraints underperform in comparison to chains. Sufficient force from a restraint is achieved when there is a load shift of more than 1 m, however, this material does not ‘bite’ into logs as is required. Another factor is that webbing is flexible, so may allow log movement within the log packet. The purpose of the net fixed across the rear of the rear trailer and the front of the front trailer, combined with webbing restraints would be to stop this movement and provide the additional security required when using webbing (Adams, n.d.; LTSA, n.d.). Fixing nets to the trailers is however a time consuming and dangerous activity since the nets need to be fixed to the top of the stanchions, requiring working at heights. This method was however used successfully for several years when transporting very short lengths from the KPP to the Port of Tauranga.

ExTe Com90

ExTe's Com90 bunks pictured in Figure 14 are an innovative solution developed to completely automate load securement. ExTe claim states, "…this unique, remote controlled load securing system provides an unbeatable working environment, in which the engineering has eliminated the physical strains on the driver…. you only need a few button clicks to secure the cargo." Their automatic hydraulic function and instant surveillance feedback completely removes the need for drivers to get out of the cab to secure or check their loads (ExTe, n.d.).

Figure 14. ExTe's Com90's automatic log securement. Source:
https://www.youtube.com/watch?v=2p6RS_5i9Sw

As pictured in Figure 15, the ExTe Com90 system is currently in use at RFH on a Kenworth K200 truck with an Evans 5-axle trailer. This system reportedly is rated at 10,000 kgs per bolster and has a lashing capacity of 4,000 kgs (Evans Trailers NZ, 2020). It can be expected that securement related injuries will drop off significantly if these systems were to be implemented throughout New Zealand. Realistically, this may be unlikely as there is some criticism with Com90's ability to secure pine logs when sappy or in wet weather. Another concern is the system's resilience to the harsh conditions typical of New Zealand operations (Adams, n.d.).

Figure 15. ExTe Com90 in use by Rotorua Forest Haulage Limited. (Evans Trailers NZ, 2020)

Chinnery-Brown *et al.* (2017) reviewed the Com90 and its feasibility in New Zealand load securement. They highlighted how the system is currently in use in the United States of America, Sweden, Finland and Norway. ExTe's auto-tensioners secure in 10-15 seconds and provide a continually tensioning force with equal distribution on either side. The system would be most viable for short routes of less than 50 km and would be particularly advantageous to keep drivers out of dangerous situations like bad weather and risky sites. The Com90's benefits are negatively impacted by its high capital cost of approximate AUD $96,400 per truck and two trailer bunks. This factor, along with the specialised technology required, are significant drawbacks to realistically using ExTe's Com90 bunks. In his report David Adams (n.d.) suggested that this system could become commercially viable if a simpler and cheaper design was created inspired by ExTe's Com90.

Chain Slinger

Rotorua Forest Haulage Ltd (RFH) have developed a methodology that uses a mechanical insert in the stanchions to sling or throw the chain over the load automatically. The mechanism uses pneumatics inside the stanchions to feed out and tension the chain. One truck and trailer unit has been fitted with this mechanism and is being operated on a trial basis. The system recovers the chain at the unloading point too, obviating the requirement for the driver to pull the chains off the load thus ensuring driver safety at this point as well. The system is still under development.

TACTICS TO STOP LOG MOVEMENT

Friction tactics

Several low-cost tactics may be used to increase friction between logs and reduce log movement when transporting. Scion's Maximising Incident Learning Opportunities Project (2017) detailed how loader operators may increase friction between logs by coating them in an aggregate like sand, dirt or slash. Mud may also be used to cover logs before being loaded onto bunks, however, this may be problematic for the customers of the logs and impede them from qualifying for export (Scion, 2017).

Most bolsters on logging trailers have a narrow strip of steel welded to the bolsters to provide a knife edge that bites into the logs, therefore restricting its forward and backwards movement. Serrated stanchion edges have also been used in Australia especially with eucalyptus logs. These have a similar effect to the bolster raised edges in gripping the outside logs.

Restraint guards (Head and Tail Boards)

French's patent for "Apparatus for Constraining the Position of Logs on a Truck or Trailer" (2003) detailed some restraint guard designs (as seen in Figure 16). The restraint guards are latticed and attach to the trailer either behind the cab or at the rear. They act as physical barriers to protect the cab and stop loose logs from escaping the packet. This design proposes that these restraint guards can secure logs independent of other restrains like chains and lashings. French claimed that this design for log load security is less laborious and much more efficient for drivers.

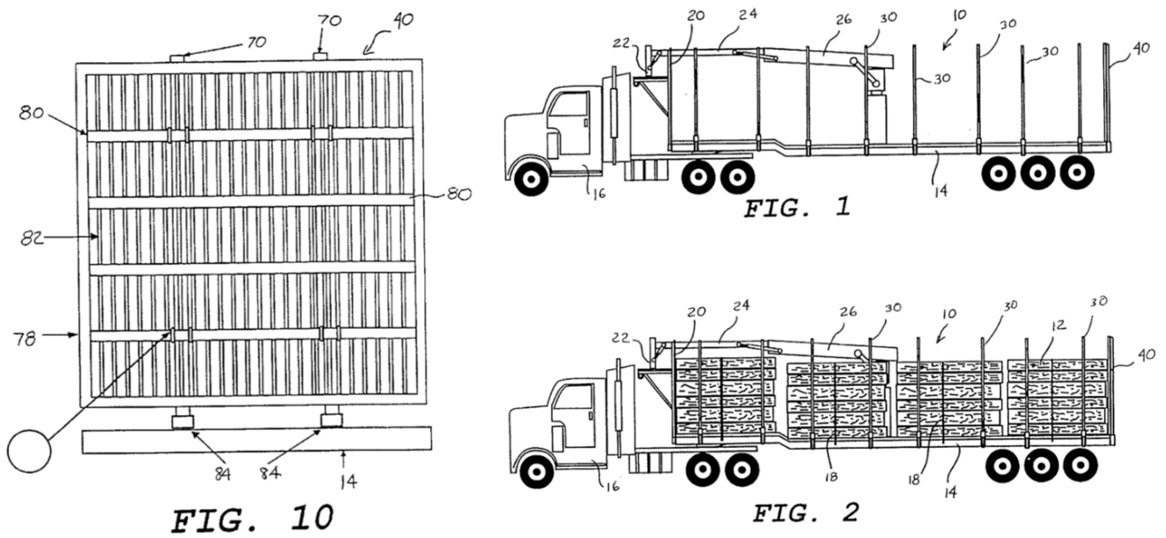


Figure 16. A tailboard pictured from the front and an unloaded and loaded semi-tractor and trailer with the restraint guards. (French, 2003)

Scion (2017) reviewed restraint guards like the ones pictured in Figure 17, both at the rear and front of the load, and whether they may be an ideal solution to better restrict log movement. Guards must be designed appropriately to handle vehicle acceleration/deceleration, strong wind speeds and vibration. This option has the drawback of adding more weight to the trailers which ultimately reduces the legal carrying capacity. This issue may be remedied if a similar design could be made from light-weight materials like carbon fibre.

Figure 17. Restraining guards at the rear and behind the cab. Source: http://www.elph.com.au/parts/cabguards.php

TENSIONING AND MONITORING SYSTEMS

Automatic tensioning

The ergonomic and safety issues associated with the use of twitches and manual ratchet winches are well documented and understood. Air winches use the air pressure from the truck's compressor to rotate the winch. It is therefore not necessary to use a winch handle to manually crank the winch. The chain is fed into the winch and an activator button is pressed which tensions the chain to a pre-set tension. This tension is automatically maintained throughout the trip, ensuring that down-force is maintained as the load settles and moves, obviating the requirement for the driver to stop and re-tension the restraints on route.

Williams and Wilshire Ltd, a NZ-based log transport operator, fitted the ExTe TU auto-tensioner winches to their short distance shuttle trucks in Gisborne in 2018. These trucks typically hauled 15 loads per day from a log processing yard facility, across town to the Port of Gisborne. The winches saved time, improved load safety and driver health. For more details, click this link: https://www.youtube.com/watch?v=ZsExez5VWL4

Automatic air winches are required by forest companies to be fitted to trucks in Victoria and NSW. These are generally fitted with webbing straps. Issues however still arise with the tension across the length of the strap with high tension at the winch side and very low tension on the opposite side of the load. This was a function of the friction generated by the straps rather than the effectiveness of the winches. Successful trials have been done with a combination of straps and chains to gain the benefit of both materials and increase the mechanical leverage on the chain (Daryl Hutton pers. comm).

Wireless motion detection sensors

There are sensors on the market that can detect movement of cargo. These could be adapted to detect movement of logs in a load and warn the driver of the fact. These are however very sensitive devices and may not be suitable to the rugged and outdoor nature of log transport. There is no information available on these sensors being used in a logging application. It would be worth following up, however.

CONCLUSION

The summarised results of the literature search are as follows:

Base Issue	Sub-Issue	Solutions	Alternatives	Comments
Driver injuries	Chain throwing	Lighter material	Polyethylene rope	Durability questionable due to wear on logs.
			Webbing straps	Friction prevents adequate tensioning.
		Throwing methodology	Rope pull-over	Easy to implement, time consuming (?)
			Loader assisted	Requires minor modifications on loader or trailer, currently used in some operations, potential man/machine interaction.
			Independent Machine	Similar to “Cherry-Picker’ platform. Additional machine in operation. Only assists with trailer. Fast operation
			Chain Slinger	Requires a mechanism installed in stanchions. Recovers chain at point of delivery. Has a payload impact.
	Tensioning	Automatic devices	Air winches	Commonly in use in Australia, some in NZ, efficient and effective.
			ExTe Com90	One in use in NZ, prohibitively expensive, principle has potential.
Load Security	Load settling	Re-tensioning load	Manually as per current practise	Load could settle between driver checks.
			Air winches	Constant automatic tensioning whilst in transit.
			ExTe Com90	Constant automatic tensioning whilst in transit.
		Warning to driver	Load movement sensors	Untried in logging.
	Load movement due to slippery logs	Increased friction	Serrated bolsters and stanchions	Already on most NZ bolsters, could serrate stanchions as an additional measure.
			Grit placed between logs	Issues with log contamination for both domestic sawmills and export phytosanitary requirements.
			Additional load restraints per packet (e.g. belly restraints on all loads)	Additional time required, ergonomic and engineering considerations
			Increase restraint tension	2:1 leverage with hybrid chain/webbing method
		Constrain load front and rear	Fit headboard and tail board	Has been used in other countries, additional tare weight, constrains log length flexibility.

This literature search suggests that chains are the best restraint for logs, especially slippery logs. If continued use of chains is envisaged, it is necessary to find better solutions for safely getting the chains over the load and constantly tensioned to a specific force that will prevent the load from shifting in transit.

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