An Analysis of Vessel Loading of Export Logs at Four New Zealand Ports

A dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Forestry Science with Honours by:

Alfred W. Duval

School of Forestry, University of Canterbury

New Zealand

2016

Abstract

Over half of New Zealand's annual harvest was exported as logs in 2015 (MPI, 2016). The large scale and economic importance of log exports highlights the importance of efficient port operations.

Productive cycle elements for the log loading operation were defined. The vessel loading cycle was split into six elements: three 'action elements' (loading, tallying, and slinging), and three 'carting elements' between the 'action elements'. Time study measurements were carried out at four New Zealand ports (Tauranga, Marsden Point, Gisborne, and Port Chalmers) to identify differences in productive time to load log export vessels. Port Chalmers wasn't compared to the other ports as it was too different operationally.

Loading had the longest productive element time, followed by slinging and tallying, and lastly the 'carting elements'.

Loading was uninfluenced by port but affected by log grade, length, operator skill, and the time of day. Tallying was significantly different between the three ports with Marsden Point fastest and Tauranga slowest. Slinging was quickest in Gisborne and faster whilst loading below-deck and during the daytime.

Carting elements were heavily influenced by distance to or from log stack for all four ports.

Tauranga displayed the fastest historic gross load rate (JASm^3/hour) yet the slowest productive cycle time. Gross load rate is influenced by delays, volume per cycle, and productive cycle time. The difference in productive time and gross load rate could therefore be assumed to be from increased volume per cycle and/or reduced delays in Tauranga.

Exporters are fined for loading slower than scheduled. This cost is greater when shipping rates are high as fines are based on shipping rates. A 5% increase in loading efficiency can save the exporter US$11,000 per vessel at historic maximum shipping rates.

Keywords*: logs, exports, efficiency, forestry, logistics, shipping, New Zealand, Tauranga, Gisborne, Marsden Point, Dunedin.*

Acknowledgements

First of all I would like to thank David Evison at the School of Forestry for all of his help, guidance, and words of wisdom during the course of this gruelling exercise. I sincerely appreciate the time he was able to set aside and the effort put in for helping me with whatever questions and queries I had regardless of how simple.

Secondly I would like to thank Pacific Forest Products for their immense hospitality, generous scholarship, and the chance to work and study with them over the summer of 2015/16. A special mention must go to John Gardner for his guidance and ideas during this project. I am also truly grateful for his words of guidance and providing me with the resources to attempt to learn to surf.

A special thanks must go to all of the marshalling and stevedoring companies I had contact with and the friendly and welcoming individuals that made up these interactions. These include employees from ISO Ltd., C3 Marshalling and Stevedoring, Quality Marshalling (QM), and Independent Stevedoring Limited (ISL). I must also thank the port staff at the four ports in which I visited for their assistance. This applies to employees I met from Port of Tauranga, Northport, Eastland Port, and Port Otago's Port Chalmers.

It is important to also thank Hunter Harrill for sharing his experience and helping in developing this study and sourcing the much needed literature. Full credit must also go to Glenn Murphy for taking the time to talk to a naïve student with little time study knowledge, let alone on port operations, and for giving much needed advice in the early stage of this project.

Lastly I would like to thank all those friends and family who have put up with my fluctuating moods whilst lacking sleep and exercise and for all the friends I have made and good times had throughout my undergraduate forestry degree I am truly thankful.

Table of Contents

1. Introduction

The New Zealand forestry sector is very reliant on export markets and in particular, export logs. 78% of the 29.6million m^3 harvest in 2015 was exported in some form, and 16.1million m^3 (54%) were exported as logs (Ministry for Primary Industries [MPI], 2016). New Zealand was the largest exporter of softwood logs (by volume) in 2015 providing 18% of the total global trade (Food and Agriculture Organisation [FAO], 2016).

This study was supported by Pacific Forest Products Ltd. (PFP) an export log marketing and logistics company which operates predominantly from four New Zealand ports Tauranga (Port of Tauranga), Gisborne (Eastland Port), Marsden Point (Northport) and Dunedin (Port Chalmers). These ports exported 10.7million m^3 in 2015 or 70% of the total log exports in that year (MPI, 2016).

The purpose of this research is to observe and measure the log loading cycle at each of these ports to identify potential areas where log loading could carried out more efficiently.

2. Problem Statement

PFP has observed that load rates (the time it takes for logs to get from storage row on port to being stored on ship) differ between ports in which they operate. This study aims to identify some of the differences between the ports in question and provide insight into reasons for load rate variations between locations.

Understanding the factors that influence load rates will help identify areas where improvements can be made. This may provide opportunities to increase load rates and reduce load rate variability. Increasing the load rate decreases the total time the ship is at the wharf and provides opportunities for the exporter to negotiate lower shipping rates. It also reduces the chances of incurring demurrage charges (fines for taking too long to load) and increases the chance of incurring despatch (financial reward for loading the ship quicker than agreed). Secondly, faster load rates increase the return for marshalling and stevedoring companies involved as these companies are paid on a per JAS m^3 (Japanese Agricultural Standard – unit of volume measurement for log exports) basis. Moving more JAS m^3 in the same time frame will increase return, provided it can be done without increasing costs.

The importance of vessel loading efficiency increases with higher shipping rates as shipping rates are positively correlated to demurrage charges (as shipping rates increase, so do demurrage fines). Shipping rates are currently very low, if they increase the importance of cost savings also increases. Log exports are a relatively low-value commodity product, therefore logistics costs can become a large part of the sale price to the customer. This reinforces the importance of identifying potential efficiency gains with regards to vessel loading.

2.1 Research Questions

1 What are the differences in loading times between the four ports studied?

(a) What are the average times for the elements of the vessel loading cycle and how do these times compare between the four ports?

(b) What explanatory variables account for the change in cycle times between ports? (Port conditions, cargo characteristics, environmental conditions, distance to log stacks etc...).

2) How do Gross Load Rate (JAS/hour) and Shipping Rate ($/JAS) affect log export cost?

3. Literature Review

This literature review is set out in three sections. Section one describes methods used in previous work to conduct similar studies. Section two reviews how data collected in these types of studies can be analysed. Section three reviews previous literature on port operational studies to gain an idea of potential gaps in the knowledge of port operations.

The importance of the efficiency of on-port operations on shipping costs was noted by Clark, Dollar, & Micco, (2004). Brooks, Schellinck, & Pallis, (2011) addressed that the effectiveness of port operations largely important as well. Effectiveness is measured through the delivery of information to port customers and the security and lack of damage to their goods (Brooks et al., 2011). The large level of volume and value of log exports from New Zealand reinforces the importance of ensuring efficiency in port operations. Performing studies where there is limited information is important as identified in Visser et al. (2012). Not only do port environments pose unique constraints on vessel loading operations but a main driver of these differences has been documented as limited available storage space (Hopper, 2012).This poses the question of whether New Zealand log export ports are performing as efficiently as possible. It is predicted for future log export volumes to increase which emphasises the importance of efficiency (Murphy, 2016; Visser et al., 2012).

Simmonds (2012) and Hopper (2012) outlined a lack of data on log delivery and crane operations for vessel loading. They displayed that there is little previous research recording log export operations in New Zealand. It is important to perform initial productivity studies when few are previously documented (Visser, Hopper, Simmonds, Wakelin, & Harrill, 2012). This study will therefore attempt to contribute to fill the knowledge gap of log export operations within New Zealand.

A Detailed Continual Elemental Time Study was the best choice for this study (Acuna et al. 2012, and Olsen et al., 1998). A previous study on the vessel loading times in the Port of Nelson also used a continual elemental time study approach due to the level of detail able to be obtained (Hopper, 2012). Conducting a 'continual' time study is a method of measuring the cycle elements continuously so that as one element finishes, the next one begins simultaneously (Acuna et al., 2012).

Increased detail obtained from elemental time studies facilitates a better understanding of the cycle as a whole (Olsen et al, 1998). Increased understanding is due to segmenting the cycle and observing the drivers of productivity and delays within each element. As many potential explanatory or nuisance variables will be recorded during each cycle to ensure any and all trends can be observed (Olsen et al., 1998).

'Elemental' denotes that the study is split into measurable segments (elements) (Acuna et al., 2012). A cycle is comprised of elements (in this case 6 elements, shown in 4.1.1 and 4.1.2 of the Methods section), in an attempt to look at trends within the elements as well as the cycle as a whole.

'Detailed' Time Studies Pro's and Con's:

Outlined in Acuna et al. (2012) there are many benefits of conducting a 'detailed' time study, these include:

- Comparison of delay-free production.
- High-precision measurements (nearest second).
- Frequent delays adequately documented.

On the contrary there are a number of negatives about 'Detailed' Time Studies, as mentioned by Olsen et al. (1998) as follows:

- Ineffective in generating long term trends.
- Costly to run due to the level of detail and time required.
- Limited sample size from time constraints.

- Large delays not documented well (>1 day).
- Lack of variation in environmental conditions.

With the resources available and the study goal in mind, the benefits of performing a detailed study outweighed the negatives for this project.

'Elemental' Time Studies Pro's and Con's:

Acuna et al. (2012) also outlines the benefits of undertaking an 'Elemental' Time Study as follows:

- High level of detail.
- Better understanding of the overall cycle.
- Identify which elements take more time.
- Separation of productive time and delay time.
- Facilitates the analysis of different factors influencing different elements when modelling.

The benefits of performing the study in a 'Detailed' manner, mean that a 'Detailed Continuous Elemental Time Study' was chosen as the best option for this research.

Information on best practice in carrying out a time study and interpreting the study results was summarised in Acuna et al. (2012) and Olsen, Hossain, & Miller (1998). A sound experiment will fulfil two factors: 1) nuisance variables are controlled, and 2) the data should lead to simple analysis (Acuna et al., 2012). The attempt to control nuisance variables has been exhaustive as these variables aid in regression analysis.

Nuisance variables may influence the data but are not the study focus (Acuna et al., 2012). They need to be controlled or noted as much as possible as it is unknown if they will influence the study. They were not always possible to control but every practicable step was made to ensure they were noted and monitored (Acuna et al., 2012). The list is as follows:

- Log grade
- Log length
- Bark status
- Ship loading stage

- Weather conditions
- Distance to log stack
- Distance from log stack
- Loading methods
- Machinery used
- Size of storage on port
- Road conditions
- Operator skill
- Time of day

Nuisance variables can be dealt with via both inclusion and constant keeping (Acuna et al., 2012). Constant keeping attempts to create the same conditions at each site repetition. Differences between the ports and study conditions made this impossible for all variables mentioned above.

In an attempt to control some of the variation due to cargo differences only the most common log grades and lengths were measured. Only A and K-grade logs of 3.8m or 5.8m lengths were measured. This ensured enough data would be available by ustilising the most common log grades and lengths.

A large proportion of the above variables are qualitative and were represented in a binary fashion. This is also known as using indicator, or dummy, variables to represent whether the variables is turned 'on' or 'off' (Olsen et al., 1998). A '1' signals that the variable is turned on, for example a '1' in the port of Tauranga column signals the measurement was taken in Tauranga. All other measurements that weren't at the Port of Tauranga would then have a '0' in the same column.

Geographic Positioning System (GPS) potential for measuring time and distance was outlined by Simmonds (2012). GPS potential was also brought up with R. Spinelli (personal communication, May 6th, 2016) but unfortunately found not viable for this study due to resource constraints.

3.1 Data Analysis

The process of data analysis is thoroughly described in Acuna et al. (2012) detailing a 6-step process to examining time study data:

1) Descriptive Statistics = Exploratory Data Analysis: mean, minimum and maximum values, and boxplots were created to visualise the data collected.
2) Checking for Outliers = Not necessary to remove outliers due to robust collection methods. The presence of outliers was checked using Cook's Distance.
3) Checking for Normality = QQ plot for normality was assessed and the data represented a normal distribution.
4) Data Transformation = To correct for non-normality of data (not needed).
5) Making Comparisons = Regression modelling was the basis for making comparisons.
6) Modelling = Regression analysis of all variables was performed through modelling the explanatory variables against the elemental times. Model fit assessed by p-values of the independent variables used.

In this study exploratory data analysis was carried out to graphically identify relationships between variables. Regression analysis was then carried out, and regression diagnostic plots were examined to check the underlying assumptions of regression analysis were met. Data transformation and ANOVA were not carried out in this study.

4. Methods

Having chosen a detailed continuous elemental time study as the best data collection method, cycle elements were defined by consultation with industry experts. It was decided to only measure productive cycle elements (not delays) as delays measured would not be representative due to the small study timeframe. If delays were included they would likely skew the data and make for difficult comparisons. In some instances, small delays were observed and noted, but are not the focus of this study.

4.1. The Vessel Loading Cycle

The vessel loading cycle was defined under three conditions: 1) all measurements are of productive time, 2) crane and digger stowing operations are not measured, and 3) cycle elements must flow on continuously from one another. This means all data recorded involved moving logs from storage row to shipside without consideration of storing the logs on the ship (stowing). The vessel loading cycle is represented in Figure 1.

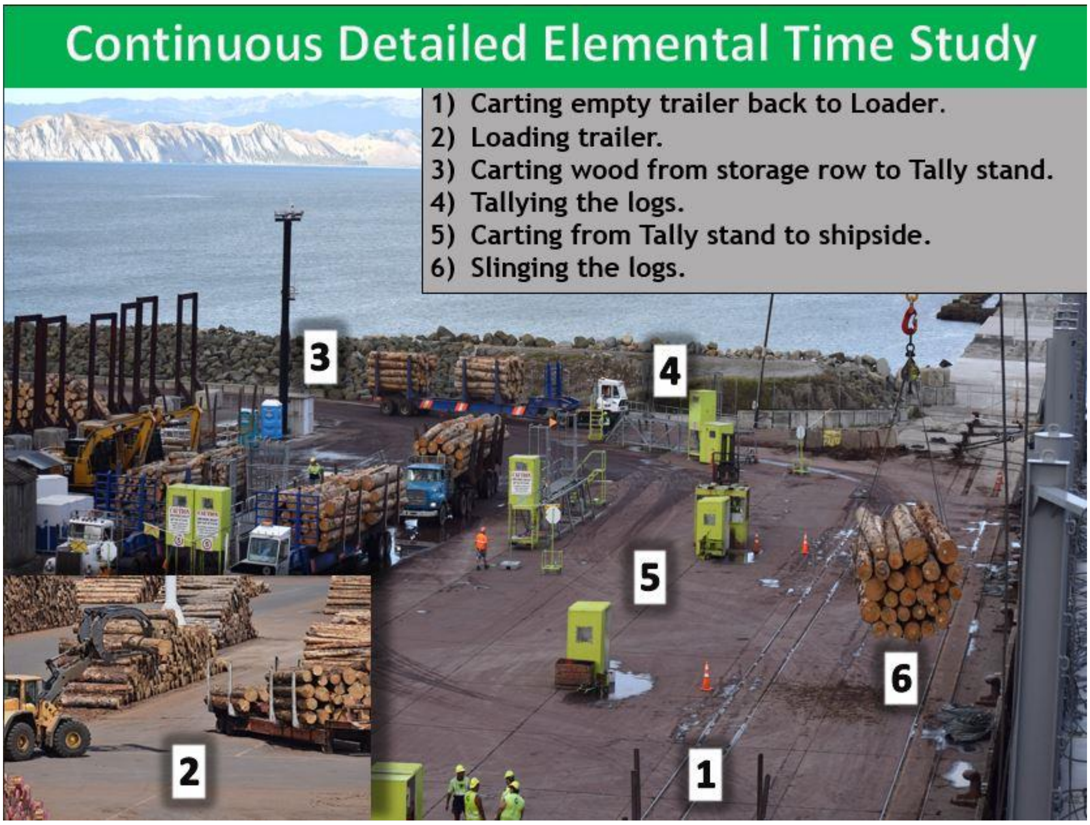


Figure 1: Vessel loading cycle elements as viewed from the bridge of the African Goshawk vessel on the 18th February 2016 at Eastland Port in Gisborne.

4.1.1. Tauranga, Marsden Point, and Gisborne

The cycle is divided into six elements; three of which are the ‘action elements’ (Loading, Tallying, and Slinging), and three are the ‘carting elements’ comprised of transport between the ‘action elements’ (Figure 1).

1) Carting empty trailer from shipside to loader.

- Starts when the second heave of the trailer is “over the rail” (in line with the side of the vessel indicating that the trailer can be moved safely) and empty trailer is ready to be taken to the loader location.
- Finishes when the empty trailer is deposited at the loader for re-filling (exact moment of disconnection of the truck and trailer). For Gisborne the moment the truck stops at the loading location signals the end.

2) Loading the trailer.

- Starts when the empty trailer is deposited at the loader for re-filling.
- Finishes once the trailer is fully loaded and straightened (the loader driver is responsible for presenting the logs in a tidy state so that when they are heaved onto the ship there is minimal risk of logs slipping).

3) Carting full trailer from storage row to shipside.

- Starts when the trailer is fully loaded and straightened.
- Finishes when the full trailer is deposited at Tally station (exact moment of disconnection of the truck and trailer). For Gisborne the moment the truck stops at the Tally station signals the end.

4) Tallying the logs.

- Starts when the full trailer is deposited at Tally station.
- Finishes when the tally cone or flag is removed from the front of the trailer (this signals the end of tallying so that the trailer may be moved safely).

5) Carting full trailer from tally to shipside.

- Starts when the tally cone or flag is removed from front of trailer.
- Finishes when the trailer is deposited directly under the crane wire ropes for slinging (exact moment of disconnection of the truck and trailer). For Gisborne the moment the truck stops at shipside and the driver exits the vehicle signals the end.

6) Slinging the logs.

- Starts when the trailer is deposited directly under the crane wire ropes for slinging.
- Finishes when the second heave of the trailer is “over the rail” (in line with the side of the vessel which indicates that the trailer can be moved safely) and empty trailer is ready to be picked up and taken to the loader location.

4.1.2 Port Chalmers

Due to differences between Port Chalmers and the other three ports, the vessel loading cycle was defined separately. Even though two of the elements defined below are given the same title they cannot be compared (tallying and slinging). Each element below concerns one ‘heave’ onto the vessel, compared to the previous three ports using trailers which contain two heaves (Table 1). With Port Chalmers, the small log storage area does not justify using log trailers for carting so they use front-end loaders instead (Volvo 220, or Wagner machines) to cart logs. Butting machines are also used to square the log ends, ensuring the heave is safe for lifting onto the ship. For the purposes of this study and subsequent analysis, Port Chalmers study data has to be kept separate.

1) Carting loader from shipside (bunk) to log stack and back to shipside (bunk).

- Starts when loader has deposited previous grab of logs in the bunk and the bunk is full.
- Finishes when loader has deposited the next load of logs in the bunk and the bunk is full.

2) Butting.

- Starts when the loader has deposited the logs in the bunk and the bunk is full.
- Finishes when the butting machines toot their horns to indicate butting has finished (indicates that it is safe for the next element).

3) Tallying the logs.

- Starts when butting machines toot their horns to indicate it is safe to start tallying.
- Finishes when it is clear that all logs have had their barcodes scanned (tallied).

4) Slinging the logs.

- Starts when the log packet in the bunk has been tallied (i.e. when tallying has finished).
- Finishes when the logs are “over the rail” (in line with the side of the vessel).

4.2 Data

4.2.1 Vessel Loading Time Study

All elements were timed to the nearest second using a pair of stopwatches. Two stopwatches facilitates accurate recording of simultaneous elements far better than one (one can be stopped whilst the other is started simultaneously).

Three of the four port operations used truck and trailers for on-port cartage. The trailers consist of two sets of bunks housing two loads per trailer. At the time the study was conducted, Gisborne did not use detachable truck and trailer units (Tauranga and Marsden Point did). Instead of 5 truck units with 5 associated drivers managing 15 log trailers, there were 15 truck and trailer units with an associated 15 drivers in Gisborne.

The fourth port (Port Chalmers) is completely different in its operations due to the restricted storage space available (Table 1). This cuts out carting and loading steps and is why the Port Chalmers loading cycle has been defined and analysed separately.

Detailed documentation of port specific variables were noted down, these included:

- Log grade and length
- Stage of vessel loading
- Distance to log stack
- Distance from log stack
- Methods of loading
- Road conditions/restrictions
- Weather conditions
- Operator skill
- Time of day
- Any operation constraints, abnormalities, or extra variables that may influence the operation (port congestion, other ships loading etc…)
- Machinery used
- Size of storage on port
- Port layout

These variables are correlated to each port and the port indicator variable therefore is included to show their effect in aggregate.

For each vessel loading operation there were two important foremen positions, one for Stevedoring and one for Marshalling. Communication with them was pivotal in finding out whether there were any trainee digger, crane, loader, or driving operators.

Measurements were taken from the bridge of the ship being loaded. This was the best vantage point for observing the entire operation especially locating the position of the log stacks which were being loaded.

A sample size of 30+ was targeted for each port in order to reduce error rates and facilitate the generation of valid models, G. Murphy (personal communication, February 2nd, 2016). Due to time and loading constraints this was not possible at Marsden Point because of the low volume loaded, and that only two, of the vessel's four, cranes were able to be sampled (Table 2).

4.2.2 Port Differences

Port Specific Conditions:

Table 1: Port specific characteristics between Tauranga, Marsden Point, Gisborne, and Port Chalmers (Dunedin).

	Tauranga	Marsden Point	Gisborne	Dunedin
Log Storage Area (ha)	31.9	21.3	10.9	3.8
Loading Machinery	Sennebogen 840	Volvo 340, 360	Volvo 340, 360	Volvo 220, 360, and Wagner
Vessel Loading Method	Trailers with 2 heaves/trailer	Trailers with 2 heaves/trailer	Trailers with 2 heaves/trailer	Bunks w one heave/bunk
Carting Machinery	Maffi Trucks w detachable trailers	Maffi Trucks w detachable trailers	Non-detachable (slightly smaller) truck and trailer units	Volvo 220, 360, and Wagner
Speed Limit	20km/hr	20km/hr	20km/hr??	20km/hr??
Road System	Wide 2-way road system	Wide 2-way road system	One-way road network	
Fumigation Capability	Yes	Yes	No	No
De-barking Capability	Yes	No	Yes	No

Additional to the port-specific information collected on the four ports (Table 1), other variables were also noted. From observation, the interaction between incoming log trucks and loading the trailers appeared to increase element times. Similarly, the interaction between the vessel being observed (measured) and other vessels being loaded appeared to also increase cycle times. These two variables appeared to cause the largest delays in both Tauranga and Marsden Point (which are not restricted by storage space).

In Gisborne, the major delays were due to congestion of the one-way road system. There was a definite bottleneck between the 'Main Log Yard', 'Level 1', and the 'Upper Log Yard' (Appendix 9.3.3). A sample delay was measured at ~15 minutes from the trailer becoming empty, and then finally being carted to the loader. There was also a distinct lack of lighting at night in the 'Main Log Yard' in Gisborne which may have influenced night-time measurements.

Study Specific Conditions:

Table 2: Environmental characteristics and vessel loading processes specific to the measurements taken on the vessels studied in Tauranga, Marsden Point, Gisborne, and Port Chalmers (Dunedin).

	Tauranga	Marsden Point	Gisborne	Dunedin
Date Measured	15/02/2016 and 16/02/2016	11/02/2016 and 12/02/2016	17/02/2016 and 18/02/2016	31/08/2016
Weather	Sporadic showers on 15th Sunshine on 16th	Sunny Sunny	Sporadic rain on 17th Sunshine on 18th	Sunny
Volume Loaded (JAS)	20200	10100	37500	22000
Slinging Operation	4 Cranes slinging logs from trailers	2 cranes w trailers, 2 cranes w bunks (bunks not timed)	4 Cranes slinging logs from trailers	4 Cranes using bunks
How many load ports?	2 (second load port)	2 (second load port)	1 (full port load)	2 (1st load port)
Loading Below Deck?	Yes (15/02/2016)	Yes (11/02/2016)	Yes	Yes
Loading Above Deck?	Yes (16/02/2016)	Yes (12/02/2016)	No	No
Marshalling and Stevedoring same company?	Yes	No	Yes	Yes
Other Vessels Loading?	Yes	Yes	No	No

Aside from vessel and environmental conditions measured (Table 2), there were additional conditions that were noted. A reduction in trailer availability in Tauranga was noted during the loading of 7.7m log lengths on the 16/02/2016. The longer lengths take up both bunks of the trailer (for just one heave) and therefore use twice as many trailers (for the same number of heaves). This reduced the number of trailers available for the 3.8m and 5.8m log lengths being measured for this study.

For Gisborne, the truck drivers have to exit the vehicle before slinging can commence. This is different to both Tauranga and Marsden Point where the trailers can be detached from the trucks. It is also important to mention that the vessel studied in Gisborne was brand new and therefore less likely to suffer any vessel associated breakdowns/delays.

4.2.3 Historic Data

PFP data from 1st January 2015 to 31st December 2015 for all vessels loaded at each of the four ports was collected. Gross load rates (Total Volume/Total Time) and other necessary data was collaborated to provide background information on port differences and aid in explaining these differences.

Average daily shipping rate data in $US from mid-2006 to mid-2016 was collected. Time study information and 2015 gross load rate data was used in conjunction with historic shipping rates to assess the financial impact of changing loading efficiency. This will help to determine the influence of increasing efficiency at different historic shipping rates.

4.3 Analysis

For detailed continuous elemental time study data, regression analysis was performed to generate models for the cycle elements. This will provide information on productive timing differences and how port and environmental conditions influence the elemental times.

Time study data was also used in conjunction with historic data for 2015 to give insight into factors (outside of the focus of the time study) that influence gross load rates.

Finally, the influence of changing vessel loading efficiency was assessed against historic shipping rates. This will show the impacts of shipping cost at different shipping rates for a typical 33,000 JAS m^3 single port load, loading 10,000 JAS m^3/day.

5. Results

5.1 Historic Information

Table 3: Weighted productivity characteristics of all vessels managed by PFP Ltd. in 2015 for Tauranga, Marsden Point, Gisborne, and Port Chalmers.

2015 Calendar Year Averages				
	Tauranga	**Gisborne**	**Marsden**	**Port Chalmers**
Length (m)	5.18	4.90	4.49	4.13
Piece Size (JAS/Piece)	0.47	0.54	0.39	0.34
Lift Size (JAS/Lift)	21.80	19.75	21.46	16.66
Lifts/Hour	7.44	7.94	6.39	7.46
Gross Load Rate (JAS/Hour)	161.56	156.51	132.50	122.18

Gross load rate is displayed on a per crane basis. On a vessel there are four cranes which operate. In order to gauge total vessel load rate, gross load rate represented in Table 3 would be multiplied by four. Gross load rate includes all delays from the start of loading (when the vessel arrives in port), to when it finishes loading.

Five average vessel loading characteristics are displayed per port in Table 3. Noticeably, Tauranga has longer length logs, larger lift size, and, most importantly, the fastest load rate (on average) out of the four ports. Interestingly, Gisborne has the largest piece size and the most lifts per hour yet only the second quickest load rate. Marsden Point is the most similar operationally to Tauranga, with a large port storage area and the same carting to and from shipside methods (Table 1), yet has a significantly lower load rate than both Tauranga and Gisborne. Marsden Point also has a larger lift size than Gisborne but fewer lifts per hour which generates the slower load rate. Lastly, Port Chalmers showed to have the slowest load rate for 2015 which appears to be because of the smaller lift size, piece size, and length characteristics compared to the other three ports.

5.2 Exploratory Data Analysis

Initial data analysis involved plotting element times per port in box and whisker graphs. This allowed visual interpretation of data spread and insight into which elements were most influential in the total cycle time within and between the four ports.

Interestingly, for Tauranga (Figure 3) and Gisborne (Figure 5), loading (Element 2) is both the most variable (largest spread) and most important (highest mean value). This has operational implications as it indicates that improvements in the loading process could lead to reductions in overall cycle time.

As for Marsden Point (Figure 4) the most important (highest mean value) is slinging (Element 6) but is relatively less variable than both loading (Element 2) and carting to shipside (Element 5). This indicates that improvements in loading and carting to shipside may have more impact than improvements in slinging times.

As described previously (section 4.1.2), Port Chalmers consists of just four elements (Figure 6). Tallying and slinging are the same process as measured in previous ports but cannot be compared as the way they are performed is too different. Moving from bunk to log stack and back to bunk (with a full load) was the most important element (Element 1). It was also relatively variable but not as variable as slinging which was 2nd most in importance. This suggests that there is potential for reducing variability in slinging time to decrease loading time in Port Chalmers.

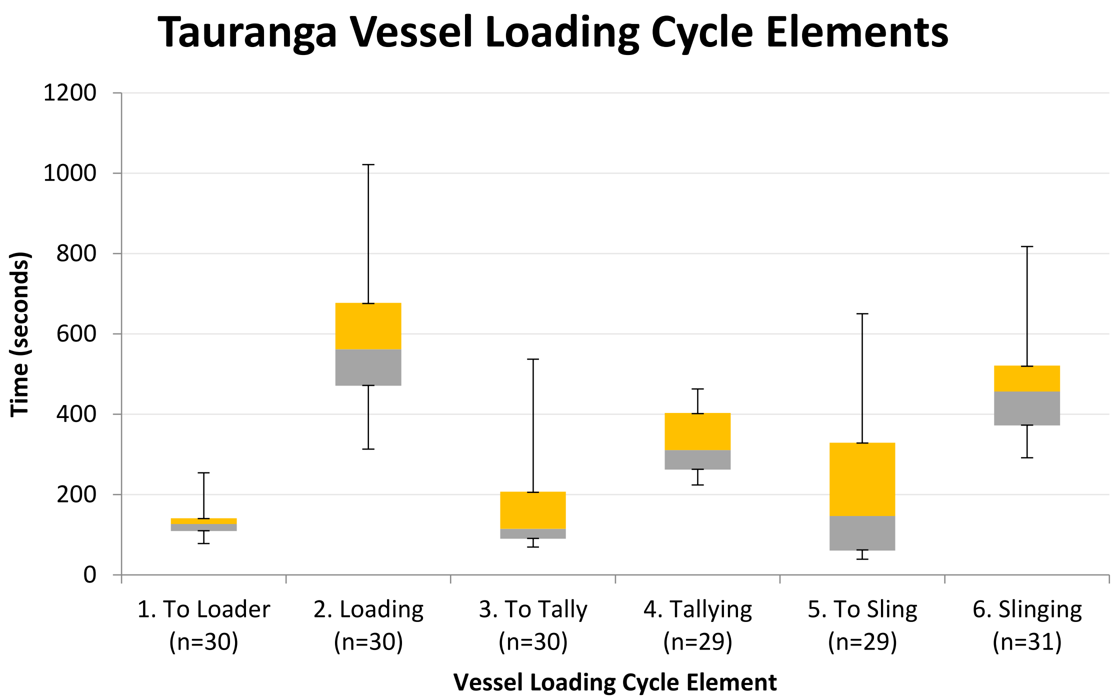


Figure 3: Exploratory data analysis of the six vessel loading cycle elements from time study data collected at Port of Tauranga on 15th and 16th February 2016.

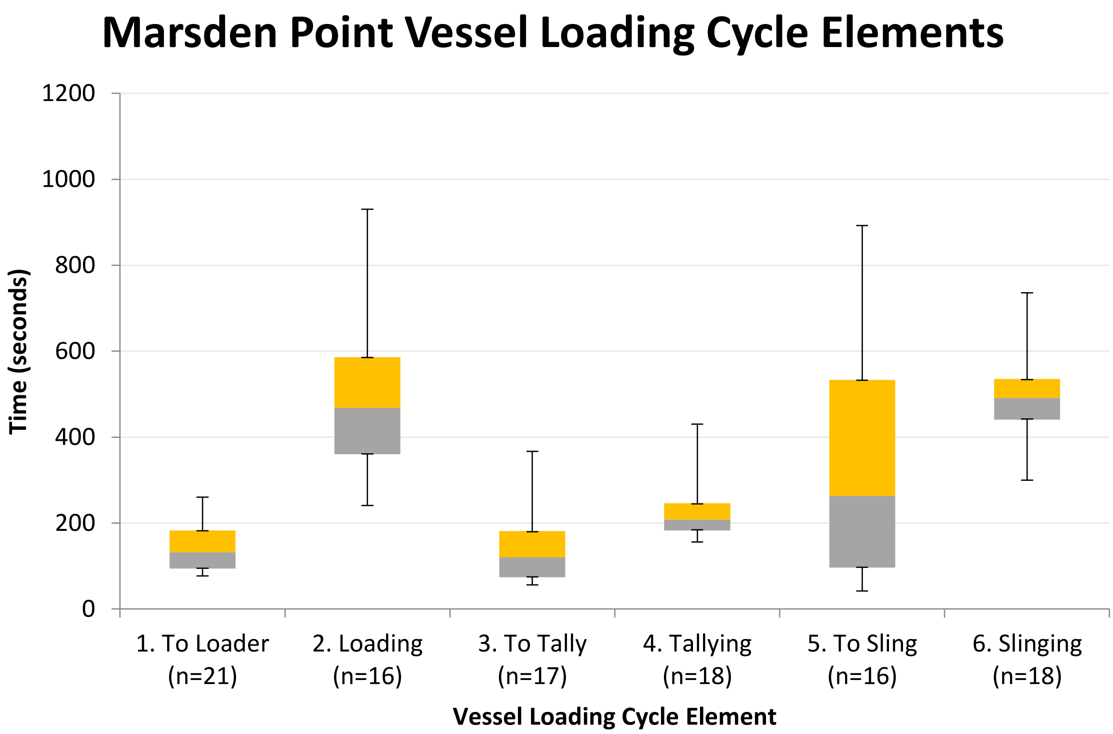


Figure 4: Exploratory data analysis of the six vessel loading cycle elements from the time study data collected at Northport (Marsden point) on 11th and 12th February 2016.

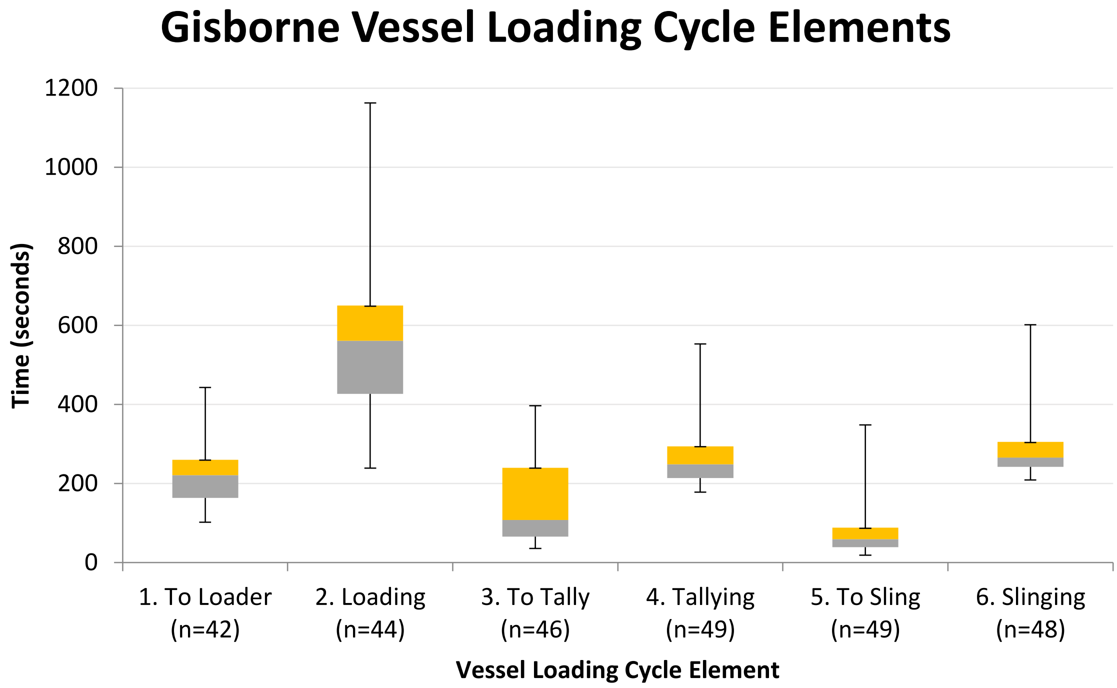


Figure 5: Exploratory data analysis of the six vessel loading cycle elements from the time study data collected at Eastland Port (Gisborne) on 17th and 18th February 2016.

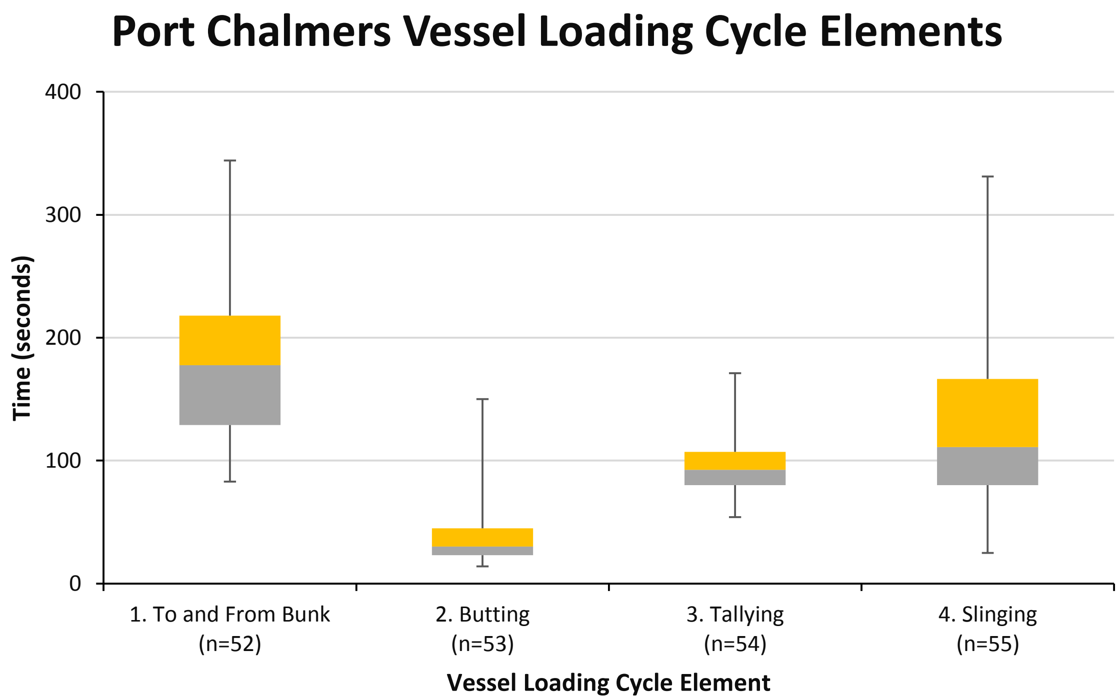


Figure 6: Exploratory data analysis of the four vessel loading cycle elements from the time study data collected at Port Chalmers (Port Otago) on the 31st August 2016.

5.3 Tauranga, Gisborne, and Marsden Point

Table 4: Average element times (in seconds) and sample sizes for each element of the vessel loading cycle for Tauranga, Gisborne, and Marsden Point.

Average Element Times (seconds)	Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	
	Carting to Loader	***Loading***	*Carting to Tally*	***Tallying***	*Carting to Shipside*	***Slinging***	**TOTAL**
Tauranga	**135**	**571**	**152**	**331**	**183**	**462**	**1834**
Sample Size	*n=30*	*n=30*	*n=30*	*n=29*	*n=29*	*n=31*	
Gisborne	**206**	**553**	**150**	**256**	**82**	**294**	**1541**
Sample Size	*n=42*	*n=44*	*n=46*	*n=49*	*n=49*	*n=48*	
Marsden Point	**142**	**493**	**144**	**233**	**199**	**505**	**1716**
Sample Size	*n=21*	*n=16*	*n=17*	*n=18*	*n=16*	*n=18*	

Observation of the average element times suggests that Gisborne is the fastest followed by Marsden Point, then finally Tauranga. This goes against what was expected as Tauranga had the fastest gross load rate (Table 3). Most notable is the average times for Tauranga are lowest of the three ports for elements 2, 3, and 4. Elements 5 and 6 were second slowest overall for Tauranga as well. Two hypotheses may account for this observed difference between productive time and gross load rate: 1) the vessels measured where not representative of the 2015 vessel loading data, or 2) other factors which influence gross load rate (delays and volume) play an important role in determining the speed of vessel loading (as well as productive cycle time).

5.4 Regression Equations

All data was collated into a matrix in Microsoft Excel (2013) spreadsheet for data analysis. There were three quantitative variables: the independent variable (element times), distance to log stack (metres), and distance from log stack (metres). All other variables were binary, and assigned a value of either ‘0’ or ‘1’. A large number of variables including: weather, log grade, log length, time of day, operator skill (crane, digger, and loader), bark status, and loading location (listed in section 4.2.1) were represented as binary.

Table 5: Vessel loading characteristics of the vessels that were timed for each of the four ports.

Vessels Studied	Tauranga	Gisborne	Marsden Point	Port Chalmers
Length (m)	4.61	4.61		4.20
Piece Size (JAS/Piece)	0.44	0.59		0.33
Lift Size (JAS/Lift)	20.58	20.49		18.27
Lifts/Hour	8.27	8.80		6.56
Load Rate (JAS/Hour)	170.2	180.4	105.7	119.9

It is important to understand the representativeness of the vessels measured for each of the four ports. Most notable in Table 5 is that Gisborne has the fastest gross load rate of 180JAS/hour, and Marsden Point the slowest. This indicates that Gisborne may be fastest in productive time even though it does not have the fastest gross load rate for 2015. It may indicate that gross load rate is influenced by other (delay and volume) characteristics as well as productive cycle time.

Table 6: Indicator variables and their associated values under 'On' (1) or 'Off' (0) conditions in the regression analysis performed.

Binary Variable Definitions								
Value	**Log Grade**	**Log Length**	**Loading Location**	**Crane Skill**	**Digger Skill**	**Loader Skill**	**Weather**	**Daytime**
1 (On)	A Grade	3.8m	Below Deck Stowing	Good	Good	Good	Good	Daytime
0 (Off)	K Grade	5.8m	Above Deck Stowing	Training	Training	Training	Raining	Night Time

Variables listed in Table 6 varied during the study. Those which didn't vary were not able to be assessed (bark status and truck driving skill). Three port binary variables allowed times to be separated by port. Changes between ports, such as size of on-port storage and machinery used, are contained within the port variable and hence not included separately.

Two distance measurements, distance to and distance from log stack, were calculated using a distance measurement tool on GIS (Geographic Information System) software using aerial imagery of the four ports. The same imagery was also used to estimate gross log storage area (Land Information New Zealand [LINZ], 2016a, 2016b, 2016c, & 2016d).

Variables which didn't change at Port Chalmers include: loading location, loader skill, weather, and time of day. As they didn't change they could not be included in the regression analysis.

Table 7: Statistical significance boundaries and their associated symbol for different levels of significance.

Statistical Significance Boundaries			
90%	**95%**	**99%**	**99.9%**
-	*	**	***

For the following regression equations the significance of predictor variables are put into five categories. Those that are less than 90% significant are deemed to not influence the model. For the ones which are >90% significant they are symbolised to aid quick interpretation of how significant some of the results are. This is expressed in Table 7.

5.4.1 Carting to Loader

Table 8: Regression results for Element 1 (Carting to Loader) time study data for Tauranga, Marsden Point, and Gisborne ports.

	Coefficients	***P-value***	
Intercept (seconds)	31.80	0.33085	
Marsden Point	55.83	0.00255	**
Gisborne	79.27	1.05E-06	***
Distance To Log Stack (m)	0.216	8.20E-05	***
Weather (1 = good)	-12.76	0.44617	
Time of Day (1 = daytime)	-2.19	0.87041	
	F	***Significance F***	
	13.41	1.30E-09	***
	Adjusted R Square	0.41	
	Standard Error	47.05	
	Observations	90	

Table 8 displays that carting to loader element time is significantly influenced by port and the distance from shipside to the log stack. For Tauranga it can be seen that the time it takes to complete the element is solely based on the distance measurement as the intercept of the regression is insignificant (the intercept represents the vessel being loaded at the Port of Tauranga). The other two ports had significantly longer element times with Gisborne being slowest and Marsden Point in between Tauranga and Gisborne.

Weather or time of day did not significantly influence the element times. The resultant regression equation from re-running the significant variables was:

Carting to Loader Time (seconds) =

MarsdenPoint(55) + Gisborne(86) + DisancetoLogStack(0.213)

As would be predicted, the further the distance, the longer the time to get to the loader. Here, it is estimated to take 0.213 seconds per meter of distance to the log stack which translates to 16.9km/hr average speed. This speed includes attaching and detaching time for the trailers as well as acceleration and deceleration.

5.4.2 Loading

Table 9: Regression results for Element 2 (Loading) time study data for Tauranga, Marsden Point, and Gisborne ports.

	Coefficients	*P-value*	
Intercept (seconds)	826.93	3.34E-20	***
Marsden point	-18.41	0.70022	
Gisborne	-64.60	0.17571	
Log Grade (1 = A-grade)	-107.38	0.07573	-
Log Length (1 = 3.8m)	-76.99	0.06738	-
Loading Skill (1 = good)	-172.35	0.06443	-
Weather (1 = good)	-131.87	0.13865	
Time of Day (1 = daytime)	163.39	0.00226	**
	F	***Significance F***	
	5.09	0.00008	***
	Adjusted R Square	0.25	
	Standard Error	142.16	
	Observations	88	

Table 9 regression results indicate that loading times are uninfluenced by port. Gisborne may become significantly different with an increase in the amount of data collected, however, this cannot be shown here. The most notable influential variable is the time of day, with daytime loading estimated significantly longer than night time loading.

Log grade, log length, and loading skill are all >90% significant. This shows that they are likely to play an important role in determining loading time. All three of these variables impact the ease of which a trailer can be loaded and therefore would be expected to influence loading time.

Loading A-grade logs (compared to K-grade logs) appears to reduce the loading time. A-grade logs have a larger minimum Small End Diameter (SED) of 30cm compared to 20cm of their K-grade counterparts. A-grade logs are larger and therefore easier to handle as this translates to fewer pieces to lift and straighten on the trailer.

Similar to the impact of log grade, shorter log lengths (3.8m) take less time to load than their longer counterparts (5.8m). Longer logs reduce the space between the two heaves on the trailer and increase the difficulty of making each heave flush. Logs must be presented flush because an uneven load is more difficult to Tally and Sling, and a potential safety hazard (an uneven log load may shift whilst being manoeuvred around the port).

From this the resultant regression equation from re-running the significant variables was:

Loading Time (seconds) =
788 - LogGrade(113) - LogLength(73) - LoadingSkill(254) + TimeOfDay(127)

During the daytime it takes significantly longer to load than at night (>99% significance). This goes against expectation, surely daylight would make it easier to navigate the log stack and load the trailer. However, the simultaneous management of all other port operations is likely the cause of this difference. During normal port working hours (which tend to follow daylight hours +/- 2-3hours) all other port operations are undertaken in conjunction with vessel loading. These operations include: incoming log trucks and trains, log marshalling operations, debarking operations, and other day-to-day port activities. It was observed that incoming log trucks may have been largely responsible for increased times during the day.

5.4.3 Carting to Tally

Table 10: Regression results for Element 3 (Carting to Tally) time study data for Tauranga, Marsden Point, and Gisborne ports.

	Coefficients	*P-value*	
Intercept (seconds)	54.09	0.11221	
Marsden Point	4.67	0.84601	
Gisborne	-27.19	0.25734	
Log Grade (1 = A-grade)	48.94	0.11018	
Log Length (1 = 3.8m)	-35.86	0.12601	
Distance From Log Stack (m)	0.223	0.00002	***
Weather (1 = good)	24.46	0.36858	
Time of Day (1 = daytime)	-40.83	0.09379	-
	F	***Significance F***	
	10.18	3.66E-09	***
	Adjusted R Square	0.41	
	Standard Error	72.45	
	Observations	92	

Table 10 displays a distinct lack of significance for any difference in the Carting to Tally element times between the three ports (unlike Element 1). However, the distance from log stack is >99.9% significant and the time of day is >90% significant. It can therefore be predicted from this analysis that Carting to Tally time is a function of the distance from the log stack and the time of day regardless of port location.

The resultant regression equation from re-running the significant variables displayed that only distance remained significant:

Carting to Tally Time (seconds) = DistanceFromLogStack(0.274)

The distance from the log stack to the Tally stand, as expected, significantly influences the element time. It is predicted that for every metre of distance the time is increased by 0.274 seconds. Notice how this is 0.06 seconds/m slower than element 1 and translates to an average speed of 13.1km/hr (3.8km/hr slower than element 1). This could be due to the weight differential between the unloaded (element 1) and loaded (element 3) trailer, with a loaded trailer travelling slower due to the additional weight.

Daytime appears to make the carting to tally time faster. This indicates that reduced visibility at night may result in drivers being more cautious compared to during the day, or that increased daytime visibility makes carting more efficient.

5.4.4 Tallying

Table 11: Regression results for Element 4 (Tallying) time study data for Tauranga, Marsden Point, and Gisborne ports.

	Coefficients	*P-value*	
Intercept (seconds)	346.99	1.09E-26	***
Marsden Point	-107.14	1.17E-07	***
Gisborne	-63.40	0.00083	***
Log Grade (1 = A-grade)	12.84	0.55592	
Log Length (1 = 3.8m)	17.17	0.23122	
Weather (1 = good)	43.02	0.03398	*
Time of Day (1 = daytime)	-93.11	2.45E-06	***
	F	***Significance F***	
	12.24	6.17E-10	***
	Adjusted R Square	0.42	
	Standard Error	56.82	
	Observations	94	

All three ports are >99.9% significant which means they have significantly different tallying times. Noticeably, Tauranga (the intercept) is the slowest as both Gisborne and Marsden Point have negative coefficients. Gisborne is the second fastest, and Marsden Point the fastest from these results.

Daytime tally times were estimated to be significantly faster than at night. The process of finding and scanning log barcodes is assumed easier during the day than at night under lights.

Good weather appears to increase tallying time. The good weather variable was defined as the absence of rain. This significance may be due to the fact that in bad weather the workers tally faster so they can shelter from the rain in the tally hut.

It can be interpolated that Tallying time is a function of port, weather conditions, and time of day. The equation from re-running the significant variables was:

Tallying Time (seconds) = 384 - MarsdenPoint(97) - Gisborne(73) + Weather(70)

In Tauranga, and in Marsden Point to a lesser extent, fully loaded trailers would queue up at the tally stand with other tallied trailers blocking their progression forward (a potential bottleneck). Although delays over a minute forced timing to stop, there were times when timing would continue through at least part of the delay process and may have increased associated tally times.

5.4.5 Carting to Shipside

Table 12: Regression results for Element 5 (Carting to Shipside) time study data for Tauranga, Marsden Point, and Gisborne ports.

	Coefficients	*P-value*	
Intercept (seconds)	133.94	0.00209	**
Marsden Point	3.76	0.92323	
Gisborne	-89.22	0.00978	**
Log Grade (1 = A-grade)	35.99	0.37842	
Log Length (1 = 3.8m)	3.74	0.88504	
Weather (1 = good)	70.50	0.05378	-
Time of Day (1 = daytime)	-50.20	0.14971	
	F	***Significance F***	
	4.68	0.00040	***
Adjusted R Square		0.20	
Standard Error		102.34	
Observations		87	

Gisborne is significantly quicker carting to shipside than Tauranga or Marsden Point. Gisborne has drivers with every trailer translating to minimal waiting time between the trailer being tallied and being carted to shipside. This makes sense as Tauranga and Marsden Point use the same carting methods (detachable cargo trailers) unlike Gisborne which uses non-detachable trailers.

Tauranga and Marsden Point had a lot of noticeable bottle-necks with full trailers tallied waiting for the trailer at shipside to be stowed. There were also times when trailers were ready but had to wait for the empty trailer at shipside to be shifted due to the imbalance between trucks and trailers (~5 drivers/trucks for 15 trailers). Therefore, there is additional time involved with moving the empty trailer before the next full one can go into place for both Tauranga and Marsden Point.

Table 12 also shows that Weather is >90% significant. It appears as if good weather makes the carting to shipside time longer than in rainy conditions. There is no obvious justification for this significant result apart from the weather variable potentially mimicking another, more influential, variable. When the regression was re-run, weather became insignificant and therefore should not be used in any form of prediction.

From the regression results it can be assumed that carting to shipside time is influenced by whether the operation is at Gisborne, and a potential influence of the weather. The resultant regression equation from re-running the significant variables was:

Carting to Shipside Time (seconds) = 188 - Gisborne(107)

5.4.6 Slinging

Table 13: Regression results for Element 6 (Slinging) time study data for Tauranga, Marsden Point, and Gisborne ports.

	Coefficients	*P-value*	
Intercept (seconds)	641.65	7.37E-11	***
Marsden Point	-37.16	0.43119	
Gisborne	-106.17	0.02037	*
Log Grade (1 = A-grade)	18.50	0.70720	
Log Length (1 = 3.8m)	-9.56	0.70494	
Loading Location (1 = below-deck)	-121.22	0.01827	*
Crane Skill (1 = good)	-43.33	0.45377	
Digger Skill (1 = good)	-36.10	0.44083	
Weather (1 = good)	32.92	0.37129	
Time of Day (1 = daytime)	-92.36	0.02089	*
	F	***Significance F***	
	12.17	3.09E-12	***
	Adjusted R Square	0.51	
	Standard Error	97.34	
	Observations	97	

Slinging is either the first or second most important element (in terms of total time shown by Figures 3, 4, 5, and 6). Table 13 shows a difference between the slinging times of Gisborne and the other two ports, with Gisborne being significantly faster.

The model shows that slinging times for loading below-deck log cargo are faster than above-deck times. A likely cause for this could be explained by the 10-11 metres extra height created when loading above-deck as the logs have to be lifted above the stanchions (a vessels stanchions are raised when loading commences above-deck and are typically 10-11m high).

Slinging is significantly faster during the day compared to night-time. This may be due to increased visibility during the day for the slinger, crane, and digger operators and therefore they can perform their operations more efficiently (than at night).

Slinging time is estimated from an interaction with port, loading location, and time of day variables. The resultant regression equation from re-running the significant variables was:

Slinging Time (seconds) =

593 - Gisborne(126) - LoadingLocation(102) - TimeOfDay(90)

5.5 Port Otago (Port Chalmers) Regression

5.5.1. Carting to and from Bunk

Table 14: Regression results for Element 1 (Carting to and from Bunk) time study data from Port Chalmers.

	Coefficients	*P-value*	
Intercept (seconds)	89.77	8.68E-04	***
Log Length (1 = 3.8m)	28.41	0.15652	
Distance To or from Log Stack (m)	0.485	1.59E-06	***
	F	***Significance F***	
	22.48	1.19E-07	***
	Adjusted R Square	0.46	
	Standard Error	44.76	
	Observations	52	

The time to get from the bunk to the log stack, and back to the bunk with a full load of logs is determined by a constant plus the distance to log stack. The subsequent equation from re-running significant variables was:

Carting to and From Log Stack Time (seconds) =

123 + DistanceToLogStack(0.390)

Length here does not appear to significantly influence element time. To and from log stack distances for Port Chalmers are the same measurement and therefore can be included as a single variable. The impact of distance is 0.390 seconds per meter which translates to 9.2km/hr. This is much slower than the 16.9km/hr and 13.1km/hr average speeds obtained for carting elements 1 and 3 from the three port regressions in section 5.2.1 and 5.2.3. This element incorporates time to and from the log stack (from the bunk) without delineation of the two stages. Therefore it also incorporates the act of grabbing the logs with the loader which results in a slower speed compared to the three previous ports.

Table 15: The average distance to (or from) log stack from the bunk at shipside showing the longer distances from A-grade logs sampled at Port Chalmers.

	Average Distance (m)
K-grade	101
A-grade	247

The effect of log grade was taken out of this regression because of interaction. All A-grade logs came from locations further away than where K-grade logs were stored (much closer to the berth). The difference between log grades is merely a difference in distance due to the location of A-grade logs compared to K-grade logs shown by Table 15 and therefore had to be removed.

5.5.2. Butting

Table 16: Regression results for Element 2 (Butting) time study data from Port Chalmers.

	Coefficients	***P-value***	
Intercept (seconds)	35.11	5.85E-06	***
Log Grade (1 = A-grade)	27.66	0.00060	***
Log Length (1 = 3.8m)	-6.52	0.38467	
	F	***Significance F***	
	8.65	0.00060	***
Adjusted R Square		0.23	
Standard Error		24.65	
Observations		53	

The Butting process takes significantly less time to complete for K-grade than A-grade logs. Log grade and log length were the only two variables assessed and therefore the regression is rather limited. Log length does not appear to influence the time it takes to butt the logs in the bunk, however only two different log lengths were measured. The inclusion of greater log lengths may show that log length has more of an impact on butting element times but this cannot be shown here. The regression equation from re-running the significant variables can be viewed as:

Butting Time (seconds) = 30 + LogGrade(29)

5.5.3. Tallying

Table 17: Regression results for Element 3 (Tallying) time study data from Port Chalmers.

	Coefficients	***P-value***	
Intercept (seconds)	112.95	9.43E-29	***
Log Grade (1 = A-grade)	-25.46	1.39E-05	***
Log Length (1 = 3.8m)	-14.54	0.00745	**
	F	***Significance F***	
	12.67	3.42E-05	***
Adjusted R Square		0.31	
Standard Error		17.34	
Observations		54	

Tallying time consists of a constant time significantly influenced by both log grade and log length. Tallying of A-grade logs is predicted to be faster than the K-grade logs. This is likely because A-grade logs are larger, meaning less logs in a 'heave', which translates to fewer barcodes to scan and therefore less time to tally (than smaller SED K-grade logs).

It is also shown by the regression that the shorter of the two log lengths studied (3.8m) significantly reduces tallying time. This may be significant because of the shorter distance to walk around the logs in order to tally them. The resultant regression equation is:

Tallying Time (seconds) = 113 – LogGrade(25) – LogLength(15)

5.5.4. Slinging

Table 18: Regression results for Element 4 (Slinging) time study data from Port Chalmers.

	Coefficients	*P-value*	
Intercept	148.39	2.78E-13	***
Log Length (1 = 3.8m)	-65.51	0.00015	***
Hatch (1 = Hatch 1)	49.51	0.00321	**
	F	***Significance F***	
	20.68	2.47E-07	***
Adjusted R Square		0.42	
Standard Error		53.07	
Observations		55	

Slinging is estimated from a constant with the influence of log length and hatch location (specifically whether it is being loaded in Hatch 1, or not). The hatch variable has been included here as it was observed that there were often delays associated with loading logs in hatch 1. This is due to its difficult shape and the additional manoeuvring skill required to stow in hatch 1. The other four hatches (there are five hatches in total on a vessel) are all of similar size and layout and therefore can all be classed as one variable. The '0' value of this variable means that the logs were slinging into hatch 4 or 5 (the only other hatches measured during this vessel). Notably, slinging into hatch 1 takes significantly longer than loading in hatch 4 or 5.

There is a significant (>99.9%) reduction in slinging time associated with shorter lengths of logs, perhaps due to the reduced weight of shorter logs. The equation to estimate slinging time at Port Chalmers would be:

Slinging Time (seconds) = 148 – LogLength(66) + Hatch(50)

5.6 Total Cycle Time Regression

5.6.1 Total Cycle Time for Port Chalmers.

Total cycle time for Port Chalmers was able to be calculated as a single regression as there were few variables measured for that port. Distance is a significant factor which increases time by 39 seconds for every 100m distance between bunk and log stack. Log grade made minimal difference with A-grade taking 4 seconds longer than K-grade. Shorter logs (3.8m) took 80 seconds less cycle time compared to the longer log choice. Hatch 1 also took 50 seconds longer to load compared to loading at the other hatches.

Productive Cycle Time (seconds) =

> ***414.3 +DistanceToLogStack(0.39) + LogGrade(4) - LogLength(80.1) + Hatch1(49.5)***

5.6.2 Total Cycle Time for Tauranga, Marsden Point, and Gisborne

For total cycle time regression, the significant variables of each regression were re-regressed and the resultant 6 equations for Tauranga, Marsden Point, and Gisborne were amalgamated into one. The coefficients of similar variables were added to produce one equation which predicts total productive cycle time.

Productive Cycle Time (seconds) =

> ***1952.7 - GIS(219.9) - MAP(41.6) + DistanceToLogStack(0.21) + DistanceFromLogStack(0.27) - LogGrade(113.5) - LogLength(73.4) - LoadingSkill(254.3) - LoadingLocation(101.6) - TimeOfDay(32.5)***

Gisborne is estimated to be the fastest port by 220 seconds (3minutes 40seconds). Interestingly Marsden Point is second fastest by 42 seconds compared to Tauranga. What we would have expected is for Tauranga to be fastest because it has the quickest historic load rate. What this implies is that the load rate is not just defined by the speed in which the operation takes place, but port and log characteristics, and delay time also factor into this equation.

Loading and carting to tally (elements 2 and 3) showed no significant differences in times between the three ports. This indicates that these operations are not influenced by what can be described as port variables, for example: port space or machinery used.

Carting to loader, tallying, carting to shipside, and slinging were all influenced by ports (elements 1, 4, 5, and 6 respectively). Notably, Gisborne was significantly different for all four of these elements.

Marsden Point had the fastest times for tallying, followed by Gisborne, and lastly Tauranga. What is even more interesting is that Tauranga has the fastest load rate but the slowest time (fastest load rate shown by Table 3). If Tauranga was able to decrease productive time taken, then the load rate would (in theory) increase as well. However, the other factors that influence load rate, volume and delays, may play a larger role in explaining this difference.

5.7 2015 Export Data for the Four Ports

Table 19: Regression results for the 2015 Calendar year of all vessels managed by PFP Ltd. from Tauranga, Marsden Point, Gisborne, and Port Chalmers.

	Coefficients	*P-value*	
Intercept (JAS/Hour)	108.18	6.01E-39	***
Marsden Point	-17.92	6.21E-05	***
Gisborne	-9.32	0.00833	**
Dunedin	-25.00	3.96E-05	***
Volume (JAS)	0.0005	0.00646	**
Avg. Piece Size (JAS)	93.33	2.02E-21	***
	F	***Significance F***	
	44.33	9.70E-31	***
	Adjusted R Square	0.51	
	Standard Error	20.23	
	Observations	208	

The regression results above confirm what is displayed in Table 3. These results (Table 19) say that Tauranga is the fastest, followed by Gisborne (9.3JASm^3/hour slower), Marsden Point (17.9JASm^3/hour slower), and finally Port Chalmers (25.0JASm^3/hour slower). Average piece size is the most significant of the other two explanatory variables (>99.9% significant), with volume loaded also being 99% significant.

Table 19 shows that load rate is heavily influenced by port. Within ports, the volume loaded and the average piece size also influence vessel gross load rates.

This more volume loaded onto a vessel at once, the faster the gross load rate. This is due to the processes undertaken when a vessel arrives at port which occur regardless of how much volume is to be loaded. If the fixed delays can be spread across more volume then the gross load rate will increase. Gross load rate is estimated to increase by 0.5JASm^3/hour for every additional 1,000JAS m^3 loaded onto the ship. Therefore a 30,000JAS m^3 load is estimated to load 5JASm^3/hour faster than a 20,000JAS m^3 load.

An increase in piece size of 1JAS m^3 estimated to increase gross load rate by 93JASm^3/hour. Average piece sizes can often be under 1 JAS m^3. When scaled down by a factor of ten, means that an increase in average piece size of 0.1JAS m^3 is estimated to translate to an increase in gross load rate of 9.3JASm^3/hour.

The subsequent equation from this regression is:

Gross Load Rate (JAS/hour) =
108.2 – MarsdenPoint(17.9) – Gisborne(9.3) – PortChalmers(25.0) + Volume(0.0005) + AvgPieceSize(93.3)

5.8 Historic Shipping Rates

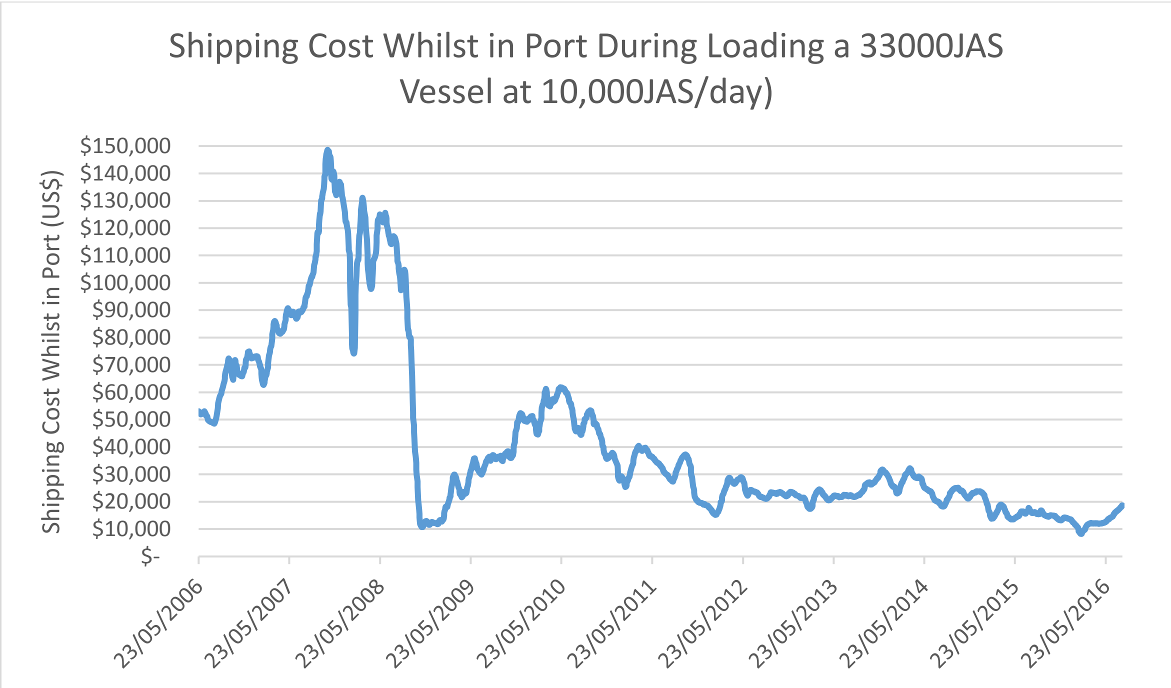


Figure 7: Shipping cost for loading in port taking 3.3 days. Cost based on average historic shipping rates in US$ for a typical 28,000DWT bulk carrier loading 33,000JAS at 10,000JAS/day in a single port load.

Shipping rates have varied considerably between 2006 and 2016. Mid to late October in 2007 saw the highest daily shipping rates of the time series, peaking at US$45,000/day. Since September 2008 these rates have been declining with February 2016 recording the lowest rate of US$2,500/day. The immense drop in the last quarter of 2008 is a direct result from the global financial crisis (GFC).

Table 20: Historic daily shipping rate minimum, average, and maximum values in US$ for the period between May 2006 and July 2016.

	Average daily rate for a 28,000 DWT bulk carrier From May 2006 to July 2016	
Minimum (Feb 2016)	**$**	**2,495**
Average	**$**	**12,771**
Maximum (Oct 2007)	**$**	**45,042**

Higher shipping rates increase the importance of port efficiency as penalties for loading slower than agreed (demurrage + extra charges) are greater than the reward for being faster. Demurrage is calculated by the amount of time the vessel is behind schedule, multiplied by the shipping rate. For despatch, which is the reward for loading faster, it is calculated by the amount of time the vessel is ahead of schedule, multiplied by half the shipping rate.

This difference is barely noticeable at low shipping rates with efficiency increases of 20% only saving the exporter US$2,500 at the historic minimum rate. However a saving of US$44,600 can be achieved at historic maximum rates. Loading 20% slower at minimum rates will cost an additional US$3,300 to the exporter, but US$59,500 at maximum rates.

Even with a small increase in efficiency of 5%, historic maximum shipping rates would translate to a saving to the exporter of US$11,100.

Table 21: Sensitivity analysis of efficiency changes for loading a 33,000JAS vessel at 10,000JAS/day using historic minimum, average, and maximum US$ daily shipping rates. Demurrage and despatch charges are included within the costings. All values are shown as differences to an expected 'normal' load (3.3days to load the vessel).

Actual Cost Saving (US$)									
	Faster Loading					**Slower Loading**			
Days to Load	**2.64**	**2.81**	**2.97**	**3.14**	**3.30**	**3.47**	**3.63**	**3.80**	**3.96**
Loading Speed	**120%**	**115%**	**110%**	**105%**	**100%**	**95%**	**90%**	**85%**	**80%**
Minimum	$ 2,470	$ 1,852	$ 1,235	$ 617	$ -	-$ 823	-$ 1,646	-$ 2,470	-$ 3,293
Average	$ 12,643	$ 9,483	$ 6,322	$ 3,161	$ -	-$ 4,214	-$ 8,429	-$ 12,643	-$ 16,859
Maximum	$ 44,591	$ 33,443	$ 22,296	$ 11,148	$ -	-$ 14,864	-$ 29,727	-$ 44,591	-$ 59,456
% Cost Saving	***30%***	***23%***	***15%***	***8%***	***0%***	***-10%***	***-20%***	***-30%***	***-40%***

6. Discussion

Ensuring efficient and effective port operations is vital for the continuing success of New Zealand log exports. If vessel loading becomes more efficient and load rates increase reliably, this may reduce costs for ship owners and increase returns to log exporters.

Of all productive cycle elements, loading takes the longest time. This research found that loading time did not vary significantly between ports but was influenced by loading skill, log grade and length, and the time of day. This is quite a surprising finding as loading methods differed between ports. Tauranga exclusively used high-stacking machines (Senebogen 840) to load logs on trailers where Gisborne and Marsden Point used front-end loaders (Volvo 340, 360) (Table 1). Loading skill, appeared to have a significant effect on loading times. If possible to train and keep well skilled staff then this is predicted to decrease loading times significantly (as would be expected).

Slinging is the second most important element for all ports, apart from Marsden Point where it was the most important. Gisborne was significantly faster at slinging than Tauranga or Marsden Point. This indicates that Gisborne operations allow them to sling the logs more efficiently. It is likely to be, in part, due to the fact that every truck and trailer in Gisborne had an associated driver. This factor reduced carting to shipside time and helped reduce delays further along the cycle. It was observed that during the stowing of the Gisborne vessel, there were minimal crane and digger stowing delays. Since the study was conducted the Gisborne operation has changed and is now running with the same carting process as Marsden Point and Tauranga (detachable cargo trailers). This may make the Gisborne operation slower (Gisborne was shown here to be fastest) but it will increase the lift size as the old (non-detachable trailers) had slightly smaller capacity (reduced average lift size of ~2JASm^3/lift – see Table 3). It would be interesting to assess the change in gross load rate from the shift in operations in Gisborne to see if load rate is positively or negatively affected.

Tallying time varied significantly between the Marsden Point, Tauranga and Gisborne ports. This signifies that there is a unique difference between the port operations and implies that there may be room for improvement. Tallying is largely a human task (without machine interaction) and therefore the differences may be due to employee differences during the time that the study was conducted.

Carting elements (elements 1 and 3) are heavily influenced by distance travelled, as would be expected. Without changes in the location of the log stacks in relation to where the ship is being loaded, or speed limits on-port, it cannot be expected for there to be reductions in these cycle elements. The difference between the ports for carting to loader could be explained through port layout conditions. These are unlikely to be influenced by the exporter due to factors limiting port storage, such as lack of space available, which is dictated by the port company. Where storage is limited, for example the case of Port Chalmers, the use of front-end loaders and bunks at shipside is deemed efficient. The small space available limits the potential for cargo trailers to be used and therefore bunks are sufficient. Other variables appear to be reducing Port Chalmers gross load rate. These include smaller piece size, lower lift size, and the fact that the port isn't deep enough to load an entire vessel.

2015 data analysis (Table 3, Table 19) showed that that Tauranga was the fastest at loading vessels for export. However, since the time study data indicated that Tauranga was slowest, it may indicate that productive time is only part of what influences gross load rate. Total cycle time is the sum of productive time and delay time. Total cycle time influences how many cycles can be performed in an hour, with a quicker time increasing the number of cycles per hour. The combination of cycles/hour and the volume being loaded per hour is what makes up gross load rate (JASm^3/Hour). It could be hypothesised then that delay time and volume/hour factors heavily influence gross load rate as well as productive time. Perhaps historical data on net load rate would yield different results to the gross load rate implied from the historical data.

6.1 Limitations

Four vessels were studied, each of which were different ages, had different companies performing the stevedoring and marshalling operations, and had unique port conditions. An attempt was made to compare all ports and vessels evenly but there may have been some material factors which were not accounted for. Every attempt has been made to factor in the multitude of variables but it is important to note that some may have been omitted by accident.

Gathering enough data on cycles that take ~30 minutes to complete involves a considerable investment of time. In some instances, for example Marsden Point, where only 13,500 JAS

m^3 was loaded, it meant that to limited data was able to be collected. Additional data may improve the estimates of cycle element times.

Delays were not measured during the study. It was shown that it is important to understand delays as they may factor heavily on the gross load rate. Sampling one vessel at each port is not representative of delays that are likely to occur and hence why they were not included. Similarly, crane and digger stowing operations were not directly measured in any part of the study.

Since the study was conducted, Gisborne has changed its operations and now uses detachable truck and trailer units (like Tauranga and Marsden Point). It would be interesting to see the impact of changing the log transport operation on cycle time to identify where the gains/losses in time are found.

In Gisborne, the location of log stacks was estimated during night loading, due to inadequate lighting in the main log yard (Appendix 9.3.3). Similarly, any log transport from the upper log yard was not able to be measured because all of the stages of the vessel loading cycle could not be identified from the bridge of the ship.

7. Conclusion

The primary focus of this study was to identify the length of each of the elements of the vessel loading cycle and identify the factors that influence these elements between four New Zealand ports. Overall, the three ‘action’ elements (loading, tallying, and slinging) took significantly longer than carting elements (elements between the ‘action’ elements) and were influenced by a multitude of factors. The carting elements were largely influenced by distance measurements with some differences occurring between ports (likely due to port storage and roading restrictions).

Trailer loading took the longest of the elements for all ports studied and was not influenced by port. Loading was however influenced by log grade, log length, loading skill, and the time of day. Contrarily, tallying differed significantly between ports with Marsden Point being significantly fastest, followed by Gisborne, and then Tauranga. Slinging performed in Gisborne was significantly faster than slinging at either Tauranga or Marsden Point but was also influenced by loading location and the time of day.

Carting to tally time was not influenced by port. Instead, it was dictated by the distance from log stack to tally stand, equating to an average speed of 13.1km/hr. Carting to loader was shown to be a factor of distance and port with Tauranga being fastest, Marsden Point second, and lastly Gisborne. Carting to shipside was significantly quicker in Gisborne than either Tauranga or Marsden Point due to the associated truck drivers in Gisborne (where Tauranga and Marsden Point used detachable trailers).

Port Chalmers, on the other hand, had its four elements influenced by log grade, log length, distance between bunk and log stack, and whether the logs were being stowed in hatch 1 or not. For carting to and from shipside the average speed was 9.2km/hr, considerably slower than the carting elements for the other three ports. This is likely due to the inclusion of grabbing the logs at the log stack. Most notable was the influence of hatch 1 which increased element times significantly for slinging and overall cycle time.

The port with the fastest gross load rate (Table 3, Table 19) was not the fastest in terms of productive vessel loading cycle time. Gross load rate is influenced by delays, volume per cycle, and productive cycle time. The difference in productive time and gross load rate could be assumed to be from increased volume per cycle and/or reduced delays.

Efficiency increases of 10% result in 15% cost reduction for shipping cost whilst loading a typical 33,000JAS vessel at 10,000JAS/day (Table 21). At minimum and maximum historic shipping rates this equates to a saving of US$1,200 and US$22,300 respectively to the exporter. A reduction in efficiency of 10% leaves the exporter 20% worse off than a usual load (3.3 days, Table 21). The cost of loading slower than planned is far greater at higher shipping rates than it is at lower shipping rates. Also, the charge for being slower is greater than the refund for being faster. Therefore it is better to negotiate cheaper shipping rates than consistently loading vessels faster than planned.

This research has shown that vessel loading operations differ between ports. This is in both productive time and in gross load rate. For reducing productive time, tallying and slinging provide the largest opportunity, with further time reductions available from having logs closer to the vessel being loaded. For gross load rate, the volume being loaded onto the ship and the piece size are important determinants, as well as productive and delay time. Each port has unique space, logistical, and machine requirements which influence load rates. A combination of environmental and port conditions influence the speed of vessel loading and subsequently the cost to the exporter of having the vessel in port whilst loading.

8. References

Acuna, M., Bigot, M., Guerra, S., Hartsough, B., Kanzian, C., Kärhä, K., ... & Talbot, B. (2012). Good practice guidelines for biomass production studies.

Brooks, M. R., Schellinck, T., & Pallis, A. A. (2011). A systematic approach for evaluating port effectiveness. Maritime Policy & Management, 38(3), 315-334.

Clark, X., Dollar, D., & Micco, A. (2004). Port efficiency, maritime transport costs, and bilateral trade. Journal of development economics, 75(2), 417-450.

Forest and Agriculture Organisation of the United Nations. (2016). Forestry production and trade. Retrieved October 4, 2016, from: *http://faostat3.fao.org/download/F/FO/E*

Hopper, D. (2012). An Elemental Time Study on the Cranes of the Rattana Naree. Final Year Engineering Project Report. University of Canterbury, Christchurch, New Zealand.

Land Information New Zealand. (2016a). Bay of Plenty 0.125m Urban Aerial Photos (2010-11). Retrieved September 26, 2016, from: *https://data.linz.govt.nz/layer/1753-bay-of-plenty-0125m-urban-aerial-photos-2010-2011/*

Land Information New Zealand. (2016b). Dunedin 0.4m Rural Aerial Photos (2013). Retrieved September 26, 2016, from: *https://data.linz.govt.nz/layer/2109-dunedin-04m-rural-aerial-photos-2013/*

Land Information New Zealand. (2016c). Gisborne 0.4m Rural Aerial Photos (2012-13). Retrieved September 26, 2016, from: *https://data.linz.govt.nz/layer/1722-gisborne-04m-rural-aerial-photos-2012-2013/*

Land Information New Zealand. (2016d). Northland 0.1m Urban Aerial Photos (2014-15). Retrieved September 26, 2016, from: *https://data.linz.govt.nz/layer/3399-northland-01m-urban-aerial-photos-2014-15/*

Ministry for Primary Industries. (2016). Annual forestry export and import statistics. Retrieved October 4, 2016, from: *https://mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/*

Murphy, G. (2016). Optimising log storage and handling in New Zealand ports. New Zealand Journal of Forestry, 61(2), 36-41

Olsen, E. D., Hossain, M. M., & Miller, M. E. (1998). Statistical comparison of methods used in harvesting work studies. Corvallis, Or.: College of Forestry, Forest Research Laboratory, Oregon State University.

Simmonds, J. (2012). A Log Delivery Case Study at the Port of Nelson. Final Year Engineering Project Report. University of Canterbury, Christchurch, New Zealand.

Visser, R. Hopper, D. Simmonds, J. Wakelin, M. & Harrill, H (2012). Efficiency of Log Vessel Loading Operations: A Loader Configuration Case Study. School of Forestry, University of Canterbury, Christchurch, New Zealand.

9. Appendices

9.1 Definitions

JAS = Japanese Agricultural Standard

Heave = a group of logs, also known as a packet, which is lifted onto the ship

Sling = to wrap the vessel crane’s wire ropes around the heave for lifting onto the ship

Tally = to scan the SED barcoded of every log presented at shipside for loading onto the ship

<u>Log grades:</u>

A-grade:

- Minimum SED = 30cm
- Knots <1/3SED or 12cm
- Minimal fluting, ovality, splits, draw wood, taper, sweep, and wobble.

K-grade:

- Minimum SED = 20cm
- Knots <1/3SED or 12cm
- Minimal fluting, ovality, splits, draw wood, taper, sweep, and wobble.

9.2 Data Collection Sheet

Port: _______________ Cycle Element: _______________

Date: _______________ Vessel: _______________

	Time	Grade/row#/delays		Time	Grade/row#/delays
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		
11			11		
12			12		
13			13		
14			14		
15			15		
16			16		
17			17		
18			18		

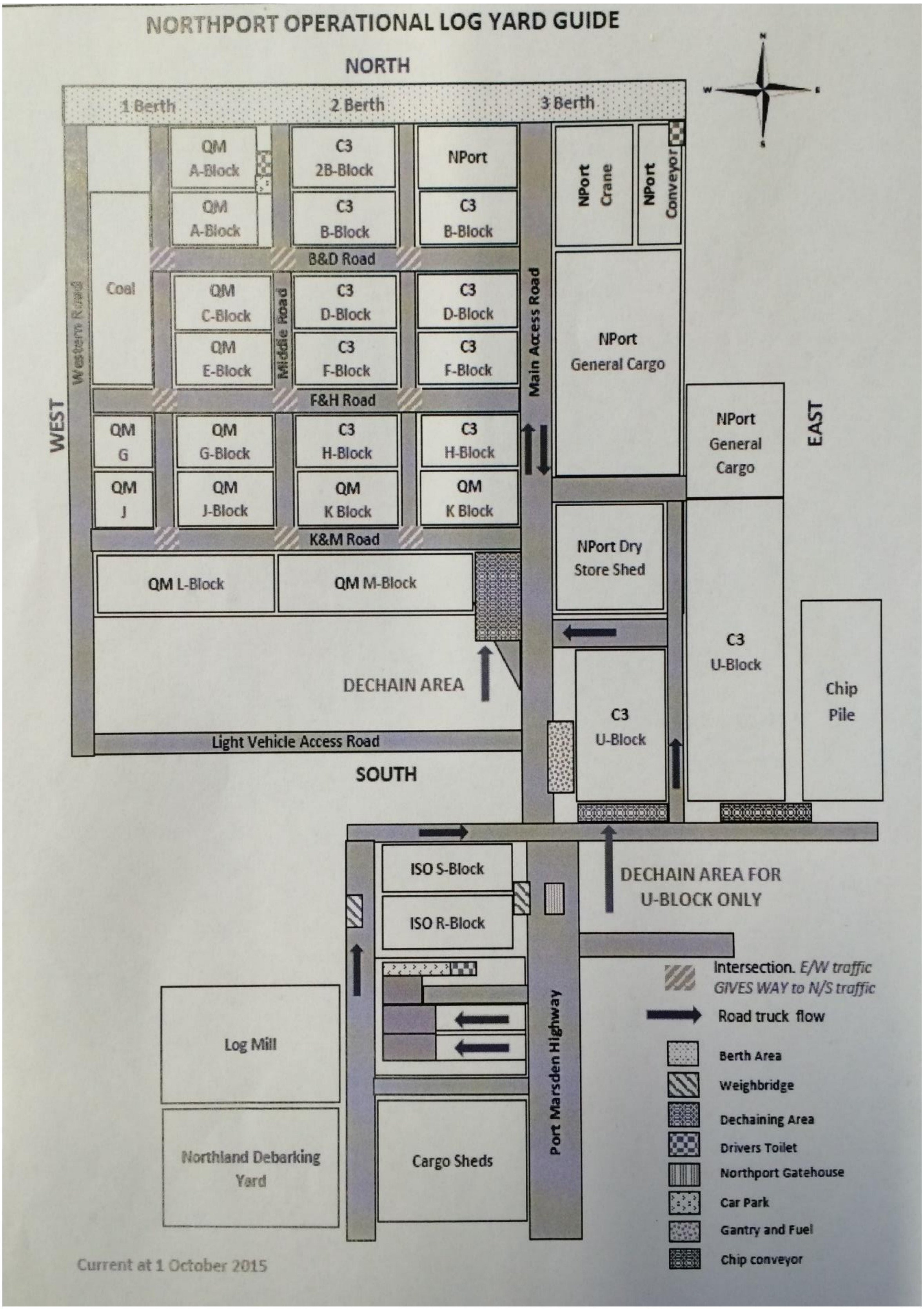
Comments:

9.3 Port Maps

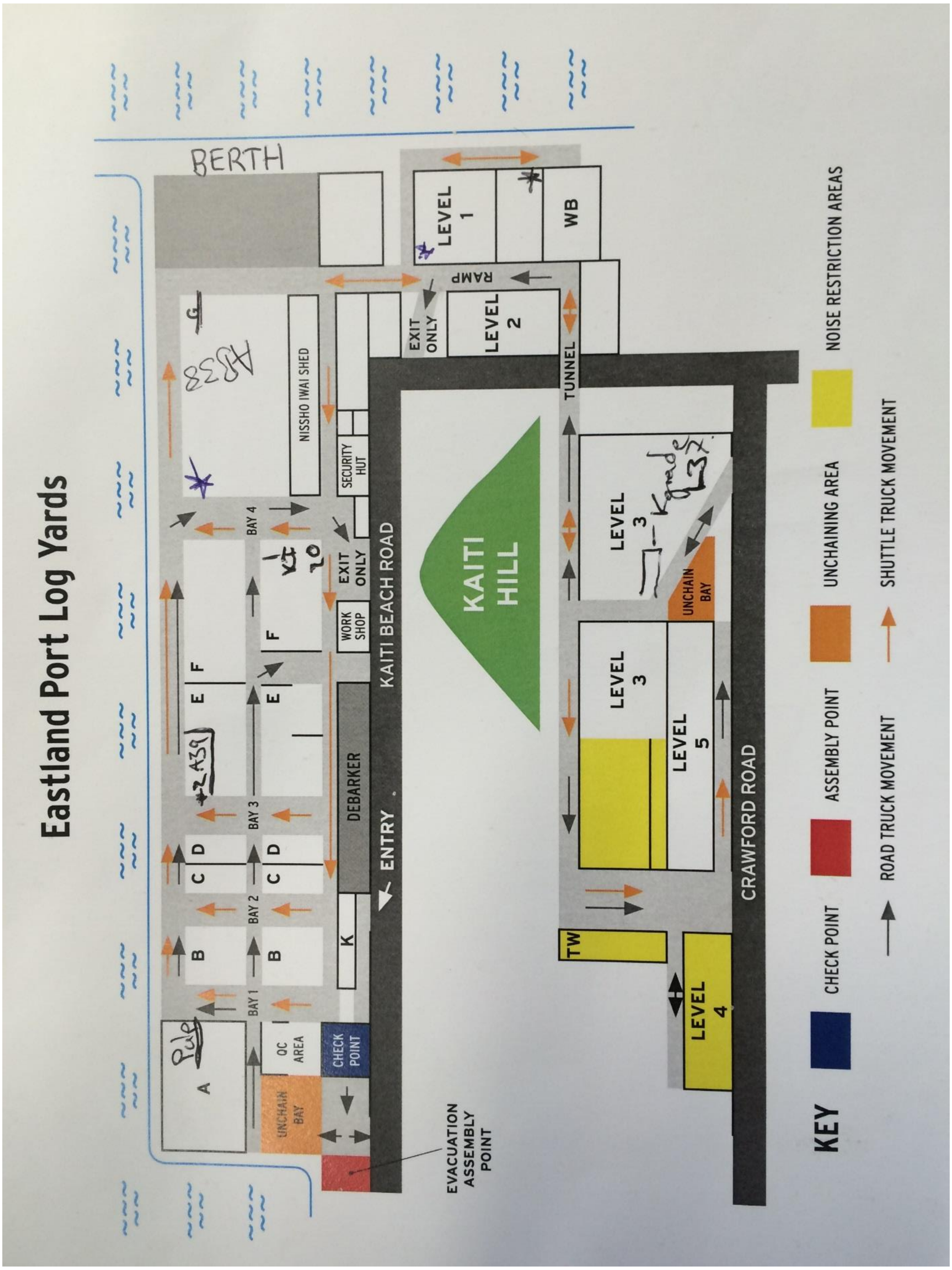
9.3.1 Port of Tauranga

Aerial imagery outlining the rough area dedicated to log storage.

9.3.2 Marsden Point (Northport)



9.3.3 Gisborne (Eastland Port)



9.3.4 Port Chalmers (Port Otago)