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# **Container Port Productivity**

A thesis submitted in partial fulfilment of the requirements of the degree of

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Nicholas Flack

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## **Abstract**

The international container port industry has recently gone through a process of rationalising the number of ports in response to increasing vessel sizes. Continued globalisation in trade means that container volumes are concentrated towards main consolidation points and hub ports. The aim of this research is to investigate the existence of a relationship between the capacity utilisation, volume and productivity of container ports. This will allow the research to provide insight to the resulting productivity impacts from the continued trend in the consolidation of container ports. Academic theory and previous research suggests that increased volume and capacity utilisation will mean downward pressure on productivity.

Inland hub facilities provide an alternative means of quickly providing additional port capacity for the ports remaining after consolidation which is traditionally cheaper than port land or technology increases. This research also investigates whether the use of inland hubs by container ports impacts on the relationships throughput volume, capacity utilisation or productivity of the integrated seaport.

The context for this research is New Zealand, which has a relatively high number of international container ports that are highly competitive across the small domestic container industry. The New Zealand port sector is predicted to go through significant change and rationalisation over the short to medium term as some ports choose not to or cannot afford to invest in the required infrastructure to handle the larger container vessels, although the speed and results of port rationalisation has been heavily debated over the past decade.

Collection of publically available information on the productivity, volume and capacity utilisation produced a quality data set for the six ports that handle ninety percent of New Zealand containerised trade. Regression and statistical analysis is completed on this data set to outline the existence and significance of any relationships. Although this data set is not primarily collected by the author, it is of high quality as has been collected by an objective government agency for the specific purposes of consistently monitoring productivity and growth of New Zealand seaport on a regular basis. The use of secondary data brings with it drawbacks in relation to quality and reliability, therefore more detailed analysis was also completed for an individual port using data collected by the author directed from port operating system. This allows for the confirmation of conclusions developed throughout the analysis of national level data.

This research expands the current academic knowledge with analysis in a smaller trade and port environment than the traditional examples of America or Europe. This research mostly confirms the relationships between volume, capacity and productivity of container ports experienced in international academic literature, however it also shows that the relationship between productivity and volume may be positive (opposite to other literature) dependent on the port, the nature of the volume change and the level of utilisation. It also shows that inland port facilities can be used as a means to improve the productivity and reduce delays in port operations. Finally, this research advances New Zealand academic literature by providing the first detailed analysis of the relationship between capacity, volume and productivity in New Zealand container ports.

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# 1. SETTING THE SCENE

The growth in carrying capacity of container vessels has been high since the start of containerised transport in 1956, and has become faster in the last two decades. The first container ships used in the 1950s and 1960s had a capacity of between 500 and 800 TEU<sup>1</sup> (Ashar and Rodrigue (2012)). The Public-Private Infrastructure Advisory Facility Port Reform Toolkit<sup>2</sup> outlines that the share of worldwide container ships with carrying capacity in excess of 5,000 TEU increased from 1 percent in 1996 to 30 percent in 2006. Maersk is current building twenty new vessels to be delivered between 2013 and 2015 with the ability to carry 18,000 twenty foot containers<sup>3</sup>. The increase in the average sizes of container ships is likely to continue as it offers a significant reduction in average carrying cost per container (Prince (2012)).

Increases in vessel size have resulted in the practice of consolidating ships' calls at fewer ports (The United Nations (1998), Prince (2012)). This is a process known as 'port consolidation' or 'port rationalisation' and is especially prevalent on long-distance routes where economies of scale at sea are most apparent (Notteboom (2008)).

In the process of port consolidation, as container port throughput volumes increase at an individual port there is likely to be significant downward pressure on productivity unless capacity can be increased quickly (Le-Griffin and Murphy (2006)). Increased volume of throughput with constant supply of land increases the utilisation of ground space. Heavily utilising ground space means stacking containers higher, reducing operational accessibility and reducing productivity.

An inland hub or dry port refers to an inland consolidation point for freight that is connected with a port terminal through rail, barge, or truck services. Often the supply chain management practices are integrated with the deep sea terminal. Inland hub facilities provide an alternative means of quickly providing additional port capacity for the ports remaining after consolidation. For capacity constrained ports, land for container terminal use can typically be set up quicker in the inland location in comparison to a portside reclamation – obtaining further land at a portside location is usually expensive and environmentally difficult (Konings, Pielage, Visser, and Wiegmans (2007)). Inland

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<sup>1</sup> Twenty-foot Equivalent Unit is a standard size of a container used for denoting the container carrying or handling capacity of a ship or port.

<sup>2</sup> <http://www.ppiaf.org/sites/ppiaf.org/files/documents/toolkits/Portoolkit/Toolkit/index.html>

<sup>3</sup> Information retrieved from Maersk.com at 11:11am on 2 May 2014.

hubs reduce the capacity utilisation of portside operations as typically more land is available at inland locations (Le-Griffin and Murphy (2006)). Non-essential elements of the port operation can then be completed at the inland location and more land can be provided to container terminal managers to reduce the stacking intensity of containers, reduce the total yard moves per container and increase the productive ability of the terminal. Therefore, inland hubs should provide an effective tool in maintaining productivity throughout the process of port consolidation.

## **1.1 INDUSTRY CONTEXT**

The research focus is on the New Zealand container port industry. New Zealand currently has a network of 12 ports operating as international and regional bulk and containerised ports, geographically spread throughout both the North and South Islands. However, six New Zealand ports handle over 90 percent of New Zealand containerised trade. These are Auckland, Tauranga, Napier, Wellington, Lyttelton and Otago ports (Statistics New Zealand 2013 Figures).

Compared to other countries, New Zealand has a high number of ports, especially when the small domestic container throughput and the small geographic area are taken into consideration (Rockpoint Corporate Finance (2010)). As a comparison, the average distance between the main container ports in Australia is nearly four times longer and the average throughput volume nearly three times greater.

The first challenge the New Zealand port sector faces is that the current state constrains effective investment in large scale port assets. This is due to the relatively high number of small international container ports that are highly competitive and have intertwined hinterlands across a small domestic market – as outlined in the industry review. Auckland Regional Holdings (2009) suggest that New Zealand ports are the ‘piggy in the middle’ between the fairly well consolidated exporters and international shipping lines, resulting in a fragmented port industry structure and a divergence from international trends in industry consolidation and private investment.

The second challenge faced is that the New Zealand port sector is predicted to go through significant change and rationalisation over the short to medium term (New Zealand Shipping Federation (2010), Auckland Regional Holdings (2009) and Rockpoint (2009)) – introducing further uncertainty.

Productivity of the remaining ports will be highlighted. Port rationalisation will result in fewer container ports, with more vessel calls at each and more containers moving across the wharves of each port. The large New Zealand container ports are already operating twenty four hours, seven days a week.

To handle the volume growth it is not a case of working longer, it is a case of generating further productivity. Therefore, after rationalisation, the remaining ports will require high productivity levels and sufficient capacity to handle the growth.

The use and integration of inland ports provide a means of quickly providing capacity. They also allow unproductive port services to be completed away from the sea port. Given the location and infrastructure requirements of an inland hub, they may be significantly less expensive and more readily available in comparison to the creation of new wharves and land increases (through reclamation) at the portside (Auckland Regional Holdings (2009).

New Zealand is an open economy with a small domestic market and is located a significant distance from major trading partners. International trade is vital to New Zealand and is the basis upon which New Zealand's GDP is generated. A well-functioning cost effective logistics system provides opportunities to enhance trade and increase the utilisation of transport assets. Over 90% of goods exported or imported are done so by New Zealand seaports (Statistics New Zealand Trade Statistics 2013). Therefore the efficiency and productivity of New Zealand seaports is a crucial component in this well-functioning and cost effective international logistics system.

## **1.2 RESEARCH OBJECTIVES**

These challenges provide the background for the objectives of this research.

### Objective 1:

*To investigate the existence of a relationship between the capacity utilisation, volume and productivity of container ports.*

This will allow the research to provide insight to the resulting productivity from the expected future consolidation of New Zealand ports which will lead to higher volumes through single container ports and the investment in the large scale port assets.

In investigating this objective it needs to be recognised that there is a balancing act between promoting economies of scale and managing the capacity constraints in order to maximise the productivity, service levels and returns of the ship side and landside stakeholders

### Objective 2

*To investigate whether the use of inland hubs impacts on the throughput volume, capacity utilisation or productivity of the integrated seaport*

This will allow the research to determine whether inland hubs are an effective means of generating capacity to handle large volume increases while maintaining productivity levels. It will also allow the determination of whether New Zealand ports are using their inland hubs to generate productivity increases or to increase their competitive ability by increasing their potential hinterland.

### **1.3 RESEARCH METHODOLOGY**

The three components of the research methodology are; 1) data collection, 2) analysis and 3) reporting. All three components have two investigations focused on different levels of detail – national level investigation and a detailed port investigation. The national level investigation aims to determine the existence of a relationship between volume, capacity and productivity at New Zealand's main container ports. The detailed port investigation aims to triangulate data and analysis and confirm the existence and significance of relationships.

The data for the national level investigation is compiled through the use of the Ministry of Transport quarterly reports titled *Freight Information Gathering System and Port Productivity Study*. This is publically available information on the productivity, volume and capacity utilisation which produces a quality data set for the six ports that handle ninety percent of New Zealand containerised trade. The productivity measures outlined are directly comparable to international industry and academic publications.

The use of secondary data brings with it drawbacks in relation to quality and reliability, therefore the detailed investigation concentrates analysis on the commercial and operational data of a single port to confirm the relationships outlined in the national overview. The data was produced from the port's operational system and checked for consistency and accuracy by the Container Terminal Managers after the completion of each vessel. Inland hub throughput data was also compiled from the financial reporting system of the inland hub business, as they bill clients directly for each container handled. Between 2011 and 2013 the author also worked as an analyst for the port of focus and gained an understanding of the data collection methods, accuracy and operational procedures of their container terminal and integrated inland hub facility.

The analysis technique used to investigate the first objective is regression and statistical analysis used to detail trends in throughput volume, capacity utilisation and productivity as well as the relationship between each of these variables. To research the second objective, analysis focuses on

investigating whether there is a change in the volume, capacity utilisation and productivity trends after the introduction of an inland hub facility.

Both multivariate regression and simple linear regression models are used. The multivariate regression is used where there are a number of measure types – for example for productivity where this can be measured in ship, crane or vessel productivity rate. It is used to incorporate all of measurement bases into one equation rather than displaying each of the numerous individual correlation equations for each variable. The simple linear model is used to concentrate on a particular combination of measurement types for each variable and is displayed especially where the variables have a more limited number of measurement types available.

The reporting of this analysis is completed by providing the time series plots so that the reader can visually see the trends described. The reporting of the investigation of the relationship between these variables is carried out by reporting the relationship (i.e. whether there is a positive or negative relationship), whether it is statistically significant and the level of the relationship. Where possible, there is an example provided to show the hypothetical change in each of the variables.

The strength of this research methodology is that it uses data and analysis techniques which are comparable with international literature and industrial publications. Typically data available for this research is secondary data – obtained via industry and government publication of port performance. Another strength of this research is that it uses detailed data with known accuracy on an individual port to triangulate the results.

The weakness of the approach is that it concentrates on the analysis of volume, capacity utilisation and productivity variables. It does not include the analysis of other factors which may impact on the performance of the container terminal, such as the financial and human elements.

#### **1.4 CONTRIBUTION OF THE RESEARCH**

New Zealand research into the performance and capacity of New Zealand container ports is relatively scarce, and has a non-academic focus – it has been completed by industry participants (Ministry of Transport (2013), New Zealand Shipping Federation (2010), Auckland Regional Holdings (2009) The New Zealand Business Council for Sustainable Development (April 2011), PricewaterhouseCoopers (2012). The previous research concentrates on the most effective means of getting goods to and from ports hinterland. There is no research, academic or otherwise, on the relationships between

throughput volume, productivity and capacity for New Zealand ports.

This research focuses on the relationships between the productivity and capacity and the use of inland container hubs as an outline to how ports could invest to increase productivity and capacity given scarce financial and operational resources.

This research is important given New Zealand's reliance on trade and the need to carefully plan infrastructure investments in transport and freight. Julian Bevis – Chairman of the NZ International Container Lines Committee and Managing Director of Maersk New Zealand – sums up the importance of this research when commenting on the freight and shipping sections of the Government's 2010 National Infrastructure Plan

“The solutions we devise need to serve the interests of the economy as a whole in a sustainable fashion. They need to minimize the costs faced by New Zealand businesses looking to trade with the world, while at the same time providing transport and logistics providers across the whole supply chain a reasonable rate of return on their investment<sup>4</sup>”  
(Bevis (2010))

This research will also add to the base of international literature on these objectives, which is typically focused on American or European seaports.

New Zealand is a different economic setting than traditional research on this topic – it has a small domestic market with a high number of ports, a lack of political direction in the port sector, an export focus and geographically isolated from major world markets.

Academically therefore the research may also be relevant and useful in informing other contexts such as:

- Other countries or areas where there is a requirement for, or trend in, port rationalisation
- Other ports where they face the challenge of trying to cater for increasing ship sizes with a scale budget for investment in infrastructure
- Other small open economies with a reliance on trade and the performance of their port industry

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<sup>4</sup> Note that the New Zealand Treasury suggests that for financial analysis at the level of the organisation – not for national analysis of net benefit – the Weighted Average Cost of Capital or Required Rate of Return for calculation purposes should be a 7.5% return on investment.

- Any other country, area or port facing constrained capacity and large scale throughput growth
- Other trade areas with highly competitive hinterlands

In summary, this research furthers the current academic knowledge by confirming the existence of the theoretical relationships in a smaller trade and port environment than the traditional examples of America or Europe. It also significantly advances the New Zealand academic literature by providing the first detailed analysis of the relationship between capacity, volume and productivity in New Zealand.

## **1.5 LIMITATIONS OF THE RESEARCH**

The first limitation of the research is the use of secondary data. The data is compiled through the use of the Ministry of Transport quarterly reports titled *Freight Information Gathering System and Port Productivity Study*.

The second limitation is that this productivity data is provided by each individual port. The Ministry of Transport then compiles and publishes the information. There is limited ability for the Ministry of Transport or any other third party to check for accuracy (with the exception of a sense check in comparison to the previous reported figures and the reported figures of other ports). This is especially important given each port has an incentive to report figures which are as high as possible as it is the single New Zealand publication which allows cargo owners and shipping lines to compare the productivity of New Zealand ports on a quarterly basis.

The use of secondary data brings with it drawbacks in relation to quality and reliability. Therefore, as detailed above, more detailed analysis using commercial port operational data (which has been checked for accuracy by a number of parties) was also completed for an individual port to triangulate results and confirm accuracy.

The final limitation of the data set used is that the port productivity data is produced only for the productive ability of a port's cranes. The data does not provide the range of information typically published by international reports, including information on berth productivity per metre, productivity of yard equipment or the productive ability of a port to handle demand from land transport operations.

## **1.6 DOCUMENT STRUCTURE**

The document structure used to effectively communicate the research carried out and resulting findings is:

- Chapter 2 – provides a review of previous academic literature and a theoretical context for this research.
- Chapter 3 – provides detailed information the New Zealand container port industry and how it fits with, and compares to, the international industry.
- Chapter 4 – outlines the proposed methodology for investigating the research objectives.
- Chapter 5 – conducts statistical analysis at the national level to investigate trends in container terminal throughput volume, capacity utilisation and productivity as well as investigating the existence of a relationship between these variables.
- Chapter 6 – conducts statistical analysis at the detailed level to triangulate the conclusions of the national level analysis
- Chapter 7 – discusses the analysis findings by relating them to the industry background and literature review.
- Chapter 8 – provides conclusions to the research by outlining answers to the hypotheses posed in the research objectives.

## **2 LITERATURE REVIEW**

### **2.1 INTRODUCTION**

This chapter provides a review of academic and industry literature relevant to the research topic and objectives. The literature review first provides a theoretical overview of container ports and how container port research relates to the broader trends in the academic research of logistics and supply chain management. The review then outlines academic research on port volumes, capacity and productivity as well as the relationship between the variables. Finally, the chapter provides a theoretical overview on the use of inland hubs.

### **2.2 REVIEW OF INTERNATIONAL LOGISTICS LITERATURE – WHERE DO PORTS FIT IN?**

A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer (Supply Chain Canada (2013)). Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves.

Logistics, on the other hand, is a section of the supply chain concentrating on the transport and distribution elements. Logistics, as defined by the New Zealand Productivity Commission (2011), “is the process of efficiently moving goods from their point of production to their point of consumption in order to meet customer requirements, which typically include the quantity and quality of goods as well as the time and place of delivery” (Page 5). Bichou and Gray (2004) simply describe the logistics channel as “specialists that facilitate the efficient progress of cargo through a supply chain”. The Ministry of Transport (2010) outlines that “efficient logistics management is about providing the right quantity and quality of goods at the right times and locations, in a way that minimises transport costs, time, storage and stock wastage” (page 2).

The simplified overview of an international logistics chain used by the Productivity Commission is provided in below.



**Figure 2.1 Simplified Logistics Chain. Source: New Zealand Productivity Commission (2011)**

Even though the movement of freight is so crucial to economic progression (United Nations Conference of Trade and Development (2014), logistics has not traditionally received large research attention. Woudsma (2001) suggests that the efficiency of moving people rather than the ability to move freight move effectively has been a concentration in order to improve the functioning of urban agglomerations. Others (Dicken 1998, Hesse and Rodrigue 2004) suggest that logistics has not received sufficient attention because the transport sector has been perceived as a residual consequence of other, more important functions or processes. However, logistics has always been a critical component of the economy – whether it be in medieval Europe (Braudel 1982), past military operations (Rodrigue and Slack (2002)) or the development of current urban infrastructure (Grabara (2012), Taniguchi (2012)).

There are two arguments as to how the study of logistics became a separate discipline, one is through industrial revolution and the other is through the development of military systems. Hesse and Rodrigue (2004) provide a high level historical review of the change in focus of the logistics industry and research and suggest that the principles of modern logistics can be traced back to Taylor's (1947) ideas, known as 'fordism', related to improving efficiency in a factory by organising labour into a production line and introducing dimensions such as sequence, duration, schedule, rhythm, synchronisation and time, which are all highly significant to today logistics and supply chain management.

Ballou (2007) provides further review of the formation of the logistics industry and research and notes that before the 1950s logistics was thought of in military terms – procurement, maintenance and transportation of military facilities, material and personnel. However, unlike Hesse and Rodrigue, Ballou believes that the pivotal role in laying the foundations for logistics as an area of study was a paper written by Lewis, Culliton and Steele (1956) which pointed out that shipping costs should be viewed by businesses not only as the transportation costs, but the total costs perspective of how transport costs, and the mode chosen, links to inventory holding costs. He believes that this paper, and the introduction of 'total cost perspective', lead to the first college course and textbook, which

discussed transportation, inventory control, warehousing and facilities location within the context of a total cost perspective. Then in 1964, Ivie and Glaskowsky's paper expanded the scope of the total cost perspective by including physical supply and called the subject area Business Logistics.

Regardless of whether the formation of logistics was through industrial or military systems, both Ballou (2007) and Hesse and Rodrigue (2004) outline that around this time business and organisational focus was not on the logistics section as a functional group of the company. Instead the focus was on the typical elements such as marketing, finance and operations/production which, from a logistics point of view, have conflicting goals – marketing wanted more inventory, shorter production runs and fast delivery whereas production want long production runs and low cost transport routing and finance want cost minimisation across all facets.

Development of logistics in the 1970s can be summarised by the introduction of lean management, which seeks to eliminate inventories and provides goods strictly on demand, shaping the nature of logistics towards a system of low inventory holdings and a just in time delivery (Rodrigue and Hesse (2004)). In this period supply chains and logistics also became of increased focus due to the increased globalisation of economic activities, especially within multi-national corporations (Dicken 1998). Rodrigue and Slack (2002) suggest that “this required higher organisational levels of physical distribution systems, which in turn favoured the development of the civilian logistical system” (page 1).

In the 1980s firms followed a more integrated approach to the supplying, warehousing, production and distribution functions, which were previously interdependent, to gain both economies of scale and flexibility to keep costs down as well as provide for increasingly just-in-time requirements (United Nations and Korea Maritime Institute (2007)).

The 1990s saw information technologies being used in the logistics network, particularly in the distribution elements, to control inventory levels, minimise distribution costs and link together logistics functions.

More recent examples of an integrated approach to global logistics are multi-national corporations across multiple sectors subcontracting logistics activities. Rodrigue and Slack (2002) outline that the management of [international] freight distribution systems is getting increasingly complex and subcontracting logistical operations to specialised operators has been a cost effective solution for corporations facing distribution bottlenecks. Basnet, Corner, Wisner and Tan (1999) confirm that this

is also the case in their 1999 review of supply chain management practices in New Zealand. They conclude that “about half the respondents [of their study] reported using outsourcing, strategic alliance or supplier certification programmes” (page 9).

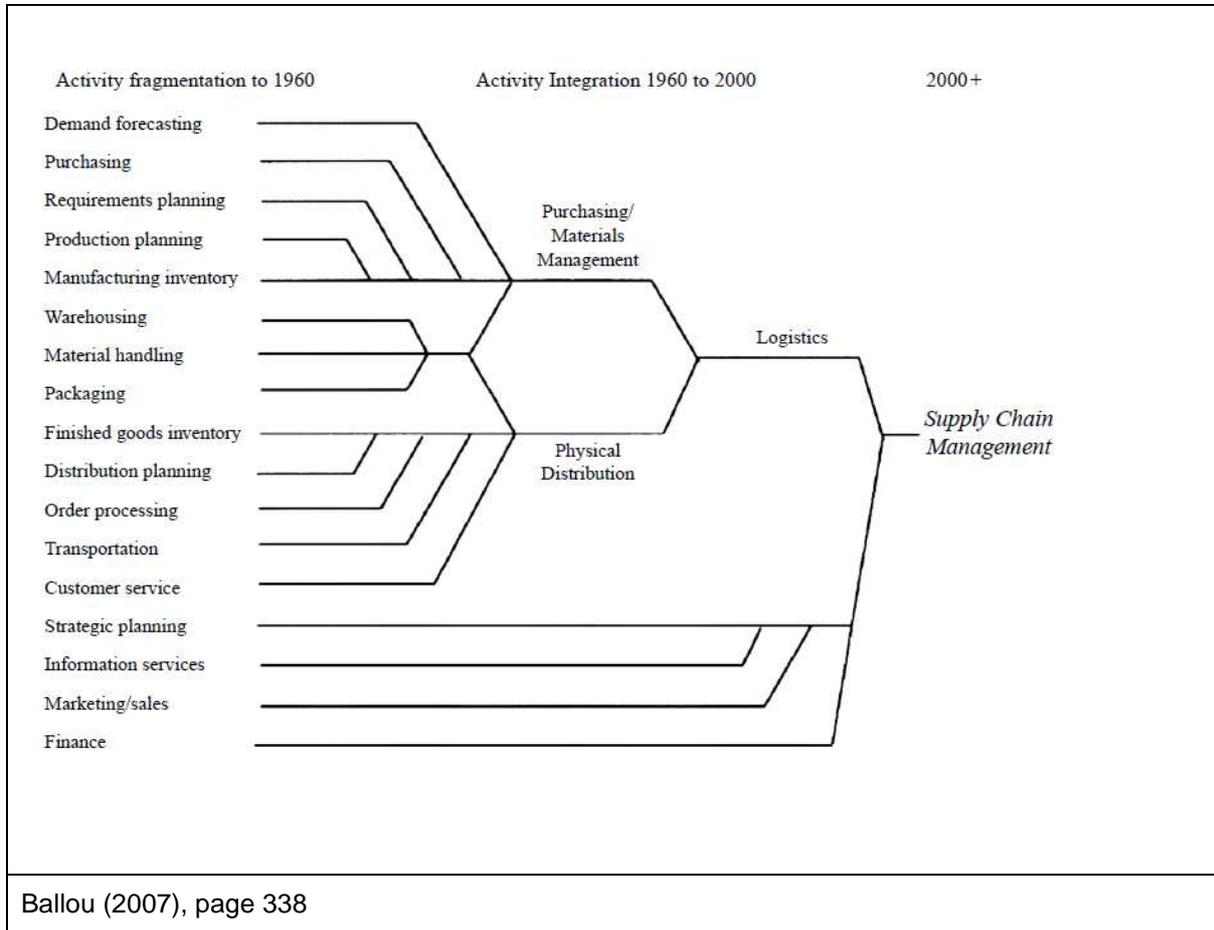
Closer, more integrated relationships enable companies to reduce costs and increase revenue as well as increasing flexibility in dealing with supply chain uncertainties (Simatupang and Sridharan (2004), Bowersox (1990) and Lee, Padmanabhan and Whang (1997)). Integrated logistics options may include sharing warehousing facilities, transport networks and information or coordinating activities through the use of autonomous and self-controlled systems. While the importance of the supply chain integration and closer relationships between stakeholders has been outlined by academic literature, the means to achieving this integration has not received much attention (Basnet and Wisner (2012)).

It is important that the means of achieving greater collaboration and integration across supply chain participants is a part of future logistics and supply chain research. PricewaterhouseCoopers and the Supply Chain Management Institute (2010) suggest that as infrastructure bottlenecks start to constrain economic growth, collaboration between supply chain participants will become critical to maintaining flexibility while maximising profitability. Ye Weilong – Managing Director of COSCO Logistics stated “Logistics service providers who follow the device ‘share and collaborate’ will benefit regardless of being a domestic logistics service provider or a multinational company in emerging markets” (PricewaterhouseCoopers and the Supply Chain Management Institute (2010b)).

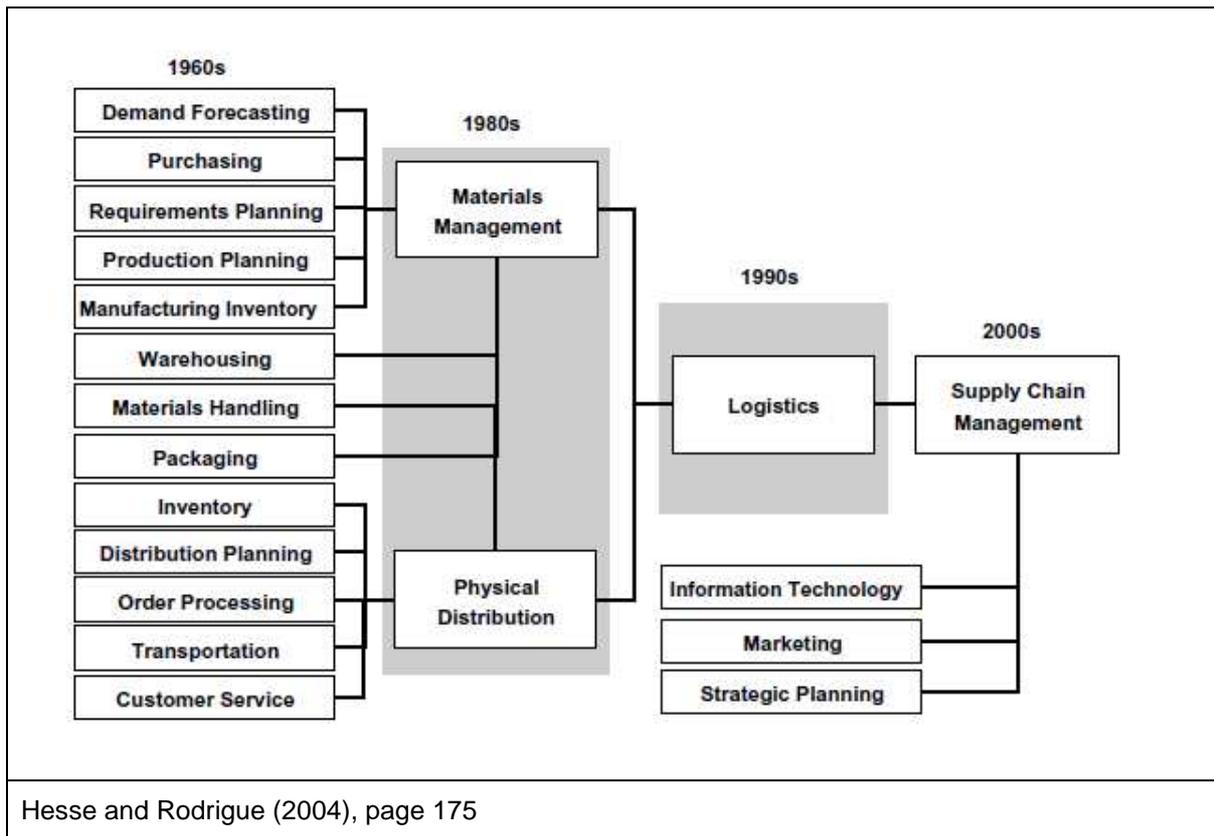
In New Zealand collaboration is currently present. Large export industries have created cooperatives to manage the marketing, processing and logistics of the entire industry. Examples include Zespri and Fonterra. Zespri is New Zealand's largest horticultural exporter, shipping approximately 100 million of kiwifruit per annum and returning over \$1 billion in exports to the 3,000 New Zealand growers they represent. Zespri works on behalf of the growers to ensure an efficient supply chain that delivers their products to market in the best condition to achieve premium prices.

In general Hesse and Rodrigue (2004) summarise the progression of logistics by saying “contemporary logistics was originally dedicated to the automation of production processes, in order to organise industrial manufacturing as efficiently as possible, the subsequent modernisation of logistics can be characterised by an increasing degree of integration” (page 174). They also suggest that this trend, which has been fostered by improvements in technology and communication, has

resulted in a significant reduction in inventory costs and logistics costs as a percentage of GDP and a reduction in the cycle time requirements. Ballou (2007) supports this view, and the diagrams below show the overview of their similar views on the evolution of supply chain management:



Ballou (2007), page 338



**Figure 2.2: Diagrammatic Overviews of Logistics Development in Academia**

Due to the reliance on maritime transport for global trade<sup>5</sup>, the development of the logistics industry has been intrinsically linked with the development of ports. Ports serve the purpose of connecting the countries to the world market, allowing trade and economic development. They connect the waterside logistics sector with the landside logistics sector. Esmer (2008) defines a seaport as “a terminal and an area within which ships are loaded and unloaded with cargo and includes the usual places where ships wait for their turn or are ordered or obliged to wait for their turn no matter the distance from that area. It has an interface with other forms of transport and in doing so provides connecting services” (page 2).

Previously ports have also allowed, and have been intrinsically linked to, the support and development of an urban agglomeration. Rodrigue (2009) suggests that conventionally, because of high inland transport costs, the maritime activities of a port were a direct driver of coastal urban areas.

Up until the beginning of the 1960s, general cargo was transported in various forms of packaging and loaded into relatively small general cargo vessels in a shelf like arrangement where goods were stowed in small pre-packaged consignments according to destination. The slow loading and

<sup>5</sup> The importance is outlined in the next chapter, the Industry Review.

unloading processes resulted in port congestion, high transport costs, higher inventory holdings and restrained development of trade (Haralambides (2012)). Containerisation is commonly traced back to Malcom McLean in 1956. The World Shipping Council (2013) outlines that he

“bought a steamship company with the idea of transporting entire truck trailers with their cargo still inside. He realized it would be much simpler and quicker to have one container that could be lifted from a vehicle directly on to a ship without first having to unload its contents.

His ideas were based on the theory that efficiency could be vastly improved through a system of "intermodalism", in which the same container, with the same cargo, can be transported with minimum interruption via different transport modes during its journey. Containers could be moved seamlessly between ships, trucks and trains”.

The large scale development of container handling facilities was carried out in New Zealand in the late 1960s and early 1970s. Examples include the Port of Wellington’s container terminal reclamation commissioning in 1968 (Johnson (1996)) in preparation for containerisation and the Lyttelton Port’s Cashin Quay container terminal reclamation being commissioned in 1971<sup>6</sup>.

Now containerships transport approximately sixty percent of the value of goods transported by sea (World Shipping Council (2012)) with greater reliability, productivity and predictability and reduced costs of total transport and warehousing between the initial production location and final destination due to the repetitive nature and economies of scale associated with handling standardised containers (Haralamides, 2012).

Traditionally, container ports have been seen as a place for loading and storage of containers – “the basic function of a container terminal is the transfer and storage of containers” Le-Griffen and Murphy (2006) (page 3) – or as a place where goods are shipped to and from (Henesy, 2006). Containers are sorted and stored in the container yard and transferred to landside transport modes or stevedored onto or off of container vessels. However, increases in freight transport demand, changes in customer requirements and increases in port competition have resulted in the integration of landside and seaside activities at the port, ports becoming a consolidation point for regional and worldwide trade and the rise of a concept known as Port Centric Logistics.

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<sup>6</sup> Obtained via internal records at Lyttelton Port of Christchurch.

Port Centric Logistics can be defined as:

*“The intelligent/selective application of assets and services, within or adjacent to, major deep-sea container ports, to generate significant reductions in supply chain costs, improved product availability , or both”*

<http://www.portcentriclogistics.com/point.htm>, retrieved on 26/11/2011 at 11:45am.

Mangan (2009) simply defines port centric logistics as the provision of distribution and other-value adding logistics services at a port. When this opportunity to create port centric logistics solutions is seized, ports are no longer a facility for berthing vessels and stevedoring cargo, they form integral parts of supply chains and as such are ideally positioned to offer value-added logistics services – in fact Bichou and Gray (2004) suggest that ports are one of the very few networking sites that can bring together various members of the supply chain. Port centric logistics as a concept has been popular in the UK port sector in recent years, especially for containerised goods (Monios and Wilsmeier (2012)). This is becoming more prominent as landside logistics become less efficient and more costly (due to congestion for example).

Examples of port centric solutions provided in the New Zealand container freight network include the Container Freight Stations set up adjacent to container terminal, with cross docking facilities as well as warehousing inside a Customs controlled area (e.g. CentrePac Wellington<sup>7</sup>).

Port Centric logistics solutions also allow the ports to minimise investment risks. “Ports rarely control logistics channels although they are key institutions in international shipping and logistics” Bichou and Gray (2004). Integration of services along the logistics and supply chain provides the hub port with opportunities to minimise the risks involved in large scale infrastructure investment by gaining greater control of the logistics chain and of market share.

Global trade, and the use of ports, has been under significant growth pressures since the rise of containerisation. Rodrigue (2009) outlines that the value of global exports first exceeded \$US 1 trillion in 1965 and by 2005 more than \$US 10.3 trillions of merchandises were exported – translating into a tripling of world containerised freight movement between 1990 and 2008. Kemme (2013) outlines that

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<sup>7</sup> <http://www.centrepac.co.nz/>. This the case of Centrepac Wellington the unloading of import containers and loading of export containers adjacent to port minimises the requirement to transport and reposition empty container as the import and export goods are matched and the same container used.

during the last decade this growth in container movements has been a result of globalisation, economic growth and geographical distribution of activities, which are likely to be contained in the future.

Therefore the importance of an efficient container port operation and industry is becoming increasingly importance to world trade. As Henesey (2006) says, based on Winkleman and Van de Voorde (2002) and other academic literature, "The importance of CTs [container terminals] to the economic and social dimensions of a community, national or regional is significant. Better performing CTs, it is often argued to contribute in increasing trade and development of national economies" (page 26). Therefore, this research which helps to understand the relationships between the volume, capacity and utilisation of container terminals is an important addition to the current knowledge base.

### **2.3 NEW ZEALAND LOGISTICS AND PORT RESEARCH**

New Zealand is relatively isolated from large international markets, has a small domestic market and a reliance on export earnings. International trade is vital and trade costs have a large effect on the profitability of New Zealand businesses. These points are outlined in greater detail throughout the Industry Background, below.

Jay Sankaran (2000) cites Cavana (1997) and the suggestion that the freight transport task in New Zealand is different than many other countries and conditioned by many factors including the island character, topography, climate and the of natural resource distribution as well as the resultant patterns of historical settlement and varying regional economic growth. These issues have led to considerable research completed on methods for improving international trade and reducing trade related financial and non-financial costs.

In terms of academic research on New Zealand logistics and supply chain management, Basnet, Corner, Wisner and Tan (1999) suggest it is limited, going on to say that "to our knowledge, there is no published study of supply chain management in New Zealand" (page 2). This statement relates explicitly to empirical studies examining supply chain management practices and their effects. Basnet, Childerhouse, Foulds, and Martin (2006) suggest that, while there has been a significant increase in the general awareness of lean manufacturing, supplier integration and quality improvement strategies [In New Zealand], the practice is still lagging behind.

While there limited academic research on the New Zealand port sector, there significant research led

by industry and government sector participants. However the industry research concentrates on the most effective means of getting goods to and from ports – the inland distribution leg. Most New Zealand Regional Councils, road controlling organisations (i.e. NZTA Regional Offices) or Regional Economic Development Agencies have completed freight studies to identify how their region can export their produce more effectively or import products quicker (for example Hyder Consulting (2009) Greater Wellington Regional Council (2011), Bay of Plenty Regional Council (2010)). The two national level documents to review the New Zealand logistics network are the Productivity Commission's Inquiry and the Freight Futures document detailed below.

In April 2009 the New Zealand Productivity Commission started an inquiry into International Freight Transport Services, with a scope which included the identification of impediments to the accessibility of the international freight transport services and identification of the mechanisms available to improve the accessibility and efficiency of the international transport supply chain. However, the productivity commission's work has an inherent focus on what the government can or should do (e.g. changing legislation and regulation) rather than what is most optimal from an industry perspective. One major conclusion made by the Productivity Commission was that New Zealand's port and border charges compared favourably with other OECD countries. However the variability in port performance suggests that there is room for improvement in port productivity and governance.

The New Zealand port industry has the characteristics of having a high unionised workforce. In order to increase productivity at New Zealand ports the Productivity Commission concentrated on the relationship between New Zealand port companies, their workforces and their Union representatives, concluding that progress is required in the governance structures of unions, as "well governed unions with high-quality leaders can play an important role in overcoming the barriers to achieving high-productivity workplaces, while also advancing the wages and conditions of their members" (page 2).

The *Future Freight Solutions: An Agenda for Action* report completed by The New Zealand Business Council for Sustainable Development<sup>8</sup> in April 2011 reviews multiple studies (both government and private sector produced) on the freight inefficiencies and capacity constraints in New Zealand and brings together the key discussions points on how to develop an efficient and sustainable freight

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<sup>8</sup> The Sustainable Business Council is a CEO led group of companies that catalyses the New Zealand business community to have a leading role in creating a sustainable future for business, society and the environment. More information can be found at <http://www.sbc.org.nz/>

transport sector.

The potential ways to improve New Zealand's logistics chain outlined by The New Zealand Business Council for Sustainable Development (2011) report which are most relevant for this research are:

- Increase the size of the ships, trains and trucks we use to help cut costs, and which may reduce frequency.
- Schedule loadings and unloading better so there is less waiting time when collections or deliveries occur.
- Increase the volume going through a facility (port or depot) so that the people and machinery, like cranes, are used more frequently and costs are reduced.
- Create regional hubs or "logistics cities" close to existing ports or rail lines so that transfers of containers or bulk cargoes can move away from city streets or residential areas.

They did not research what has been applied internationally, nor did they complete research on whether or where the ways identified would actually work.

Rockpoint Corporate Finance also completes regular reviews of the components of the national logistics network, and identifies components where problems exist. However, there is little research completed on international supply chain theory or testing of whether/where initiatives to improve supply chains would be more successful.

In August 2010 the New Zealand Shipper Council, made up of large New Zealand export organisations released a report titled *The Question of Bigger Ships* which investigated the costs and benefits of New Zealand ports investing to cater for container vessels with a capacity of 5,000 to 10,000 TEU, concluding that New Zealand could realise up to \$144 million of net supply chain benefits with bigger ships operating on the most important trade route.

The recent New Zealand port specific publication is the Upper North Island Ports Study which was completed between academic and industry stakeholders and details the expected cargo throughput demand at the Auckland, Tauranga and Whangarei ports and the most rational means of catering for the expected demand.

In summary, there is limited academic research on the New Zealand port sector, but there is significant research led by industry and government sector participants. However the industry research concentrates on the most effective means of getting goods to and from ports (the inland distribution leg) and the need to handle big ships. There is no research on the relationships between productivity and capacity or research which outlines **how** ports should invest to increase productivity and capacity given scarce financial and operational resources. This research investigates the relationship between volume, capacity utilisation and productivity of New Zealand container ports. It adds significantly to the limited New Zealand academic literature on the performance of New Zealand container terminals, and will help inform decisions on the best means to invest scarce capital to increase the productivity in New Zealand.

Greater understanding of port operations is important for New Zealand, as well as worldwide, as ports facilitate trade and are gateways to the globalised market – which small open economies such as New Zealand are reliant upon. Exponential growth in trade volumes combined with continuous increases in ship size and technological advances in [container] handling have produced a constantly changing environment for port development. Therefore, if New Zealand is to take advantage of the international markets by increasing the efficiency of its import and export logistics, and in particular its ‘port gateway’ then a detailed understanding of this constantly changing industry and how to extract maximum productivity out of a scarce infrastructure resource will be required. This research investigates the relationship between volume, capacity utilisation and productivity of container ports. It will help provide further understanding for container terminal operators and countries aiming to handle future increases in container volumes, while maintaining productivity levels or having limited ability to expand.

## **2.4 OVERVIEW OF CONTAINER PORTS**

At the simplest level the function of a container terminal is the transfer and storage of containers. Containers are sorted and stored in the container yard and transferred to landside transport modes or stevedored onto or off of container vessels (Le-Griffen and Murphy (2006) page 3). However, in reality, a container terminal is a much more complex operation and links regional trade and the business located in close proximity under the port centric logistics concept to the international market. Bielli, Boulmakoul and Rida (2006) outline that a container port provides the interface between railroads, ocean going ships and road trucks and represents a critical link in the intermodal chain.

In explaining the operational components of a container port, the division of the totality of the container terminal operation into smaller components for explanation is different depending on the author and the intended level of detail. Henesey (2006) outlines the four components of a container terminal being ship to shore, transfer, storage and receipt/delivery. Ship to shore is the movement of containers from wharf to and from container vessels using quay cranes. Transfer is the movement of containers between the wharf/crane area and the storage area, usually using container trucks, straddle carriers, automated gantry vehicles or gantry cranes. The storage component covers the storage and organisation of containers in large stack, easily accessed by the wharf or gate operations. The receipt/delivery of containers refers to the gate between road and/or rail land transport access and the access to the storage component for container being imported and exported by the port.

Bielli et.al (2006), on the other hand, provide an overview of the container terminal by breaking a container terminal down into three components of quay crane operations, storage yard operations and shuttle truck operations. In this description the transfer and storage components outlined above by Henesey (2006) are combined to form the storage yard component.

This research outlines below, the three components of a container terminal being; Waterside (cranes and stevedoring), yard operations and land transport integration. The transfer functions are incorporated throughout the other elements.

#### **2.4.1 Waterside – Cranes and Stevedoring**

The operational task of loading or unloading a container vessel is completed by cranes and stevedoring at the waterside, or wharfside location. The crane refers to the infrastructure used and the stevedoring refers to the labour component carrying out the task through the use of the infrastructure.

The main wharfside infrastructure used in this operational component is the quay crane. "A quay crane is a crane that services containership by shifting on a rail to reach the assigned stowage within the same ship and also to move from one ship to a successive ship once the first one has been completed" Bielli (2006) (page 1732).

Prior to the unloading of containers from a ship and after container have been loaded, workers must lash/unlash containers to secure them on the vessel to minimise damage at sea. Depending on the productivity measure and the method of recording labour time, the lashing activities can impact on the

productivity recorded for the loading and unloading of the ship.

Other potential operational delays which may restrict crane operations are:

- The time that the crane takes to move between storage bays of the vessel
- Hatch lids. Hatch lids are large sheets that form the deck of the ship, which are removed once the above deck section of a container ship storage bay is empty in order to access the below deck component of a storage bay. Usually hatch lids are placed behind the crane (in its backreach) but in the case of Lyttelton there is no room, and containers are stacked up to the back of the crane, the crane is required to move up the wharf, place the hatch lid and then move back into position
- Ordering/sequencing of planned moves on the container vessel – if these are not planned effectively it may result in restows and DLRs (Discharge, Load and Re-loads) – with the crane handling each container on multiple occasions, increasing operating costs and decreasing productivity

#### **2.4.2 Yard**

The function of the yard is to organise and store containers and integrate with both landside and shipside operational requirements. The yard is organised upon the requirements of different containers, including import and export, empty or full, origin and destination and the type of container. Bielli et.al (2006) outline “containers destined for a particular ship are placed together. In the same way, specialty containers, empty containers and port specific containers are stored in designated areas” (page1734). Twenty and forty foot containers are also typically stored separate from each other.

The pickup of full containers for loading to the ship or land transport requires that the exact container is provided. While the sequence of loading and discharging a ship can be planned and sequenced to minimise the process of gaining access to a particular containers under another container, the pickup of containers from land transport operators is carried out on a more random basis, unplanned by the container terminal. Therefore, lower stacks with straddle access into the middle of a bay are the most efficient as they reduce the possibility of the required container being buried deep or within a block

stack. In the case of empty containers though, operators call to pick up a particular type of container, rather than an individual container, which allows for higher block stacks and the use of forklifts.

The organisation and optimisation of yard operating equipment and the seamless integration of the yard and either landside or wharveside activities are carried out through customised computer software to optimise movements and minimise total operating costs. Bielli et.al (2006), on page 1734, suggests that “stacking requires that close attention be paid to the location, or address, of the containers to prevent multiple restows or misplaced containers”, which would lead to multiple straddle moves, increased costs and a reduction in productivity. Some international ports have moved to automate the functions of gantry yard operational equipment by implementing technology allowing for the 24/7 unmanned operation of all stacking cranes, aimed at reducing mechanical damage caused by operator skill, improving container tracking through reduced miscommunication and reducing operational costs through reduced labour costs (Blaiklock (2013)).

### **2.4.3 Landside**

The standard of investment in land transport connections and a port’s connection to the urban agglomeration has a major impact on the financial and operational success of individual ports. As Le-Griffin and Murphy (2006) outline “throughout most of maritime history, the competitiveness of a commercial port has been collectively determined by its geographic location, its physical characteristics and its relationship to landside transportation systems and urban centres” (page 1).

Road and rail land transport operators are loaded or unloaded by the terminal operating equipment (gantries, straddles and forklifts) outlined above. The productivity provided to the port’s landside stakeholders dependent of the deployment of the container terminal’s equipment and labour across the yard, wharf and landside components.

### **2.4.4 TEU vs. FEU vs. Container Units**

Introduction, outline and clear definition of the TEU, FEU and Container units is required at this stage to provide the understanding necessary to easily articulate the remainder of this research as the terms are used interchangeably to describe a container but the three terms don’t equal the same

The World Shipping Council<sup>9</sup> outlines the difference between TEU and FEU “the 20-foot container,

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<sup>9</sup> <http://www.worldshipping.org/about-the-industry/containers>, retrieved 21 September 2014 at 12:26pm

referred to as a Twenty-foot Equivalent Unit (TEU) became the industry standard reference so now cargo volume and vessel capacity are commonly measured in TEU. The 40-foot length container - literally 2 TEU - became known as the Forty-foot Equivalent Unit (FEU)". A container unit is counts each container as one, regarding of whether it is a TEU or FEU.

## **2.5 PRODUCTIVITY OF A CONTAINER TERMINAL**

The Oxford Dictionary (7<sup>th</sup> Edition, 1982) defines productivity as the production per unit of effort or the effectiveness of productive effort. Tipper and Warmke (2012) suggest that productivity is a measure of how efficiently inputs (such as machinery, computer software, land and labour) are being used to produce outputs.

As outlined above, the container terminal has three distinct components – the wharfside operations, yard operations and landside operations – all with different productive inputs, operational output and, therefore, determinants of productivity. Le-Griffin and Murphy (2006) outline that productivity of the entire container terminal is directly related to the transfer functions of container terminal, including the number and movement rate of quayside cranes, the use of yard equipment and the productivity of workers employed in waterside, landside and gate operations – therefore each component is vital to the overall productivity performance of the port. However, productivity analysis and reporting is usually restricted to, or concentrated on, only to wharfside or stevedoring component.

This is a result of the transfer function between wharf and container vessel being the largest revenue component for a container port. New Zealand ports generate the majority of their revenue by providing marine and wharfside services (including wharfage, pilotage, and stevedoring) to international shipping companies (Productivity Commission (2012)). Shipping companies then bundle the port charges with the charges of the international sea leg before passing a total charge onto the freight owner/transporter/freight forwarder. This charging regime results in a focus towards increasing the productivity of terminal operations so that a vessel can be serviced faster, spending less time in port, and providing the shipping company with the ability to generate further revenue.

UNCTAD (2004) supports this suggesting that the segmentation of the port market has traditionally been oriented towards the sea-leg component of the transport chain; with port marketing and competitive strategies being typically formulated to meet the requirements of sea transport and related shipping services. Bielli et.al (2006) states that quay crane operations provide “the single most

important operation (called move) associated with loading and unloading a ship” (page 1732). Kasypi, M and Shah. M (2013) suggests that high wharf or crane productivity is a measure of a good container terminal and able to attract shipping line to berth.

The Tioga Group, in 2010, completed a report as part of the Cargo Handling Cooperative Program, which is a public-private partnership sponsored by the United States Maritime Administration, with objective of increasing the productivity of cargo transportation companies through the implementation of cargo handling research and development. They reviewed the technical and industry literature to determine how port productivity could and should be measured in the United States and assembled the available data into a set of marine terminal profiles. They outline a number of different productivity measures including TEU per hectare, TEU per berth, crane moves (of TEU) per hour, vessel turn times, and TEU or crane moves per man/labour hour. These measures of productivity are used by different ports, with different infrastructure and commercial drivers. Kasypi, Shah and Mohammad (2013) provide the summary table of the measures of productivity typically used across the different elements of the container terminal:

Element of Terminal	Measure of Productivity	Measure
Crane	Crane Utilization Crane Productivity	TEUs/Year per Crane Moves per Crane-Hour
Berth	Berth Utilization Service Time	Vessel/year per Berth Vessel Service Time (hrs)
Yard/Storage	Land Utilization Storage Productivity	TEUs/Year per Gross Acre TEUs/Storage Acre
Gate	Gate Throughput Truck Turnaround Time	Containers/hour/lane Truck Time in Terminal
Gang/Stevedore	Labor Productivity	Number of Moves/Man-hour

**Figure 2.3: Summary of the measures of productivity typically used across the different elements of the container terminal Source: Kasypi, Shah and Mohammad (2013)**

However, a critical suggestion made by the Tioga Group (2010) is that the productivity measured and analysed by ports, industry groups and academics is more closely aligned to the data available:

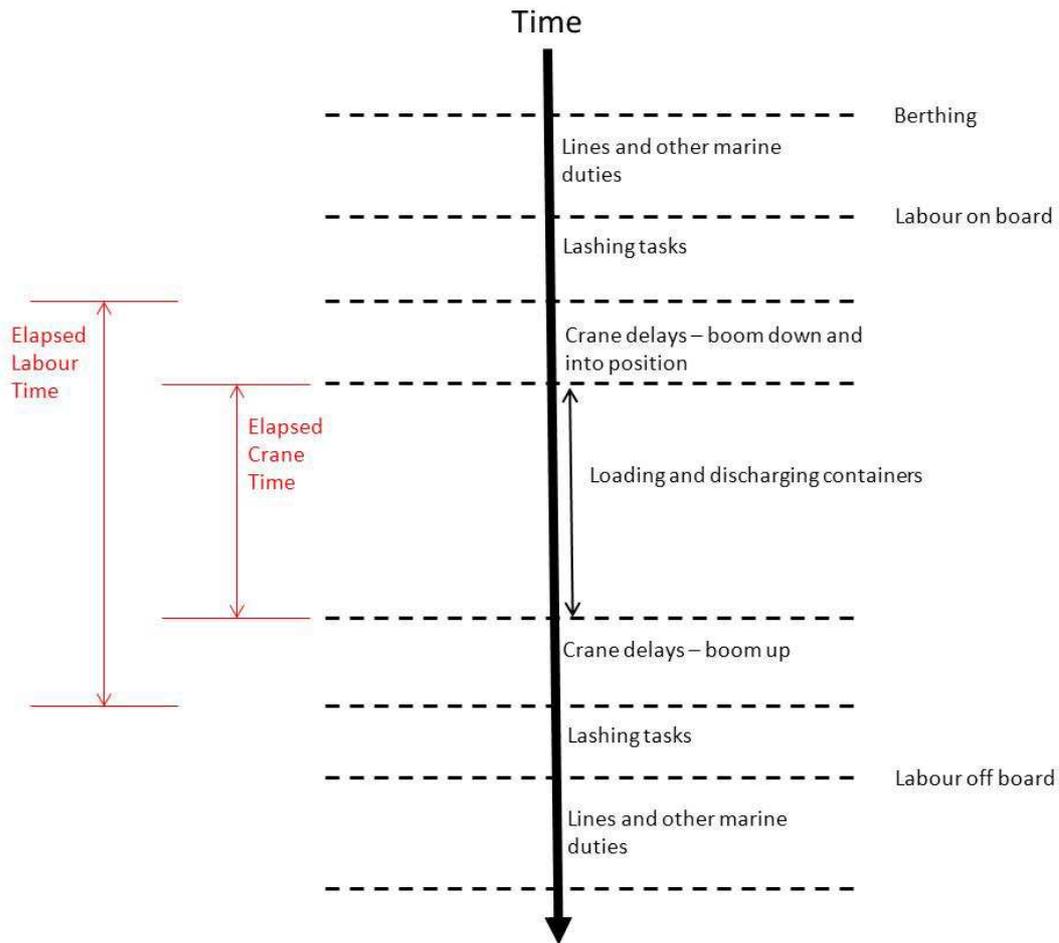
The general approach used in this study was chosen primarily to suit the readily available port and terminal data elements, with the anticipation of regular data collection, analysis, and publication. More precise estimates are possible, but would require a much greater investment in data collection and analysis, and would change frequently as ports and

terminals change their facilities and operations. Tioga (2010, page 2)

The data and analysis completed by industry and government participants in New Zealand and Australia (in particular New Zealand Ministry of Transport (2013) and The Australian Bureau of Infrastructure, Transport and Regional Economics) typically concentrates on the ability of individual cranes or a collection of cranes in loading and loading container vessels – i.e. TEU or crane moves per hour or per labour hour as this information is more readily available and consistently measured by container terminals.

The New Zealand Ministry of Transport has, since 2009, been working with New Zealand container ports to obtain data on productivity. The purpose of the Freight Information Gathering system is “to provide a detailed understanding of this traffic, including volumes, export/import imbalances, and the mode of inland transport used to carry cargo to and from ports” (Ministry of Transport (2012)). The container ports provide the number of containers handled (in units), the average crane rate, ship rate and vessel rate, which are directly comparable to the Australian Bureau of Statistics reporting of Australian Port Productivity.

Figure 2.4 outlines the high level timeline of tasks involved in completing the stevedoring operation and highlights the difference between elapsed labour time and elapsed crane time and their impact upon the calculation of vessel and ship productivity rates.



**Figure 2.4 Timeline of Tasks Involved in Completing the Stevedoring Operation Source; Authors own work based on observing tasks at Lyttelton Port of Christchurch and CentrePort Wellington**

The variables monitored by the Ministry of Transport are:

- Total container units (as opposed to TEUs or FEUs) – total containers handled, irrespective of whether they are twenty foot or forty foot units. Both twenty foot and forty foot containers equate to one unit.
- Crane Rate – the average number of containers handled by a single crane for every hour that it is used to load or discharge a vessel. The crane rate is calculated by dividing the total container handled by the elapsed crane rate. This measure excludes all operational and non-operational delays such as wind, hatch lids and lashing tasks, as outlined by Figure 2.4.
- Ship Rate – the average number of containers handled per hour, across all cranes employed, for every hour that cranes are used to load or discharge a vessel. The ship rate excludes all operational and non-operational delays. It is calculated by multiplying the crane rate by crane

intensity. Crane intensity is measure of the number of cranes employed to load or discharge a vessel.

- Vessel working rate – the average number of containers handled for every hour that labour is employed on the berthed vessel – i.e. the total number of containers handled divided by the elapsed labour time. The vessel working rate includes all operational and non-operational delays and therefore the reported productivity figure is typically lower than ship rate figure.

The Ministry of Transport describes the measures used as “the crane rate is a measure of the average productivity of container cranes at a port after allowing for operational and non-operational delays in using cranes. However, the crane rate does not reflect the productivity of a port’s container terminal operation which may use two or more cranes to load and unload containers from a ship. The ship and vessel rates help to give a better overall perspective of container productivity at a port”. (page 1. Ministry of Transport (2011), Container productivity at New Zealand ports, October 2011),

The Australian port statistics outline further measures of port productivity, however, “the Ministry [of Transport in the New Zealand case] believes that looking at the three measures gives a good initial overview of container productivity at New Zealand ports” (page 1. Ministry of Transport (2011), Container productivity at New Zealand ports, October 2011).

The Australian Government’s Department of Infrastructure and Transport’s Bureau of Infrastructure, Transport and Regional Economics produces quarterly statistical reports titled *Waterline*. The *Waterline* reports provide details on trends in container handling productivity of the five major Australian container ports – Brisbane, Sydney, Melbourne, Adelaide and Fremantle – as well as the

The *Waterline* reports provide detailed trends in the stevedoring productivity (shipside productivity) and costs of importing and exporting containers. However, unlike the New Zealand productivity trends published by the Ministry of Transport, the *Waterline* reports also outline the productivity of landside performance. These measures include truck turnaround times on average for each port, the number of vehicle booking slots available against the number used, and at what periods during the day and other non-financial statistics.

Lubulwa, Lightfoot and Malarz (2010) analyse the stevedoring productivity of Australia’s five major container ports with the aim of gaining a better understanding of what drives performance at an individual container port. They conclude that there have been significant improvements in both labour

productivity and total factor productivity between 2000 and 2009 at each of the five ports. They also suggest that stevedoring operations became more capital intensive in general and stevedoring operations at all five ports were also found to have experienced decreasing returns to scale during this period.

The productivity of New Zealand container ports ranks well against Australasian counterparts. The Ministry of Transport (2011b) study of port productivity rates of New Zealand's six largest container ports concluded that "the container productivity of New Zealand ports appears at least comparable with, and in some cases better than, Australian and other international ports". Port of Tauranga is clearly the most productive New Zealand port, however the relative productivity of other New Zealand ports depends on the productivity measurement considered and the strategic objectives, container throughput or equipment employed of each port.

## **2.6 CAPACITY OF A CONTAINER TERMINAL**

The Oxford Dictionary (7<sup>th</sup> Edition, 1982) defines capacity as the maximum amount that can be contained, received, experienced or produced.

The Tioga Group (2010) study of U.S container ports is the most comprehensive analysis of container port productivity and capacity. The Tioga Group (2010), Merckx (2013) and UNCTAD (1999) outline that the capacity of a container terminal has the following constraints:

- Container yard area and stacking height – enough space and density is required to avoid congestion
- Operating hours – enough hours and labour hours are required to service the entire vessel
- Berth length and draft – berths need to be long and deep enough, with enough cranes to avoid vessels waiting for each other causing delays

Evaluation of the capacity of the container terminal using the above factors assumes that the berths and yard space are dedicated to container operations, as is the case in most large container terminals, rather than a mixture of container and bulk operations. The inputs to the terminal operations, which seek to maximise that productivity and utilisation of capacity in the five dimensions above, are labour, capital equipment (such as gantries, straddles or forklifts in the yard and the wharfside crane), land and systems and technology used in organising and optimising terminal

infrastructure and labour.

There were three methods employed by the Tioga Group (2010) to calculate container terminal capacity. One was a calculation of the yard capacity, second was the wharf capacity and third was the vessel capacity. The yard capacity was completed through the calculation:

$$\text{Total annual throughput capacity} = \text{the number of container slots available} \times \text{the annual rate of slot turnover}$$

The number of slots available is equal to the total area of the container terminal divided by the slots per acre and is dependent upon the equipment and the stacking technique employed. The slot turnover is dependent upon the throughput and average dwell time of the terminal. Dwell time is an important factor in the analysis, and is information not often published in New Zealand port statistics. Merckx (2013) suggests that a dwell time decrease of 50% (i.e. 6 days to 3 days) gives capacity increase of 100% across the six terminals within his analysis.

The Tioga Group (2010) suggests completing this yard capacity calculation under two scenarios, one at peak and one at a sustainable level, as it is unlikely that the maximum annual slot turnover is sustainable day in day out, although it is theoretically possible as a peak demand or loading on the system. Their study team assumed that the sustainable container yard capacity was 80% of the peak container yard capacity, following an industry rule of thumb.

The 1999 Port Master Plan for the Port of Anchorage, Alaska, United States of America<sup>10</sup> uses the phrases “maximum practical capacity” and “sustainable practical capacity”. The Facilities Plan section outlines that the maximum practical capacity of a terminal is defined as the high end of a realistic operating scenario, representing the peak operation of a terminal. Sustained operation at this level for a significant period of time is generally uneconomical, impractical and unsafe. The section goes onto also suggest that prolonged operations at 100% of maximum practical capacity tend to drive up operating and maintenance costs and are considered unrealistic for long durations. Therefore a 75% to 85% capacity utilisation is assumed as a sustainable practical capacity for the basis of terminal and port planning and future facility demand analysis. This is a suggestion aligned with the Ports of Auckland 2008 Port Development Plan<sup>11</sup> which suggested that “peak yard capacity is critical for

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<sup>10</sup> <http://www.muni.org/Departments/port/Pages/MasterPlan.aspx> retrieved 4 October 2014 at 9:52am.

<sup>11</sup> [http://www.poal.co.nz/news\\_media/publications/POAL\\_port\\_development\\_plan\\_2008.pdf](http://www.poal.co.nz/news_media/publications/POAL_port_development_plan_2008.pdf) retrieved on 4 October 2014 at 10:04am.

handling larger vessels, because of the larger container exchanges which need to be accommodated” (page 13).

Liu (2010) suggests that ports are required to keep operational levels well below capacity as a means of providing the platform for growth. He suggests that “productive headroom not only attracts more traffic to the port, but it is a signal of its reliability, a crucially important factor for port users” (page 86). Productive headroom is especially important in high growth or volatile markets.

Merckx (2013) suggests an alternative calculation of yard capacity being:

$$\text{Total annual throughput capacity} = [\text{the number of ground slots available} \times \text{maximum stack height} \times 365] / [\text{average dwell time} \times \text{peaking factor}]$$

Where the peaking factor is the maximum stack height divided by the average stack height. This is a calculation method widely used in terminal capacity analysis, since the first being outlined by Dally and Maquire in their 1983 publication *Container Handling and Terminal Capacity*.

The information requirements are different for the two different yard capacity calculations. The most suitable calculation method will therefore require examination of the information available.

The wharf/crane capacity was completed through the calculation:

$$\text{Total annual throughput capacity} = \text{the number of container cranes available} \times \text{the number of crane hours available to each crane} \times \text{average crane rate}$$

The number of cranes available will depend upon the infrastructure availability of individual ports. The Drewry (2010) report concludes that the average annual volume handled per gantry crane across the industry is only around 55-65% of each crane's "real world" capacity (i.e. taking into account downtime for maintenance and typical maximum berth occupancy levels).

The analysis of maximum vessel capacity carried out by the Tioga Group (2010) evaluated the vessels calling at a port and examined the utilisation of slots on a vessel when entering and exiting a port. This method is not appropriate for New Zealand ports as the vessel call rotation which calls to multiple New Zealand ports in between entering and exiting New Zealand trade waters means that vessel utilisation would typically be low. Also, the utilisation of vessels is not something that the ports have great influence over.

Other academic research papers use simultaneous equations and mathematical models to model the capacity of each section of the container terminal and compute the capacity of the container terminal based on the model of each section and the relationship between each of the sections (Huang, Hsu,

Chen, Ye and Nautiyal (2008)). Simultaneous equations and large mathematical models are difficult and timely to set up and provide very little benefit to the analysis of the individual equations outlined above. Simultaneous equations also present challenges when reporting the results of analysis due to the inherent detail and complexity.

Many of the largest international container terminals are currently reaching their maximum capacity. Henesey (2006) illustrates that this is the case at large North West European terminals such as Antwerpen, Bremerhaven, Hamburg, Rotterdam and Southampton with utilisation, in 2004, of 92.9%, 95.5%, 93.2%, 92.5% and 99.3% respectively. Even though these ports have a container throughput up to 5 times that of New Zealand ports, they are still struggling with the same problem of maintaining and growing capacity in the face of rapidly increasing throughput demand while maintaining productivity levels to shipping lines.

While these North West European terminals are operating at high levels of utilisation, Drewry (2010) suggest that Asian and Middle Eastern terminals generally achieve considerably more intensive use of their resources (quayline, cranes and land) than European ones and that North American terminals are generally at the lower end of the scale, particularly in terms of the intensity of land usage.

There are difficulties associated with operating at a high capacity utilisation and maintaining suitable levels of productivity to satisfy container shipping line customers. Haralambides (2012) outlines that once 70% port capacity utilization has been reached, congestion starts to set in. And, today, congestion is not an option given the supply chain pressures and dependencies. However, excess capacity is difficult to sell to the taxpayer or investor and many ports continue to operate effectively beyond this level of utilisation.

## **2.7 MEANS OF INCREASING CAPACITY AND PRODUCTIVITY – INLAND HUBS**

This research concentrates on determining the most optimal means of increasing productivity and capacity to allow New Zealand ports to handle the increased throughput that will result from changes in market demands and customer requirements. This is an approach supported by Wilmsmeier and Monios (2013):

“Ports today can no longer expect to attract cargo simply because they are natural gateways to rich hinterlands. The ports’ role has changed from a monopoly to a dynamic inter-linkage and to a subsystem in the logistics chain (Robinson, 2002), significantly influenced by the

availability of infrastructure in its hinterland and the infra- and superstructure provided [by the port] to connect the maritime and inland transport systems” (page 3).

Different operational processes of the road, rail and barge transportation methods of getting things to and from port has traditionally resulted in a large space requirement due to the different timing and space requirements of each inland transport mode Rodrigue (2009). As a consequence, even with increased productivity and turnover, the space consumed by container terminals has grown substantially to a point where inland terminals spaces have developed where shipside land is not available.

An inland hub or dry port refers to an inland consolidation point for freight that is connected with a port terminal through rail, barge, or truck services, often through a high capacity corridor and has supply chain management practices that are integrated with a deep sea terminal. Le-Griffin and Murphy (2006) suggest that “terminal operators [at the Port of Long Beach] will need to improve their capacity while avoiding higher handling costs. One method of accomplishing this is to move some containers to holding sites outside of the terminal area, farther inland, where there is more land available for storage” (page 18).

Inland hubs allow the port particular benefits in the face of capacity constrained operations wharfside, in particular inland hubs allow ports to:

- Carry out non-essential activities away from port where deep sea terminal have limited land available for expansion. This leads to an intensification of activities at the main terminal and the search for lower value land locations which can support less intensive freight activities— Lyttelton Port’s CityDepot is an example of this, where empty containers are stored offsite and railed to port when required.
- To penetrate the local hinterland of competing ports, extend the cargo base and increase market share. This is the case for Port of Tauranga’s inland port (called MetroPort) being located in South Auckland. The Reserve Bank of New Zealand’s paper titled *Any port in a storm? The impact of new port infrastructure on New Zealand exporter behaviour* concluded that the dramatic increase in usage of Port of Tauranga following Metroport’s opening shows that distance to port is a factor over longer distances – many firms do not export through Tauranga until the logistics are made easier for them.

Notteeboom and Rodrigue (2000), on page 16, summarise the use of inland hubs and their integration with the portside operation:

The process of integration between maritime and inland transport systems increasingly results in a number of penetration and modal shift strategies where each mode is used in its most cost and time effective way. These configurations can ease the pressure on deep sea container terminals by moving the sorting functions inland, thus increasing the efficiency of existing terminal and the overall throughput.

Inland terminals are well advanced in Western Europe and North America, with a close integration of port terminals and land transport modes due to a large portion of the market being inland. Whereas in Asia, like New Zealand, coastal population concentrations and export oriented development strategies have meant that the development of inland freight hubs is not as advanced.

An example of a large scale inland port in New Zealand is the 300 hectare inland port and commercial hub at Ruakura (East Hamilton) currently being developed by Hamilton-based Tainui Holdings to serve Auckland, Bay of Plenty and the Waikato regions. The property will be served by existing rail and the planned Hamilton bypass (a key section of the Waikato Expressway – a road considered of national importance). The inland port will sit halfway between the Ports of Auckland and Tauranga and will include light industrial, distribution centres for major retailers and commercial activities. The project is expected to be in place in 2018/19 and the long lead time for development is designed to give logistics companies, manufacturers and distributors time for long term planning around this new option.

Inland hubs also provide benefits outside the port, benefits to the greater logistics network outside if they are set up correctly. These benefits include increased freight consolidation (Campbell (1990), Bot and Neumann (2003), Ministry of Transport (2010), Marshall (2011)), a reduction in unproductive backhaul movements of empty containers (PricewaterhouseCoopers and the Supply Chain Management Institute (2010), Rodrigue (2009), Hummels (2009), Takahashi (2010), Konings (2005), Cooper (2011)) and more effective modal integration (Ruijgrok and Tavaassy (2007), Mainfreight (2011)).

## **2.8 RELATIONSHIPS BETWEEN THROUGHPUT, PRODUCTIVITY AND CAPACITY**

The development of container port systems, in terms of their capacity and performance, is an area that internationally does have some coverage in academic research. This is not surprising given that the logistics activities of a container terminal are costly, complex – combining the use of several expensive resources (berths, cranes, terminal yard equipment and specialised labour) – and contribute significantly to worldwide trade (Legato and Mazza (2001)). The coverage of these relationships in international academic literature ranges from the traditional analysis of port expansion and upgrading of berthing and handling facilities to the more recent focus on port competition through hinterland accessibility (Wilmsmeier and Monios (2013)).

As detailed extensively in the industry background, the growth in container throughput of major container terminals has been fast since the outset of containerisation. However, the container terminal is usually physically constrained in terms of the land area available for use – obtaining further land is usually expensive and environmentally difficult (Konings, Pielage, Visser, and Wiegmans (2007)). In terms of the capacity utilisation equations previously outlined, if the slot turnover remains and the yard size remains the same, yard capacity utilisation would increase as throughput volume increases. With respect to the crane capacity, if the number or productivity of cranes remains constant, the utilisation of crane capacity would also increase with the increase of the container terminal's throughput volume. The rate of increase in capacity utilisation that results from increase in throughput volume will be dependent on the overall capacity calculated and the actual level of container throughput. Therefore volume and capacity utilisation have a positive relationship.

Assuming the container terminal is operating efficiently, the alternatives for increasing container terminal capacity include increasing the size of the land area of the terminal, increasing the investment in yard stacking equipment or increasing the number of cranes or berths. Ilmer (2014) illustrated that European container ports have been required to increase productivity levels in order to minimise port time for increasing vessel sizes and that the first response of container terminal operators was to invest in new hardware such as gantry cranes and yard equipment. This illustrates the expected negative relationship between capacity utilisation and productivity – as capacity increases, capacity utilisation decreases and productivity increases.

Given the cost and scale of increasing land availability or crane equipment, they are only completed when they are vital. In other cases, container terminal managers are required to maximise throughput

growth at higher levels of capacity.

Container terminal managers can use techniques to gain capacity, however the consequences of changes need to be managed as there may be negative repercussions. One operational technique a container terminal manager has to increase the available capacity is to increase the rate that containers turn over – achieved through reducing the average dwell time (the time the container stays in the yard for). As outlined in the Merckx (2013) presentation “a dwell time decrease of 50% (i.e. 6 days to 3 days) gives capacity increase of 100% across the six terminals within his analysis” (page 34). However, the decrease in dwell times directly results in a greater number of slot turns if the land area of the terminal remains constant, further pressure on operating equipment throughout the container yard and downward pressure on productivity rates (as terminal equipment is working on yard rotation rather than servicing the wharf crane). Therefore, there is a balancing act between capacity and productivity as there is an inverse, or negative, relationship between the two variables.

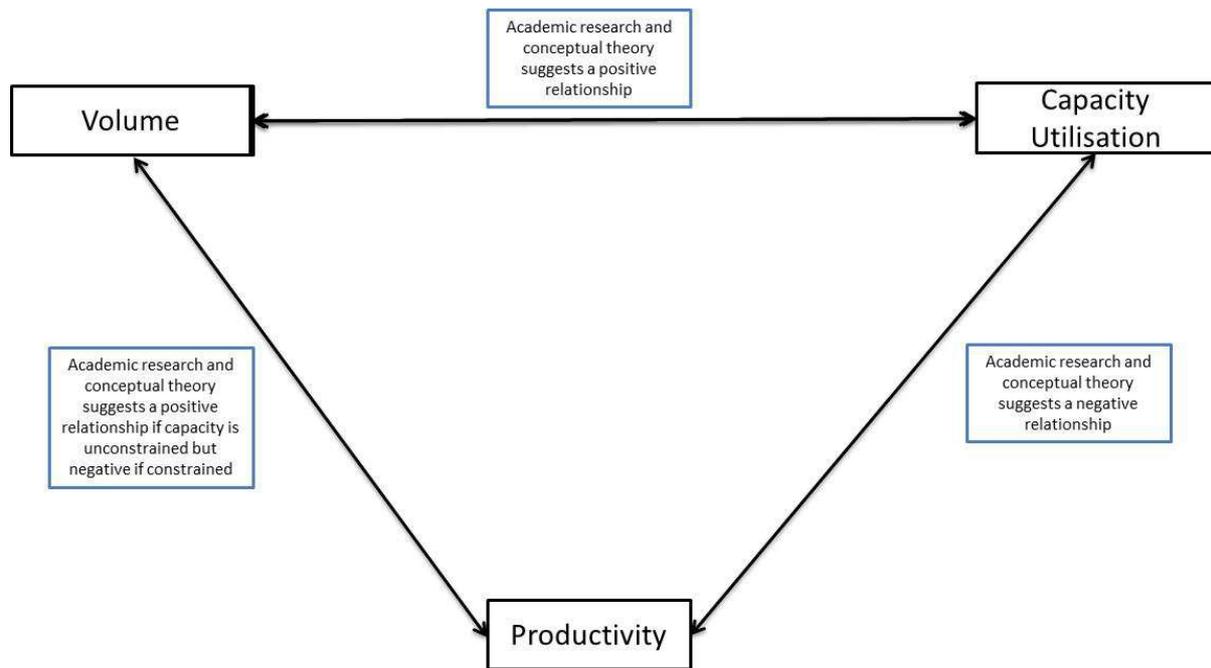
As Le-Griffin and Murphy (2006) outline, the utilisation of ground space available is vital. However, heavily utilising ground space means stacking containers higher, reducing operational accessibility and reducing yard (and therefore crane) productivity. Therefore there is a negative relationship between volume or capacity and productivity.

As throughput volume increases, so does utilisation of capacity. Increases in capacity utilisation have a negative impact upon terminal productivity. However, this may not be the case at an individual vessel exchange level. Merckx (2013) provides an insight into the Port of Singapore Authority’s research into their productivity across their six international container terminals handling approximately seven million containers per annum. He suggests that the total vessel productivity increases as the size of vessel exchange increases, indicating a positive relationship between vessel productivity and exchange size. This is also the case with the New Zealand ports of CentrePort Wellington and Lyttelton Port of Christchurch based on my time spend in their operating environments and the anecdotal evidence generated through discussions with the terminal managers at each port. The line of thought is that economies of scale increases productivity of the port, this however assumes that capacity is unconstrained. Tuner, Windle and Dresner (2004) conclude for North American container ports that the increased economies of scale between 1984 and 1997 increased in the productivity of container ports.

The other balancing act that container terminal managers must manage is between productivity and cost/staff resourcing. Hanh Dam Le-Griffin and Murphy (2006) assess the productivity indicators typically used by the shipping industry and determine whether maximising these indicators is the most appropriate goal for the container terminals of Los Angeles and Long Beach. They conclude that both ports are operating at a productivity level less than other ports compared because their competitors have better terminal technologies (automated stacking cranes for example). However, existing operating agreements between terminal operators and port labour prevent the implementation of such technologies and practices to increase productivity only escalate costs. The container terminal managers in New Zealand that I have worked with in Lyttelton and Wellington have also outlined that they are under constant pressure to minimise average labour costs per container handled while maintaining high productivity levels.

Inland hubs allow the port to carry out non-essential activities away from port where deep sea terminal have limited land available for expansion. As the inland hub allows a decrease in reliance on the port side container terminal land, containers are not slacked as high, and there is less yard congestion (if operating a straddle yard). This results in, theoretically, an increase in container terminal productivity.

A summary of the theoretical or conceptual relationships between volume, capacity utilisation and productivity is outlined in Figure 2.5.



**Figure 2.5: Theoretical Relationship between Volume, Capacity Utilisation and Productivity. Source: Author's own work**

Throughout the analysis and discussion these variables will be estimated and the relationships between the variables analysed.

## 2.9 SUMMARY

The development of logistics as a separate academic or industrial topic occurred in the 1950s, although there is still debate as to whether this was as result of military operations or private sector business process. Regardless, logistics has always been a critical component of the economy. Recent academic literature highlights an integrated approach to logistics with collaboration between industry/supply chain stakeholders, at both an international and domestic level.

Due to the reliance on maritime transport for global trade, the development of the logistics industry has been intrinsically linked with the development of ports. Ports serve the purpose of connecting the countries to the world market, allowing trade and economic development. They connect the waterside logistics sector with the landside logistics sector

Up until the beginning of the 1960s, general cargo was transported in various forms of packaging and loaded into relatively small general cargo vessels in a shelf like arrangement where goods were stowed in small pre-packaged consignments according to destination, resulting in port congestion, high transport costs, higher inventory holdings and restrained development of trade (Haralambides (2012). Containerisation, which can be traced back to 1956, has increased productivity at ports due to the repetitive nature and economies of scale associated with handling standardised containers. Containerisation has also allowed for the reduction in cost and time of inland transportation.

Traditionally, container ports have been seen as a place for loading and storage of containers – “the basic function of a container terminal is the transfer and storage of containers” Le-Griffen and Murphy (2006) (page 3) – or as a place where goods are shipped to and from (Henesey, 2006). However, increases in freight transport demand, changes in customer requirements and increases in port competition have resulted in the integration of landside and seaside activities at the port, and ports becoming a consolidation point for regional and worldwide trade.

The three components of a container terminal are; Waterside (cranes and stevedoring), yard operations and land transport integration. However, there are transfer functions incorporated between these three components. The waterside component refers to the operational task of loading or unloading a container vessel, completed by crane infrastructure and stevedoring personnel at the waterside, or wharfside location. The function of the yard is to organise and store containers and integrate with both landside and shipside operational requirements, using various types of yard

operating equipment and container stacking configurations. The landside component refers to the connection of the container terminal with the landside transport modes of rail and road transport.

Productivity analysis and reporting is usually restricted to, or concentrated on, wharfside or stevedoring component, even though, as Henesey (2006) outlines, the performance of a container terminal depends on a wide mix of factors affecting the individual components of a container terminal, rather than just the performance of the quay-side cranes. Ports are typically focused on the productivity of the wharfside component as it is the component which generates the majority of the port's revenue and is the interface which the container port's customers (the shipping lines).

The review of the literature highlights two main measures of capacity; crane capacity and yard capacity. The crane capacity is dependent on the number of cranes available, the crane operating hours available and the average productivity of the crane per hour. Yard capacity, on the other hand, is dependent on the number of container storage slots and the average rate of slot turnover.

Academic and industrial research also suggests that capacity rates should be calculated at two different levels; one at peak and one at a sustainable level, as it is unlikely that the maximum annual slot turnover or crane productivity is sustainable day in day out, although it is theoretically possible as a peak demand or loading on the system. Theoretically and traditionally empirically, as container throughput volume increases so too does the utilisation of yard capacity (unless the yard size or average slot turnover increases) and crane capacity (unless the number or average productivity of cranes increases). Therefore there is a positive relationship between volume and capacity utilisation – both variables move in the same direction.

However, as volume and capacity utilisation increases, the increased utilisation of ground space means stacking containers higher, reducing operational accessibility and reducing yard productivity. This will also result in crane capacity decreases if the labour and yard equipment is not increased to keep up with the wharfside operational demand. Therefore the relationship between capacity utilisation or volume and productivity is negative – the variables move in opposite directions. The relationship between volume and productivity may be positive in unconstrained conditions if increased volumes allow economies of scale.

An inland hub or dry port refers to an inland consolidation point for freight that is connected with a port terminal through rail, barge, or truck services, often through a high capacity corridor and has supply chain management practices that are integrated with a deep sea terminal. Inland hubs have, in recent times, been seen as means of capacity expansion and a way to improve productivity which is easier than traditional measures such as increasing yard size through land reclamation or increasing crane capacity through the expensive procurement of quay cranes. Therefore, it is expected that the throughput of the inland hub facility will have a positive relationship with terminal productivity (as inland hub volumes increase so does the productivity of the terminal) and a negative relationship with terminal capacity utilisation (as the through of the inland hub increases the capacity utilisation decreases at the terminal).

## **2.10 GAP IN LITERATURE AND WHERE THIS RESEARCH FITS IN**

New Zealand's small market, reliance on trade and significant distance from trade markets means that investing in effective and productive infrastructure is critical. One of the largest infrastructure components in the freight supply chain are ports.

There is significant industry and government demand for increasing the productivity of New Zealand container ports and the requirement for New Zealand to handle 'big ships'. However, there is a lack of academic research on the relationships of port productivity and the capacity requirements to handle freight growth, bigger ships and increased supply chain pressure in what is a key area for New Zealand trade and New Zealand's economy.

New Zealand research into the performance and capacity of New Zealand container ports is relatively scarce, and has a non-academic focus – it has been completed by industry participants. The industry research concentrates on the most effective means of getting goods to and from ports (the inland distribution leg).

This research focuses on the relationships between the productivity and capacity and the use of inland container hubs as an outline to how ports could invest to increase productivity and capacity given scarce financial and operational resources.

This research is important given New Zealand's reliance on trade and the need to carefully plan infrastructure investments in transport and freight – where funding is scarce.

There is no research, academic or otherwise, on the relationships between throughput volume, productivity and capacity for New Zealand ports. Greater understanding of port operations is important for New Zealand, as well as worldwide, as ports facilitate trade and are gateways to the globalised market.

This research focuses analysis on the New Zealand context where the domestic market is small in scale, there are a relatively high number of container ports with highly competitive and intertwined hinterlands, a lack of political direction in the port sector, an export focus and a long distance to international markets.

However, academically it may also be relevant and useful in informing other contexts such as:

- Other countries or areas where there is a requirement for, or trend in, port rationalisation or nations struggling with the optimal number or size of ports in a domestic market
- Other ports where they face the challenge of trying to cater for increasing ship sizes with a scale budget for investment in infrastructure
- Other small open economies with a reliance on trade and the performance of their port industry
- Any other country, area or port facing constrained capacity and large scale throughput growth
- Other trade areas with highly competitive hinterlands for example the study of Container Throughput and Capacity in the Mediterranean by Dynamar (2012) outlined that some of the ports monitored were situated so close to each other that they must be competing for the same hinterland business.

## **3 INDUSTRY BACKGROUND**

### **3.1 INTRODUCTION**

This chapter provides information on New Zealand trade, the importance of the New Zealand container port industry and the importance of correctly utilising New Zealand's scarce resources. The chapter provides information as to how the New Zealand container port industry fits with, and compares to, the international industry. The chapter concludes by outlining the trends and challenges currently being experienced by the New Zealand port industry. The purpose of the chapter is to contextualise the research setting in terms of the New Zealand container port industry and its relationship with the global logistics chain.

### **3.2 IMPORTANCE OF TRADE TO NEW ZEALAND**

Trade, and in particular exporting goods, is vital to New Zealand's overall economic growth. As a geographically isolated nation with a small domestic market, New Zealand firms are reliant on access to foreign markets to gain economies of scale, reduce costs of production and remain internationally competitive. Efficient access to large international markets allows the generation of profits, jobs and increased standards of living for the New Zealand population. The New Zealand International Business Forum (2011) outlines the importance of trade for the creation of employment opportunities in New Zealand

“Statistics New Zealand figures show that two out of three New Zealand jobs are dependent on trade. The New Zealand Ministry of Foreign Affairs and Trade estimate that \$4 of every \$10 our economy produces is generated by exports - so nearly half our income is generated by what we sell off shore.”

New Zealand does have a natural advantage in the production of agricultural, horticultural and forestry products due to the temperate climate and fertile soils that make it ideal for almost all land-based production. New Zealand's geographic isolation has also resulted in a natural environment and unique disease-free animal populations.

New Zealand also has a natural advantage in the production of seafood due to its long and narrow shape with extensive marine resources and an Exclusive Economic Zone which is one of the largest in the world (Teara (2014)).

However, even though New Zealand has a natural advantage in the production of these products, the geographic isolation of the New Zealand economy creates substantial challenges especially when this factor is coupled with the New Zealand economy's inability to create agglomeration benefits or a strong domestic market due to its lack of size (Redding and Venables 2002; McCann 2009).

The New Zealand Productivity Commission's Inquiry into International Freight Transport Services July 2011 Issues Paper outlines that New Zealand exporters will only be successful if either:

- The local cost of the goods exported plus trade costs are lower or equal in the destination market to the similarly-calculated costs of goods from competing sources; or
- The quality of their goods is sufficiently superior to outweigh any price disadvantage.

In either case trade costs and service levels directly impact the profitability of exporting industries, and if too high they may preclude a business from exporting at all. This is a view supported by Krugman and Venables (1995) who suggest that lowering trade costs may help New Zealand compete on the world stage. It is also a view supported by New Zealand's largest exporter – Fonterra managing director of trade and operations Gary Romano said in 2011 "We [New Zealand] are the most remote developed country in the world relative to international markets and the way we get our products to and from these markets is critical to continued success."(Romano quoted in National Business Review (2011)).

It is a view that is also supported by the New Zealand Government – the Ministry of Transport's *Connecting New Zealand; A summary of the government's policy direction* (2011) suggests "As a trading nation that is far away from our international markets, New Zealand, and our exporting businesses, need an efficient transport system" (page 6). The importance of this supply chain is likely to increase as New Zealand attempts to handle a projected doubling of the freight task by 2040, as suggested by various government reports and freight analysis conclusions, such as the National Freight Demand Study completed by Statistics New Zealand in 2008.

Where imported goods (e.g. farm machinery) are used in the production of goods for export, trade effects compound lower exporter profitability even further.

Ports play a vital part in ensuring the international competitive power of New Zealand as they contribute greatly to the operation of an effective and efficient supply chain. Esmer (2008) summaries Tongzon (1989) and Chin and Tongzon (1998) by outlining that “ports form a vital link in the overall trading chain and, consequently, port efficiency is an important contributor to a nation’s international competitiveness” (page 239). Esmer (2008) also suggests, based on literature such as Thomas and Monie (2000), that port or terminals are vital to the economy of a country and the success and welfare of its industries and citizens.

New Zealand, in each of the last six quarters, has exported or imported more than three times the value of goods in comparison to services. In the period between 1990 and 2009 the value of New Zealand imports and exports has been similar; however the volume of exports is typically greater than imports. This implies that the average value for imports is a lot higher<sup>12</sup>.

### 3.3 NEW ZEALAND’S DISTANCE TO TRADING PARTNERS

New Zealand’s most significant trading partners are Australia, China, Unites States and Japan who collectively make up over 47% of both imports and exports by value. The import and export markets for the top eighty percent of New Zealand trade by value are outlined in Table 2.1.

Imports		Exports	
Country	2012 Year	Country	2012 Year
Australia	21.51%	People's Republic of China	16.34%
People's Republic of China	14.89%	Australia	15.22%
United States of America	9.19%	United States of America	9.29%
Japan	6.97%	Japan	6.47%
Republic of Korea	3.38%	Singapore	4.47%
United Kingdom	3.03%	Germany	4.44%
Malaysia	1.93%	Malaysia	3.89%
Hong Kong (Special Administrative Region)	1.89%	Republic of Korea	3.83%
Singapore	1.83%	Thailand	3.20%
Indonesia	1.82%	United Kingdom	2.67%
Taiwan	1.80%	Brunei Darussalam	2.55%
India	1.71%	Oman	2.49%
Germany	1.60%	Saudi Arabia	2.17%
Saudi Arabia	1.49%	France	1.94%
Philippines	1.47%	Italy	1.67%
Thailand	1.36%	Taiwan	1.66%
United Arab Emirates	1.33%	Indonesia	1.40%
Netherlands	1.24%	Canada	1.23%
Canada	1.23%	Qatar	1.11%
Venezuela	1.00%	India	0.89%

**Table 2.1 New Zealand Trade by Value 2012 Calendar Year - Percentage of Total Source; Statistics New Zealand**

<sup>12</sup> These conclusions are derived from the author’s investigate of Statistics New Zealand Merchandise Trade Statistics between 1989 and 2009.

The table outlines the importance of our key markets for both imports and exports, but it also outlines the diversity in trade routes required to get products to and from market. This shows a diversification in trading partners between the years 2000 and 2012 but an increasing importance of the Chinese market for both imports and exports. Also, Australia is the closest major trading partner to New Zealand but is declining in importance to New Zealand for imported products. Therefore, the average distance of imports to New Zealand is increasing.

John Whitehead – Secretary to the New Zealand Treasury, in his *Putting Productivity First* speech in 2008, outlines the impact of the distance to market.

*Evidence has become clearer that proximity to other individuals and firms is positive for productivity – particularly the benefits of tacit knowledge and relationships – but a quick glance at a world map shows that New Zealand doesn't exactly get a lot of foot traffic. Within a three and a half hour flight from Auckland we can access 0.4 percent of the world's population and one percent of world GDP. Compare that with Hong Kong, where a flight of similar length would put you in reach of 58 percent of the world's population and 37 percent of world GDP. The OECD estimates that distance from markets accounts for around three quarters of New Zealand's gap in GDP per capita versus the OECD average, or around a 10 percent reduction in New Zealand's per capita GDP.*

He goes onto outline that New Zealand needs to develop international linkages that enable New Zealand firms to be internationally competitive.

### **3.4 IMPORTANCE OF NEW ZEALAND SEAPORTS**

Given New Zealand has no international land borders, trade is required to be carried out through the use of either airports or seaports.

The Statistics New Zealand database is used to gain a trend of the relative importance of sea and air trade in New Zealand. The major conclusion from this analysis is that air as a means of importing or exporting freight is relatively insignificant in terms of volume (i.e. less than 1%) but significant in terms of value (i.e. 17.8% in 2010). The dominance of ports for international trade in New Zealand is similar to that of worldwide trade. Esmer (2008) outlines, on page 1, that seaborne trade represent more than 90 percent of the international trade in the world.

The OECD (2011), in its Long Term Strategic Transport Infrastructure needs review, highlights the importance of quality investment in transport infrastructure (such as ports) as a means of increasing trade:

*Quality infrastructure is a key pillar of international competitiveness. Infrastructure networks reduce the effect of distance, help integrate national markets, and provide the necessary connections to international markets. Quality infrastructure is trade enhancing – especially for exports – and has positive impacts on economic growth. Not surprisingly, therefore, most of those countries with high-quality infrastructure also rank high in the world index for overall competitiveness.*

Transport infrastructure assets are large, capital intensive and have very long payback periods and the financial viability of these assets is only achieved when the assets are sufficiently utilized (International Transport Forum (2013), Arif, and Bayraktar (2012), Kunert and Link (2013), PricewaterhouseCoopers (2010). “As a country we have limited financial resources. It is critical that we continue to invest wisely in our transport infrastructure to drive the lift in productivity and competitiveness that New Zealand needs” (Ministry of Transport (2011) page 6). This research will provide further understanding for decision makers to maximise the effectiveness of long term port and land transport infrastructure investment.

### **3.5 INTRODUCTION TO NEW ZEALAND'S SEAPORTS**

New Zealand currently has a network of 12 ports<sup>13</sup> operating as international and regional bulk and containerised trade, geographically spread throughout both the North and South Islands. In 2008 these ports handled 60 million tonnes of freight including international, transshipment and coastal movements. Containerised freight currently represents approximately 40% of total tonnes handled. This figure has increased dramatically from only 13% of total freight tonnes in 1995 (Rockpoint Corporate Finance Limited (2010)).

Six New Zealand ports handle over 90 percent (Ministry of Transport (2013)) of New Zealand containerised trade. These are Auckland, Tauranga, Napier, Wellington, Lyttelton and Otago ports. Southport Bluff, PrimePort Timaru, Port Nelson, Port Taranaki and Northport also handle international containerised trade, but in relatively insignificant volumes.

The New Zealand Productivity Commission (2012), in Figure 3.6, provides the diagrammatic overview of New Zealand's main ports in terms of their location and percentage of total value of imports and exports – note that the values outlined include both containerised and non-containerised products.

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<sup>13</sup> Note; this number reduces to 11 if we counts the Waitamata Harbour and Onehunga ports as the single Ports of Auckland company.

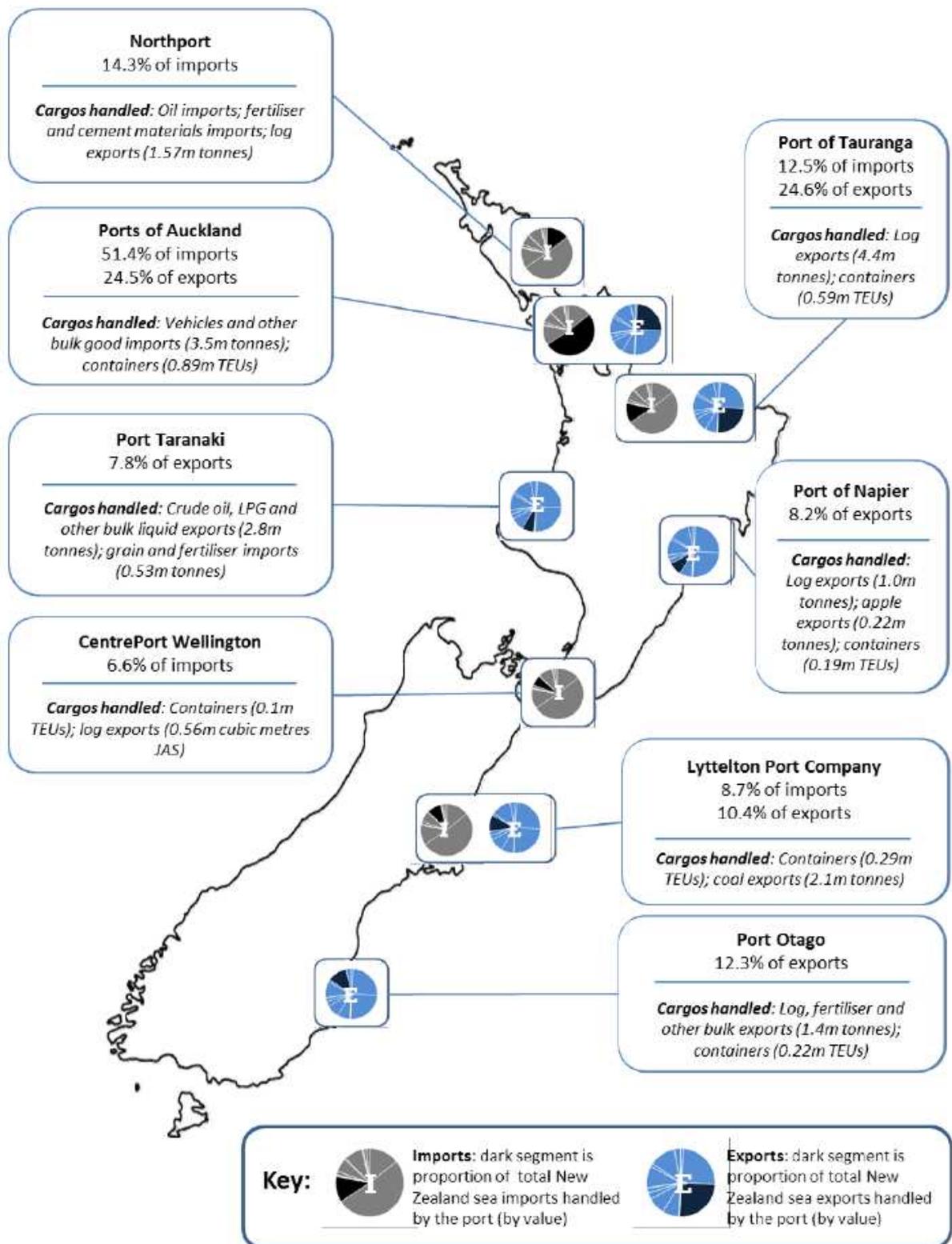


Figure 3.6: New Zealand's Main Ports by Percentage of Value of Imports and Exports Source; New Zealand Productivity Commission (2012) Note: Includes both Containerised and Non Containerised products

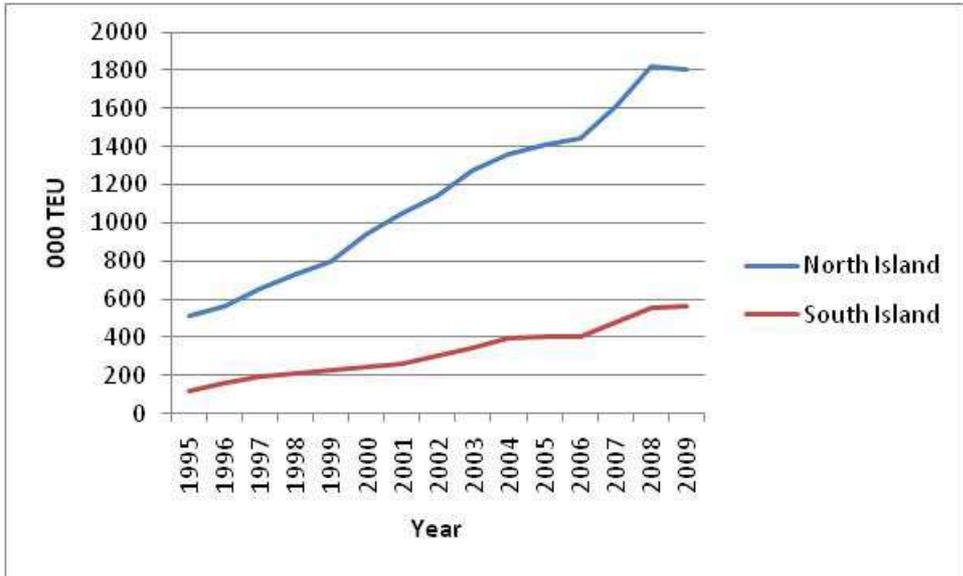
Port of Napier is the only port of these top six not using quay cranes. They operate harbour mobile cranes which typically have a slower productivity per crane, but are relatively inexpensive in comparison to gantry cranes and can be used across multiple berths.

The ports of Auckland, Tauranga, Wellington, Lyttelton and Otago use a mixture of straddle carriers and forklifts throughout their container terminals. Straddles are used for the storage and organisation of full containers to three high. Forklifts are used in the handling of empty containers to allow for increased height (7 high) and density (through the employment of block stacks). The port of Napier operates a range of forklifts across all of its operations. In the international container terminal industry Rubber Tyred Gantries (RTGs) are the most common equipment deployed in container terminals for yard operations, accounting for more than half of the total (Drewry (2010)) and allowing for greater density and high of stacks compared to straddles. However, Drewry (2010) also note that small terminals rely much more on more basic equipment such as reach stackers, while straddle carrier terminals are a largely European phenomenon.

All New Zealand ports are connected to the land transport system by either road or rail. All six largest ports have rail access direct to their container terminal as well as good road transport access.

Rockpoint Corporate Finance (2010, page 27) use port company annual reports and published documents to outline the throughput of New Zealand's 11 principal ports that handle a combined 55 million tonnes of cargo annually, which provides an accurate representation of throughput volumes across New Zealand ports. As outlined in the data collection sections of the national and detailed investigations carried out below, other throughput statistics may inaccurately represent some ports due to the problems associated with transshipment containers.

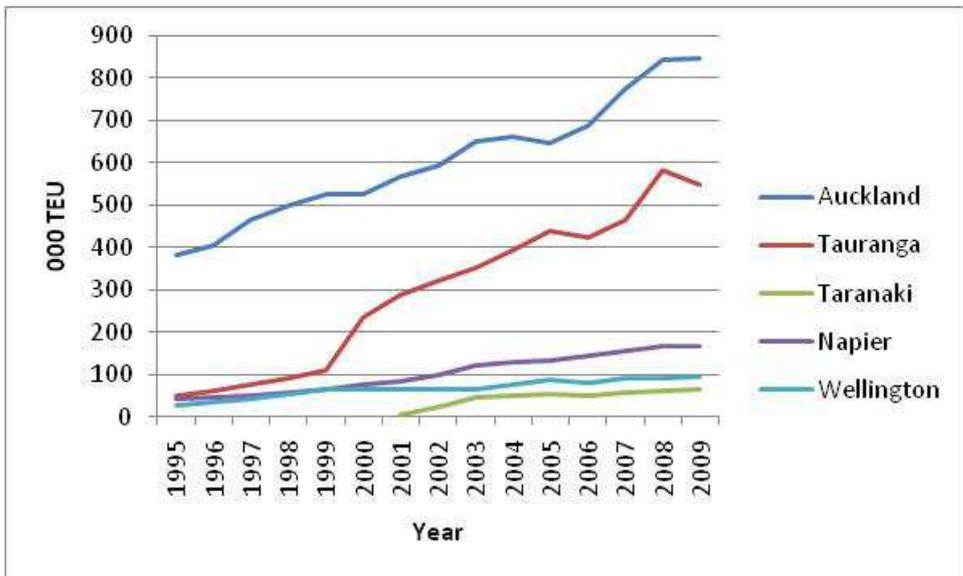
Figure 3.7 details the growth in port volume throughput between 1997 and 2009, by total containers (as measured in twenty foot equivalent units – TEU).



**Figure 3.7 Comparison of Total Annual Throughput of North and South Island Ports by TEU volumes between 1997 and 2009. Source: Rockpoint Corporate Finance**

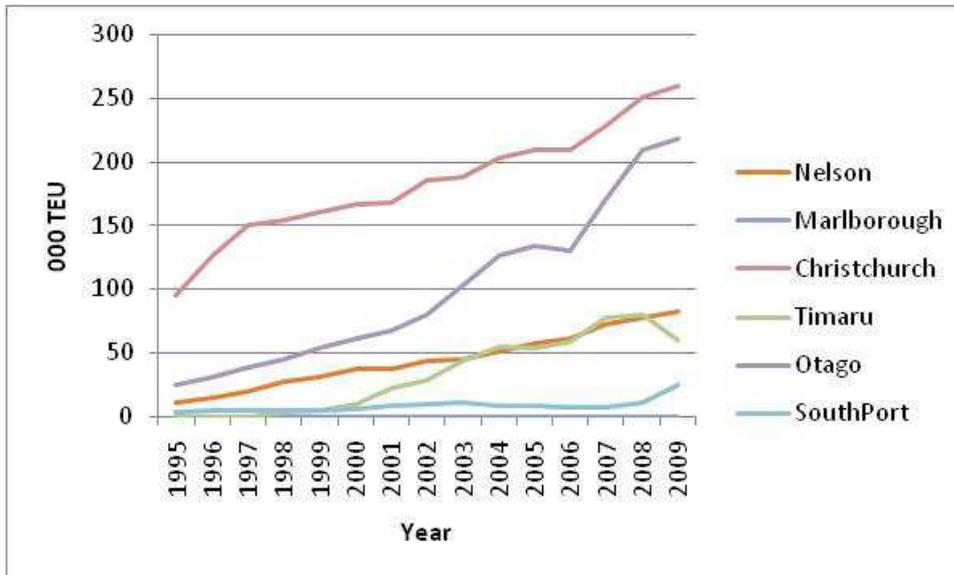
North Island ports have experienced far superior growth rates in containerized cargo. Total containers handled by North Island ports is approximately three times that handled by that South Island ports.

Ports of Auckland's container throughput is significantly greater than any other New Zealand port and accounts for 36% of total New Zealand containerized trade (Ports of Auckland (2013), as outlined in Figure 3.8. Containerized trade has grown rapidly through the Port of Tauranga over the evaluation period – by 1016% or 498,000 TEU – but particularly between 1999 and 2001.



**Figure 3.8 Comparison of Total Annual Throughput of North Island Ports by TEU Volumes between 1997 and 2009. Source: Rockpoint Corporate Finance**

Also of relevance is that CentrePort Wellington's port throughput has experienced steady but low growth in containers over the 15 year period.



**Figure 3.9 Comparison of Total Annual Throughput of South Island Ports by TEU Volumes between 1997 and 2009. Source: Rockpoint Corporate Finance**

Lyttelton Port of Christchurch is clearly the most significant point of international trade in the South Island. However, Port Otago has experienced rapid growth in container volumes – in 2001 the difference between Port Lyttelton and Port Otago was 100,000 TEU and in 2009 it was 42,000.

### 3.6 COMPETITION BETWEEN NEW ZEALAND SEAPORTS

The high number of container ports, small domestic market and short distance between New Zealand ports the means that New Zealand ports are in fierce competition, allowing easier capture of cargo from each other’s geographical hinterlands. This situation increases the difficulty of generating economies of scale, increases costs and increases the uncertainty or risk associated with investments in terminal technology or infrastructure. The New Zealand Productivity Commission (2012) research concludes that “Auckland [container shipping] routes were considerably more expensive than the Sydney routes....The difference is at least partly explained by the fact that New Zealand has lower freight volumes, with the result that the high fixed costs associated with ships calling at ports have to be spread across fewer containers” (page 2).

Australia’s main container ports are Brisbane, Sydney, Melbourne, Adelaide and Fremantle. Together they accounted for 94% of Australia’s 7.06 million containers handled in the 2011/12 financial year (Bureau of Infrastructure, Transport and Regional Economics (2012)).

Table 3.2 illustrates that each Australian container ports has access, on average, to a greater population base, land area and container throughput than their New Zealand counterparts.

	Australia	New Zealand	Notes
Main container ports	5	6	
Total containers in all ports	7,060,000	2,593,482	1,2,3
Average containers through main container ports	1,412,000	432,247	
National Population	22,969,392	4,451,017	
Average Population per main container port	4,593,878	741,836	
National Land Mass (square kilometres)	7,692,024	268,021	
Average Land Mass per Main container port	1,538,405	44,670	
Average distance between ports	2,212	709	
Notes:			
1	Australian port throughput taken from Ports Australia's Trade Statistics		
2	New Zealand port throughput taken from Annual Report figures		
3	Port throughput figures include restows		

**Table 3.2 Comparison of the Average Hinterlands of New Zealand and Australian Main Container Ports**

Table 3 and Table 4 outline the land transport distances between New Zealand ports. New Zealand is made up of two islands, the North and South Island, and a rail and truck ferry provides the main freight connection between the two islands. The distance across Cook Strait on the Ferry of 96.5km is included where a crossing is required – Northland, Auckland, Tauranga, Napier, Taranaki and Wellington are in the North Island while the remaining ports are in the South Island.

	Northland	Auckland	Tauranga	Napier	Taranaki	Wellington	Nelson	Lyttelton	Timaru	Otago	Southport
Northland		144	349	555	502	773	978	1221	1365	1555	1794
Auckland	144		211	417	364	635	841	1082	1228	1417	1655
Tauranga	349	211		295	322	526	732	973	1119	1309	1546
Napier	555	417	295		418	317	522	764	909	1099	1336
Taranaki	502	364	322	418		356	561	802	948	1138	1375
Wellington	773	635	526	317	356		206	447	593	783	1020
Nelson	978	841	732	522	561	206		427	573	763	1000
Lyttelton	1221	1082	973	764	802	447	427		174	364	602
Timaru	1365	1228	1119	909	948	593	573	174		191	428
Otago	1555	1417	1309	1099	1138	783	763	364	191		246
Southport	1794	1655	1546	1336	1375	1020	1000	602	428	246	

**Table 3 Land Transport Distances between all New Zealand Ports, in Kilometres. Source: Author's Calculations**

	Auckland	Tauranga	Napier	Wellington	Lyttelton	Otago
Auckland		211	417	635	1082	1417
Tauranga	211		295	526	973	1309
Napier	417	295		317	764	1099
Wellington	635	526	317		447	783
Lyttelton	1082	973	764	447		364
Otago	1417	1309	1099	783	364	

**Table 4 Land Transport Distances between New Zealand's Main Container Ports, in Kilometres. Source: Author's Calculations**

The average distance between New Zealand's main container ports is 709 kilometres – approximately eight hours drive (assuming an average speed of 80 kilometres per hour). The average distance between the main ports in Australia is 2,722 – 3.8 times the distance as between New Zealand's main container terminals. Both of the Australian and New Zealand distance calculations can be argued to be skewed – Australian distances would be significantly lower if Fremantle was excluded, while New Zealand would be significantly lower if ferry crossing were excluded. However, the main point of these calculations remains – there is a significantly greater distance between hinterland markets in Australia in comparison to New Zealand. Boulhol, Alain de Serres and Molnar (2008) research on overall transport costs over the period 2000-04 for 21 OECD countries concludes that overall transport costs are the highest for New Zealand and Australia second highest for Australia. It was estimated that the cost for transporting goods to market is over 2½ times that observed in North America, due to the geographic distance from major trading markets.

Hesse and Rodrigue (2004) also suggest that geography is a major component influencing logistics and freight distribution, based on textbooks on transport geography edited by Hanson (1995), Taafe et.al (1996) and Hoyle and Knowles (1998). They also suggest that the link between freight transport and geography has highlighted with particular regard to trade and ports. The geographic difference between New Zealand and Australia is significant to the point where the mountainous geographic of New Zealand makes land transport sufficient more difficult than that of Australia's relatively flat geography, resulting in the requirement for more ports in New Zealand closer to hinterland cargo concentrations.

The high number of container ports, small domestic market and short distance between New Zealand ports the means that New Zealand ports are highly competitive. Auckland Regional Holdings (2009) suggests the "ports operate in an intensely competitive and dynamic environment influenced by ever-changing trends in economies, trade, transport and technology" (page 3). This competition has intensified as a large proportion of total freight has been transported in a containerised form. Nottboom (2008) outlines that "literature on gateway/hinterland relationships has acknowledged that containerisation has expanded the reach of ports and has thus intensified inter-port competition" (page 4).

The intense competition between New Zealand container ports has resulted in two interesting concepts. Since the start of containerisation in New Zealand it has resulted in a high number of container ports and low utilisation of current infrastructure. Esmer (2008) outlines that underutilisation [of port infrastructure] results in capital loss and higher cost for running the port. Currently the intense competition means that importers, exporters and international shipping companies can shop around for the cheapest port solution. This ability to shop around results in uncertainty of asset utilisation, difficulties generating economies of scale and an underinvestment in the infrastructure upgrades required to increase productivity, minimise cost or cater for increasing vessel sizes.

### **3.7 GOVERNMENT LEADERSHIP IN THE SECTOR**

Multiple trade and infrastructure publications (in particular NZIER (2010), Auckland Regional Holdings (2009), Rockpoint (2010) and The New Zealand Business Council for Sustainable Development (2011)) have outlined the need for the Government to take a more hands on approach in directing the prioritisation of investment in both port and land transport infrastructure or for the reduction in local government influence in New Zealand ports.

New Zealand Business Council for Sustainable Development (2011) report details the problems that currently exist in New Zealand, that are hampering the ability to improve supply chain efficiency, meet the long term challenges and seize the opportunities available. One problem outlined by this report is that the current port ownership and management structure is stopping New Zealand from realising the potential supply chain efficiencies from servicing and accommodating bigger ships for container traffic. They suggest private ownership of ports or to splitting the management of port operations under contract from the public ownership of ports in an attempt to increase productivity levels and drive optimal investment outcomes.

NZIER (2010) suggest that the OECD and the 2025 taskforce, together with private commentators, have highlighted the high level of local government ownership in the New Zealand port industry and suggested that this is a barrier to port rationalisation and maybe leading to inefficient investment. NZIER (2010) researched the validity of these suggestions and concluded that local authority ownership has mitigated against the rationalisation of port activities and that Ports of Auckland, and possibly Lyttelton Port of Christchurch, have in the past succumbed to port throughput growth [and regional growth] by providing services at a level that may not make a full economic return.

One of the policy options put forward by NZIER (2010) is:

“require local authorities to divest their shares in port companies to reduce the extent to which parochial interests inhibit the introduction of more efficient operational procedures and efficiency-improving rationalisations between ports.” (Page 2)

Rockpoint (2009) outlined that interviewed industry participants across all freight transport modes expressed a desire for the Government to be more active in the development of a broader vision for the freight sector. Rockpoint (2009) also recommends, in its review of the New Zealand Freight Transport industry, that “Government, in a facilitator role, clearly articulates its policy views in relation to potential consolidation or coordination of port service capability from a national benefit standpoint” (page 18). These views are supported by the New Zealand Productivity Commission’s Inquiry into International Freight Transport Services where they outlined “a number of submitters [on the draft report] identified a need for some form of central planning to coordinate future infrastructure investment’ (page 4).

However the New Zealand Productivity Commission (2012) concluded that centralised planning and control carries a high level of risk, and has been unsuccessfully carried out in the past – in particular sighting the failed New Zealand Ports Authority, set up in 1969 to decide which ports would become container ports. Instead they recommend the use of facilitated discussion models of cooperation, based on information sharing and relationship building without being bound to particular outcomes.

Therefore, either central government leadership or strong market cooperation is critical to achieving the best outcome for New Zealand as a whole. This would also allow a coordinated approach to the investment in land transport capacity over New Zealand. In the last decade the government has had a hands off approach. Instead they have allowed the market to dictate its own direction through natural competition and industry dynamics.

In the market, however, ports have continued to compete and only small changes have resulted – small scale rationalisation of Timaru and Taranaki ports in favour of Lyttelton and Tauranga respectively being the largest change– and there remains large scale asset duplication and investment uncertainty.

There has been more collaboration and cooperation occurring in the industry recently. Examples include both the Upper North Island Freight Study and the South Island Freight Study involving

regional and local government authorities, land transport infrastructure stakeholders, Ministry of Transport, port companies, shippers, and freight transport and logistics operators.

In Australia, the Australian National Ports Strategy, launched in January 2011 by Infrastructure Australia and the National Transport Commission, provides a coordinated planning approach for Australian governments to help plan for port infrastructure and the associated road and rail linkages that connect these important gateways to all Australian cities and towns. The UK on the other hand has the official government position on port policy of leaving port development to market forces ( Wilmsmeier and Monios (2012)), much the same as New Zealand.

In summary, local government ownership is limiting industry progression and investment and increasing regional competition at the expense of the New Zealand supply chain and there is a lack of national level government guidance to limit the duplication of assets. There is also limited industry collaboration/cooperation between ports to minimise investment risk – instead they compete.

### **3.8 USE OF INLAND HUBS**

Ports of Auckland, Tauranga and Lyttelton all own and operate inland container depots while Port Otago is intrinsically linked with Fonterra's inland storage hub in Mosgiel (South Dunedin).

Ports of Auckland established a subsidiary company, CONLINXX Limited, to manage the Wiri Freight Hub in South Auckland. The Wiri Hub is a 15 hectare depot off Wiri Station Road in Auckland, close to the major freight routes of State Highway 1 and State Highway 20. Wiri offers the ability for shipping lines and cargo owners to tailor the supply chain to their requirements, taking advantage of Wiri's flexible demurrage options, proximity to New Zealand's manufacturing and warehousing heartland in South Auckland and storage space. A rail exchange connecting Wiri Freight Hub with the Waitemata seaport creates significant supply chain efficiencies. For example, cargo owners have the ability to drop off and pick up their cargo at Wiri instead of trucking it through central Auckland.

Port of Tauranga owns an inland hub called MetroPort. MetroPort is located in the heart of Auckland's industrial belt in south Auckland. Shipping lines contracted to use MetroPort call at the Port of Tauranga where import cargo destined for Auckland is offloaded at the Tauranga Container Terminal. Cargo is then railed to MetroPort Auckland before distribution to its final destination. The same process happens in reverse for Auckland sourced export cargo. It is aggregated at MetroPort Auckland, railed to Tauranga and loaded on to the vessel.

MetroPort Auckland is fully Customs bonded and MAF approved. There is an on-site fresh produce quarantine inspection facility along with fumigation and door inspection areas. Currently there are 1,000 ground slots. Its own dedicated twin rail sidings can cater for unit trains of 100 TEU.

Lyttelton Port of Christchurch operates an inland container terminal called CityDepot, located approximately ten kilometres from the Lyttelton Container Terminal on the Christchurch side of the Lyttelton tunnel. CityDepot provides expanded container services, reducing port congestion and attracting cargo to a centralised location. It has a total of sixteen hectares of land for container storage and servicing, including MAF approved decontamination facility, full repair and pre-tripping, receipt and delivery of Full Container Load (FCL) break-bulk and empty containers available six days per week giving added flexibility to main trunk schedules.

CityDepot has continued to experience growth in recent times with high demand for dairy containers, and experienced additional rail volume through the rail siding all in conjunction with extended hours of service. CityDepot is different to other NZ inland ports in that it is very close to the port.

In the last 18 months both Port of Tauranga and Lyttelton Port of Christchurch have purchased land in south west Christchurch (approximately 25km from central Christchurch) to set up inland hubs and handle the growing Christchurch, Canterbury and South Island container trade. The Port of Tauranga has the aspiration of being New Zealand's single hub port and has purchased a half stake in PrimePort Timaru to allow the opportunity to marshal South Island cargo to be transhipped over Port of Tauranga. The Timaru location has latent capacity and has the potential to again attract throughput volumes from large exporters in close proximity which currently export out of Lyttelton Port. The Port of Tauranga inland port in Christchurch is an extension of their operations in Timaru. Neither of the inland ports have begun operations out of their south west Christchurch inland hubs.

In New Zealand, outside the inland run by ports to provide additional storage space, exporters minimise on wharf dwell times and demurrage costs by holding containers away from port and moving them in a just in time fashion. Fonterra, as New Zealand's largest exporter, is an example of this.

Fonterra, in their logistics strategy, aim to have 5 regional hubs strategically located throughout New Zealand. These rail access inland regional hubs generate the economies of scale in the logistics chains by aggregating output from surrounding factories. Fonterra expect that by aggregating inland and concentrating of efficient land transport logistics to a smaller number of ports will also help drive

efficiencies in blue water logistics (MacKeller 2011 page 16) – i.e. they believe in the notion of ‘bigger ships’ driving efficiencies in New Zealand supply chains<sup>14</sup>.

### **3.9 FUTURE EXPECTATIONS FOR THE INDUSTRY - RATIONALISATION**

Maersk is current building twenty new vessels, known as the ‘Triple-E Class’ vessels to be delivered between 2013 and 2015. These vessels will be 400 metres long, 59 metres wide and 73 metres high with the ability to carry 18,000 twenty foot containers<sup>15</sup>. These vessels will be the largest in the world. This is a large increase in capacity from the first container ships used in the 1950s which had a capacity of between 500 and 800<sup>16</sup> (Ashar and Rodrigue (2012)). Figure 3.10 outlines the evolution in container ship size.

Ducruet and Notteboom (2012) outline the relationship between vessel size increases and port rationalisation on the Far East – North Europe international container route. In the year 2000 the average vessel capacity was 4,500 in comparison to over 7,500 in the year 2010, with the average number of port calls per loop being 3.77 in October 2000 compared to 3.35 in December 2009. This is a similar trend outlined by The Public-Private Infrastructure Advisory Facility Port Reform Toolkit in which the share of ships in excess of 5,000 TEU increased from 1 percent in 1996 to 30 percent in 2006.

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<sup>14</sup>While Fonterra believe that bigger ships will drive efficiency in the dairy industry and for their shareholders, it is yet to be proven that there are sufficient imports and sufficient products outside New Zealand’s main export season to support the calling of 7,000 TEU vessels.

<sup>15</sup> Information retrieved from Maersk.com at 11:11am on 2 May 2014.

<sup>16</sup> Twenty-foot Equivalent Unit is a standard size of a container used for denoting the container carrying or handling capacity of a ship or port.

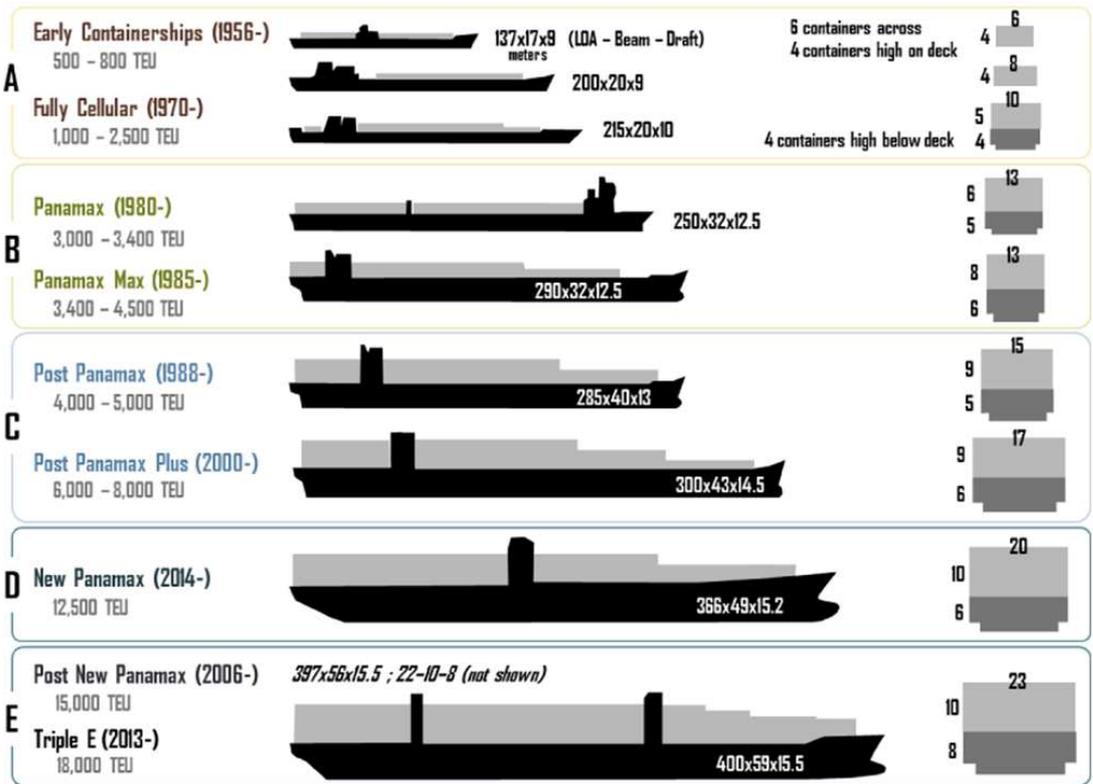


Figure 3.10: Evolution of Container Ships Source; Ashar and Rodrigue (2012)

Sys, Blauwens, Omeij, Van de Voore and Witlox (2008) suggest that the continued increase in container vessel size has resulted in the restructuring and consolidation of the liner shipping industry since the 1990s. The consolidation of ships lines, and the use of larger vessels, has resulted in the consolidation of port calls and the use of 'hub and spoke' models. Prince (2012) outlines examples of increases in vessel size resulting in "load centering" (the practice of consolidating ships' calls at fewer ports).

The New Zealand port sector is predicted to go through significant change and rationalisation over the short to medium term (New Zealand Shipping Federation (2010), Auckland Regional Holdings (2009) and Rockpoint (2009)). Container vessel lengths, draughts and beams have been increasing for some time as the shipping industry looks to utilise economies of scale in vessels.

The Shippers' Council (2010) review on the impact of the introduction larger container vessels illustrates the trend in the size of container vessels, indicating that at present the average size container vessels calling New Zealand ports is 2,700 TEU , with the largest being 4,100. The Shippers' Council go on to conclude

“it is anticipated more vessels with the capacities in the range of 4,000 to 7,000 TEU will be redirected from major international trading lanes to smaller lanes such as New Zealand, as major trading lanes become serviced by larger and larger ships (up to 14,000 TEU capacity)” (page 8).

The New Zealand Shippers' Council (2010) review of the implications of the trend in increasing vessel sizes concluded that if NZ invests in the infrastructure required to support 7,000 TEU vessels NZ Inc. will benefit \$338 million per annum. If the investment is not undertaken, they believe it will cost NZ Inc. \$194 million per annum. Benefits to NZ of investing in the required infrastructure include lower operating costs, reduced CO2 emissions and lower transit times while the costs of not investing is that New Zealand ports become feeder ports to Australian hubs, increasing transit time and handling costs..

Notteboom (2008) outlines that “containerisation and the deployment of ever larger container vessels have gone hand in hand with a concentration of vessel calls in a limited number of load centres, especially on the main long-distance routes where economies of scale at sea are most apparent” (page 4). Tauranga and Lyttelton were recommended by the New Zealand Shippers Council (2010) as the two ports that should undertake investment in infrastructure upgrades first due to the comparatively low cost requirements and political objections to increasing port capabilities. However, they believe that in the longer term it is likely that both Auckland and Otago ports will also be required to be big ship capable. These conclusions were supported by New Zealand's largest exporters including Fonterra, Zespri, Carter Holt Harvey, the Meat Industry Association and Solid Energy. Auckland Regional Holdings (2010) also completed research into the long term optimisation of the New Zealand port sector. They supported the introduction of larger vessels hubbing at fewer ports and concluded that the hub ports will be Auckland and Tauranga ports in the North Island and

Lyttelton and Otago ports in the South Island<sup>17</sup>.

In the absence of a large greenfield port development, the challenges identified by Auckland Regional Holdings are; increasing the capacity and productivity of the big ship capable ports. They suggest that New Zealand container ports require significant investment in both port and transport infrastructure to achieve the economies of scale and to maintain internationally competitive productivity levels.

The port capacity analysis completed by Auckland Regional Holdings in 2009 concluded that, in the North Island, the key physical constraints for ports were container terminal area and berth length. In the South Island, the capacity analysis completed concluded that container terminal area (rather than berth length) appears likely to be the future constraining factor, but also noted that inland ports can be used to reduce dwell times at terminals and that significant additional container land would require extensive reclamation.

In the North Island, Auckland and Tauranga have both outlined their investment recently. Ports of Auckland released the Development Plan to the public in May 2013. They will continue to develop capacity to meet demand by further land reclamations and extension of container berths. [http://www.poal.co.nz/about\\_us/port\\_development.htm](http://www.poal.co.nz/about_us/port_development.htm).

In April 2013 the Port of Tauranga opened up a major expansion of its container terminal facilities, increasing wharf length by 170 metres (28%), installation of a new Super-Post Panamax ship-to-shore twin lift gantry cranes (resulting in the port having six container cranes), increasing straddle numbers, increasing ground slot capacity by 30% and refrigerated container outlets by 60% and investment in a new rail siding to increase the productivity of land transport. On the 5<sup>th</sup> of March 2013 Port of Tauranga became the second New Zealand port (behind Port Otago) to receive final approval for its plan to widen and deepen its shipping channel to accommodate larger ships.

In the South Island, Lyttelton Port of Christchurch is currently completing a ten hectare reclamation using demolition materials from the 2010 and 2011 Christchurch earthquakes. As at their 28 February 2013 press release on their interim profit results the Te Awaparahi Bay reclamation was over 3.5 hectares with 8,000 square metres of storage space available.

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<sup>17</sup> While Fonterra, and other large exporters involved in the New Zealand Shippers Council (2010) report, believe that bigger ships will drive efficiency in the dairy and other export industries, it is yet to be proven that there are sufficient imports and sufficient products outside New Zealand's main export season to support the calling of 7,000TEU vessels.

Port Otago has also previously signalled its intent to invest to become big ship capable. In their Interim Financial Report outlining their progress for the first six months of the 2012/13 Financial Year they outline their highlights of the period – “the first [highlight of the six month period] being the granting of the consents to deepen the channel which sees Port Otago being the first port company in the country to have a fully consented project to deepen its channel” (page 2).

The Port of Tauranga has the aspiration of being New Zealand’s single hub port and has purchased a half stake in the PrimePort Timaru to allow the opportunity to marshal South Island cargo to be transhipped over Port of Tauranga. The Timaru location has latent capacity and has the potential to again attract throughput volumes from large exporters in close proximity which currently export out of Lyttelton Port.

Ports of Auckland, Port of Tauranga, Lyttelton Port of Christchurch and Port Otago all have good access to New Zealand’s major trading partners. However, the Ports of Napier and CentrePort Wellington also have good access to international markets and are often on the same schedule rotation as the largest New Zealand ports. These ports were not suggested as logical port to become big ship capable by the New Zealand Shippers’ Council.

Port of Napier’s Chief Operating Officer wrote an article in CILT New Zealand (2010)<sup>18</sup> arguing that “competition between lines and for shippers will probably result in a continuing evolution of the current mix of shipping services [with international direct calls to four or five ports rather than a single hub port in each island rather than a two port model (page 9). He also suggested that there is already evidence of Australian ports aggregating New Zealand cargo and international shipping lines hubbing New Zealand containers through large Australian ports. Therefore New Zealand shippers have, in some cases, already adjusted and the impact cost outlined by the Shippers’ Council is overstated and the situation of hubbing through Australian ports is entirely possible.

Wellington has good infrastructure and is close to a large population base but doesn’t have a large output of goods, with limited primary sector output and the manufacturing sector, which was once strong, has moved to other New Zealand cities or overseas.

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<sup>18</sup> CILT New Zealand (2010), *Logistics and Transport New Zealand; the official publication of CILT New Zealand*, Volume 8, Issue 4, June 2010

Therefore, logically Wellington and Napier ports could be large scale ports capable of servicing the largest container shipping entering New Zealand waters. It is also possible that New Zealand containers may be aggregated in Australia, with shipping lining hubbing through one of the large Australian ports.

However given the net supply chain cost of hubbing through Australia, the resilience needed by New Zealand shippers and the desire by international lines to rationalise port calls it is most likely that the four largest container New Zealand ports will remain the largest and will be the only ports that invest in the ability to service larger container ships. Therefore the four largest are likely to be the remaining ports after rationalisation, assuming that the rationalisation process is economically viable for each of the ports with or without government support.

A similar trend has occurred in the United Kingdom. Wilmsmeier and Monios (2013) outline that “over the last 30 years, several factors have caused a shift in UK trade from using local ports to using the large south-eastern ports” page (13). They go on to outline the factors behind this trend being ports have turned into major hubs for cargo to pass through rather than a regional trade centre, the container revolution has eased handling, the increased economies of scale available from ever increasing ship sizes and the rationalisation of shipping services to concentrate on major trade routes – i.e. the same factors behind the export industry in New Zealand wanting to rationalise ports to concentrate on only one major port in each island.

New Zealand is continuing with port industry development which is focused on rationalisation and concentration of container handling through fewer locations in order to generate sufficient economies of scale to reduce per unit handling costs. This is in line with the international container port industry. Wilmsmeier and Monios (2013) suggest that “for institutional and legacy reasons, all [UK] ports are pushing for development and to attract ever larger vessels, whether or not a sound business case is in evidence” (page 14). Authors such as Barke (1986), Hayuth (1981), Slack and Wang (2002), and Notteboom (2005), however, warn against continuing with a concentration of port throughput towards one location, suggesting that the system is likely to reach a limit and invert, leading to a process of decentralisation. From the review of international literature it means that there is a balancing act required for the future rationalisation of New Zealand ports. On one side there is a need to ensure port rationalisation creates efficiency and lower per unit costs in both the port and the national transport system. On the other side there is a need to ensure long term supply chain resilience and

the elimination of the need to recreate ports in the future if the rationalised ports, and their surrounding infrastructure systems, can't cater for long term growth in throughput or become congested and inefficient with increased demand.

### **3.10 SUMMARY**

As a small domestic market, New Zealand firms are reliant on access to foreign markets to gain economies of scale, reduce costs of production and remain internationally competitive. New Zealand exports and imports approximately three times more goods in comparison to services. Therefore, the movement of goods to and from market is vital in the economic prosperity of New Zealand.

However, due to New Zealand's isolation from the world's largest markets, and its major trading partners, the supply chain and network logistics must be effective and efficient to allow New Zealand's firms to get these goods to market, and to compete on a level playing field with the rest of the world.

The majority of New Zealand's international trade of goods is transported by sea, rather than air. Therefore, New Zealand's ports play a vital component in the efficiency of the international supply chain and the competitiveness of New Zealand firms.

Compared with other countries, New Zealand has a high number of ports, especially when the small domestic container throughput and the small geographic area and mountainous topography are taken into consideration. The small distance between New Zealand ports, the high number of container ports and the small domestic market means that New Zealand ports are in fierce competition and can easily move into each other's geographical hinterlands. This competition has previously resulted in asset duplication and the lack of economies of scale required making New Zealand ports internationally competitive in terms of productivity and costs.

Because of this competition without government regulation or even guidance, and lack of scale in New Zealand port throughput volumes, oligopolistic large international shipping companies and large New Zealand exporters have the ability to play ports against each other as they compete to claim some ascendancy of volume to gain economies of scale, with exporters and shipping lines choosing the port that offers the best combination of cost, service levels and reliability.

These large shipping companies have recently introduced measures to increase historically low rates of return across their asset base. The main introduction is the increasing vessel sizes and rationalisation of port calls.

Rationalisation will result in the selection of ports and cannibalise the ones that can't cope with the vessel sizes or provide world class productivity levels in servicing the larger vessels. The four largest New Zealand container ports have, in recent times, posted good financial returns and have all made steps to invest in the capability to productivity service the impending larger vessels.

Inland container depots have been a measure employed by New Zealand ports and exporters to provide suitable capacity enhancements and minimise on wharf dwell times. They also allow importers and exporters to generate economies of scale, reduce costs and provide them with greater ability to negotiate beneficial supply chain service levels.

## **4 METHODOLOGY**

### **4.1 INTRODUCTION**

The literature review introduced the theoretical and academic research context of container ports, the measurement of throughput, productivity and capacity and the expected relationship between these variables. The industry background has also contextualised the research setting in terms of the New Zealand container port industry and its relationship with the global logistics chain. This chapter outlines the proposed methodology, based on the background already provided, for investigating the research objectives.

### **4.2 RESEARCH OBJECTIVES**

As outlined above, the objectives of this research are:

#### Objective 1:

*To investigate the existence of a relationship between the capacity utilisation, volume and productivity of container ports.*

This will allow the research to provide insight to the resulting productivity from the expected future consolidation of New Zealand ports which will lead to higher volumes through single container ports and the investment in the large scale port assets.

#### Objective 2

*To investigate whether the use of inland hubs impacts on the throughput volume, capacity utilisation or productivity of the integrated seaport*

This will allow the research to determine whether inland hubs are an effective means of generating capacity to handle large volume increases while maintaining productivity levels.

### **4.3 THE PROCESS OF DEVELOPING A RESEARCH METHODOLOGY**

Saunders, Lewis and Thornhill (2009) outline all elements that should be included when detailing the research methods for students undertaking research in business, or business related industries. Research is not as simple as gathering data, analysing it and then producing conclusions. Saunders et.al (2009) uses 'the research onion' to depict "the issues underlying the choice of data collection techniques and analysis procedures" (page 106). Before the data is gathered, analysed and conclusions produced, the researcher must first understand how the research objectives and researcher's background relate to each layer of the research onion. Each layer of the research onion

and the potential approaches are outlined in Table 4.5.

Layer	Potential Approaches
Philosophy	Positivism, Interpretivism, Realism, Pragmatism
Approach	Deductive, Inductive
Strategy	Experiment, Survey, Case Study, Action Research, Grounded Theory, Ethnography, Archival research
Choice	Mono, mixed or multi methods
Time horizons	Cross Sectional, Longitudinal
Data Collection	Sampling, Secondary data, Observation, Interviews, Questionnaires

**Table 4.5: Overview of the Research Layers and Available Approaches Saunders et.al (2009)**

The rest of this chapter outlines each of the approaches within of the research onion layers and then determines which of the approaches most suits the research objectives presented above. The literature reviewed and the nature of the industry will also be used to help determine which research approach should be used for each of the research onion layers. After each of the layers has been examined, the research methodology to be used in this research is overviewed and summarised.

#### **4.4 RESEARCH PHILOSOPHY**

The first layer of the research onion is the research philosophy. Saunders et.al (2009) suggests that the research philosophy “relates to the development of knowledge and the nature of that knowledge” (page 107). They then go onto contrast how a philosophy based on staff attitudes and feelings could provide different research conclusions than a philosophy based on fact when reviewing a manufacturing process, for example. The research strategies and methods will probably also be different under different research philosophies. Saunders et.al suggest that there are four different research philosophies; Pragmatism, Positivism, Interpretivism, Realism. It must be noted that “the methodology chosen depends on what one is trying to do rather than a commitment to a particular paradigm [or philosophy]” Krauss (2005) – the research philosophy needs to be chosen in relation to the research objectives.

The positivism position “is derived from that of natural science and is characterised by the testing of hypothesis developed from existing theory” (Flowers 2009, page 3). “Interpretivism advocates that it is necessary for the researcher to understand differences between humans in our role as social actors”

Saunders et.al (2009), page 116. The realism position relates to the scientific enquiry. Krauss (2005) outlines that while positivism concerns a single concrete reality and interpretivism multiple realities, realism concerns multiple perceptions about a single, mind independent reality. The three research philosophies described above make a researcher choose a clear view on how the research is to be completed. Whereas, finally, pragmatism argues that the research objectives and the philosophy adopted are more of a continuum and should be more interactive. Pragmatism describes a process where theory is extracted from practice, and applied back to practice to form what is called intelligent practice.

Guba and Lincoln (1994), Saunders et.al (2009) and other authors suggest that the axiology should be evaluated alongside ontology and epistemology in order to determine which of the four research philosophies should be used in management research. Flowers (2009) outlines that understanding the different research philosophies and clearly articulating the philosophies used is important to completing research of this nature:

“Since these parameters [research paradigms and matters of ontology and epistemology] describe perceptions, beliefs, assumptions and the nature of reality and truth (knowledge of that reality), they can influence the research is undertaken” (page 1).

Flowers (2009) suggest that evaluating the research philosophies and the matters of ontology and epistemology will help ensure that researcher biases are understood, exposed, and minimised.

### **Ontology, Epistemology and Axiology and their relationship with the four research philosophies**

Ontology is the study of being, existence or reality and deals with the question concerning what entities exist or can said to exist. Blaikie (1993) exerts that ontology encompasses claims about what exists, what it looks like, what units make it up and how these units interact with each other. As Flower (2009) simply puts it; “ontology describes our view (whether claims or assumptions) on the nature of reality, and specifically, is this an objective reality that really exists, or only a subjective reality, created in our minds.

Ontology is important to understand in the carrying out research. If the researcher doesn't understand his/her embedded ontological assumptions they may be blinded towards particular conclusions if the inherit assumptions are in fact incorrect or are not at least questioned. Saunders et.al (2009) outline that ontology becomes the researcher's view of the nature of reality or being. How

ontology relates to the four research philosophies is described below (from Saunders et.al (2009), page 119):

- Positivism; external, objective and independent of social actors
- Realism: is objective. Exists independently of human thoughts and beliefs or knowledge of their existence, but is interpreted through social conditioning
- Interpretivism; socially constructed, subjective, may change, multiple
- Pragmatism; external, multiple, view chosen to best enable answering of research question

Flowers (2009) surveys literature to outline multiple definitions of epistemology, in particular Blackie (1993) describes epistemology as the theory or science of the grounds of knowledge, whereas Chia (2002) describes it as how and what it is possible to know, and Hatch and Cunliffe (2006) summarise it as knowing how you can know. Saunders et.al (2009) outline it as “the researchers view regarding what constitutes acceptable knowledge” (page 119). How epistemology relates to the four research philosophies is described below (from Saunders et.al (2009), page 119):

- Positivism; only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements
- Realism; observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations. Alternatively, phenomena create sensations which are open to misinterpretation. Focus on explaining within a context or context.
- Interpretivism; subjective meanings and social phenomena. Focus upon the details of the situation.
- Pragmatism; either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, investigating different perspectives to help interpret the data.

Before deciding upon the research philosophy, axiology must also be reviewed. Saunders et.al (2009) describes axiology as the researcher’s view of the role of values in research. How it relates to the four research philosophies is described below (from Saunders et.al (2009), page 119):

- Positivism: research is undertaken in a value-free way, the researcher is independent of the data

and maintains an objective stance

- Realism; research is value laden; the researcher is biased by world views, cultural experiences and upbringing.
- Interpretivism; research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective
- Pragmatism; value plays a large role in interpreting results, the researcher adopting both objective and subjective points of view

The research philosophy adopted in this research is a positivism approach, is based on the examination of fact rather than impression consistent with the notion of observable social reality employed by physical or natural sciences. This approach automatically lends itself to quantitative statistical data analysis and the investigation of casual relationships between individual variables without any qualitative or subjective evaluation from the researcher.

#### **4.5 RESEARCH APPROACH**

A research approach is the relationship between the development of theories and/or hypothesis and the collection of data for analysis. There are two approaches; deductive or inductive. Deductive research is where the theory or hypothesis is already developed and then the data is collected and analysed to determine whether the theory or hypothesis holds given the parameters and variable of the data analysis. Inductive, on the other hand, is where the data is collected and analysed by the researcher and a theory or hypothesis is developed based on the conclusions of the data analysis under the parameters and variables analysed.

Saunders et.al (2009) suggests that the approach taken has consequences for the emphasis of data collection and principles. For example, a deductive approach emphasises scientific principles, the need to explain causal relationships between variables, the collection and validity controls of quantitative variables and a highly structured approach, whereas under a inductive approach emphasis is given to the research context, qualitative data and a more flexible structure to permit changes of research emphasis as the research progresses.

In the case of this research the theoretical trends and relationships have been described in the literature review and previous academic research has been overviewed to determine the expected

relationship between throughput volume, capacity and productivity. The method of investigating the relationship between the throughput, capacity and productivity in this research will use statistical analysis techniques on container terminal data of New Zealand ports. This method will use the analysis techniques to determine whether the New Zealand container ports are consistent with the theoretical underpinnings and the international research outlined in the literature review. The research approach is therefore a deductive approach.

#### **4.6 RESEARCH STRATEGY**

A research strategy, in this context, is the way in which data is collected to allow the analysis of the research objective and development or testing of a particular hypothesis. Saunders et.al (2009), on page 141, suggests that the following research strategies exist; Experiment, Survey, Case Study, Action Research, Grounded Theory, Ethnography, Archival research. Research strategies are not mutually exclusive and multiple strategies may be combined in one research process.

- Experiment; Hakim (2000) suggests that the purpose of an experiment is to study causal links; whether a change in one independent variable produces a change in another dependent variable. Saunders et.al (2009) suggests that this is the case for the most simplistic experiments, however more complex experiments also consider the size of change and relative importance of two or more independent variables.
- Survey; involves the structured collection of data from a sizable population. Although survey is often used to describe the collection of data through the use of questionnaires it may also include the use of interviews or structured observation (Saunders et.al (2009), page 601).
- Case Study; involves the empirical investigation of a particular contemporary phenomenon within its real life context, using multiple sources of evidence (Saunders et.al (2009), page 588).
- Action research; is concerned with the management of a change and involving collaboration between practitioners and researchers. In some cases the research is completed by diagnosing, planning, taking action and then evaluating, and completing this loop until the research objective has been answered.
- Grounded theory; this strategy is where theory is developed from data generated by a series of observations or interviews primarily involving an inductive approach. Theory is developed from data generated by a series of observations. These data then lead to the generation of

predictions which are then tested in further observations.

- Ethnography: “the purpose [of ethnography] is to describe and explain the social world the research subjects inhabit in the way in which they would describe and explain it” (Saunders et.al 2009, page 149)
- Archival; “makes use of administrative records and documents as the principal source of data” (Saunders et.al 2009, page 150)

The research to be completed in this report will use the experiment method when comparing the capacity and performance of different New Zealand ports against an international example, however there will also be elements of the case study and survey research strategies when detailed investigation is completed on a single container terminal.

#### **4.7 RESEARCH CHOICE**

Literature, such as American Public University (2012), Borrego.M, Douglas.E and Amelink.C (2009) and Olds, Moskal and Miller (2005), generally concludes that there are three different approaches available; quantitative, qualitative and a mixed method approach.

The quantitative approach is “where a researcher looks for things like cause and effect, correlations between specific variables, measurements and observations through tests, experiments and surveys, and collection of data for the purposes of statistical analysis” (American Public University (2012)). Borrego.M, Douglas.E and Amelink.C (2009) suggest that quantitative methods are a good fit for deductive approaches, in which a theory or hypothesis justifies the variables, the purpose statement and the direction of the narrowly defined research questions.

A qualitative approach is where a researcher looks at multiple meanings of individual experiences and derives information from narratives, phenomenologies, ethnographies, or case studies to identify themes (American Public University 2012). Olds, Moskal and Miller (2005) suggest that qualitative analysis is typically completed through the collection of textual data – surveys, focus groups, or observations – and has an emphasis on the context of the data rather than the relationship between two variables. Borrego.M, Douglas.E and Amelink.C (2009) suggest that qualitative research questions are answered through a summary of quantitative data along with rich, contextual descriptions of the data. They suggest that qualitative studies are typically answering questions such as; what is occurring? Why does something occur? How does one phenomenon affect another?

A mixed method approach blends components of both the quantitative and qualitative approaches. Creswell, Plano Clark, Gutmann, and Hanson (2003) define mixed method research as a study involving “the collection or analysis of both qualitative and/or quantitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages of research” (page 212)

The question then becomes; which approach should be used for logistics and transport research?

The American Public University System’s Research Methods in Transportation and Logistics Methods suggests that there are three questions that are central to the design of research as it relates to Transportation and Logistics Management:

1. What knowledge claims are being made by the research?
2. What strategies of inquiry will inform the procedure?, and
3. What methods of data collection and analysis will be used?

Based on how a researcher answers these questions, approach – quantitative, qualitative, and mixed methods – is selected. Borrego.M, Douglas.E and Amelink.C (2009) research the use of the three methods and concluded that “no particular method is privileged over any other” and the research method used should be driven by the research questions. This is a position supported by Creswell (2002). Johnson and Onwuegbuzie (2004) suggest that the research methods should follow research questions in a way that offers the best chance to obtain useful answers.

Therefore, the approach used to carry out the research of this paper will be quantitative as it will use regression analysis to investigate whether the trends in throughput, capacity utilisation and productivity of New Zealand ports, and the existence of a relationship between these variables, are consistent with the theoretical and statistical research outlined in the literature review. It is likely that this research will arrive at conclusions based on the only the collected data and measures of statistical analysis – as Creswell (2002) and Thorne and Giesen (2002) suggest should be the case with quantitative approaches.

Further to the question of quantitative, qualitative or mixed methods approaches, Saunders et.al (2009) suggests that research choice can be separated into mono, mixed or multi methods, some of which have various levels of integration between qualitative and quantitative data collection and

analysis.

Mono method research choice, as described by Saunders et.al (2009), use a single data collection technique and corresponding analysis procedures – i.e. a researcher will either use a quantitative data collection (such as surveys) and analyse the data using quantitative techniques or will use a qualitative data collection technique and a qualitative analysis procedure. Leeds Metropolitan University (2014) defines the mono method research choice as when a researcher adopts a single approach to research, for example quantitative approach, to the exclusion of other types of approaches.

Multiple method research choices, on the other hand, use more than one data collection technique and analysis procedures to answer the research question. Multiple methods come in either multi method or mixed methods types.

Saunders (2009) suggests that multi method research choices are when more than one data collection technique is used with associated analysis techniques, but both the collection and analysis align with either a quantitative or qualitative approach – i.e. if the data collection uses qualitative methods the analysis must then also use qualitative methods. Therefore this defines multi method quantitative and multi method qualitative.

Bryman (2012) indicates why the multi method research choice is used in what is a purely quantitative or qualitative research methodology:

Multimethod research entails the application of two or more sources of data or research methods to the investigation of a research question or to different but highly linked research questions. Such research is also frequently referred to as mixed methodology. The rationale for multimethod research is that most social research is based on findings deriving from a single research method and as such is vulnerable to the accusation that any findings deriving from such a study may lead to incorrect inferences and conclusions if measurement error is affecting those findings. It is rarely possible to estimate how much measurement error is having an impact on a set of findings, so that monomethod research is always suspected in this regard. (page 1).

Therefore, multi method research choices are used in situations where mono method research choices produce a research where triangulation or further investigation of results is required.

A Mixed methods research choice approach, on the other hand from multi methods approach, is when both quantitative and qualitative data collection techniques and analysis procedures are used in the same study – i.e. the data collection maybe quantitative and the analysis qualitative (Molina Azorín and Cameron (2010) and Leeds Metropolitan University (2014)). Johnson et al. (2007) provide a synthesis of 19 definitions:

Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (p. 123)

The approach used to carry out the research to investigate the relationships between container port capacity, productivity and the use of inland hubs will be a quantitative approach with a multiple method research choice to utilise multiple data collection and analysis techniques. This approach allows for exactness in calculating any relationship and the significance of individual variables. It also allows for triangulation of results produced from secondary data, where faults and measurement error is possible.

#### **4.8 TIME HORIZON**

Woodridge (2003) suggests that in economics and other social sciences data analysis typically uses economic data with the one of the following structures:

- Cross sectional data – a sample of individuals, households, firms, cities, states, countries or a variety of other units, taken at a given point in time.
- Time series data – consists of observations on a variable or several variables over time
- Pooled cross sections – independent cross sections, usually collected at different points in time, are combined to produce a single data set.
- Panel data – a data set constructed from repeated cross sections over time.

Therefore the panel data set takes elements from both the cross sectional and time series data sets.

The research conducted in this paper will use variables of port productivity performance, capacity available and volume handled collected by New Zealand container ports over their recent history. Therefore, this data structure is a panel data set. The time horizon analysed will be dependent upon

the data available for port productivity performance. The benefit of the panel data is that it allows for the investigation of both the trend in an individual variable as well as the relationship between the variables throughout the time period.

#### **4.9 DATA COLLECTION**

Saunders et.al 2009 suggests the following data collection techniques: Sampling, Secondary data, Observation, Interviews, and Questionnaires.

- Sampling consists of taking a subset of the total population and assuming that it represents the remainder of the population in order to minimise data collection costs and timeframe.
- Secondary data is when data used for a research project that were originally used for some other purpose.
- Observation is the systematic observation, recording, description, analysis and interpretation of people's behaviour (Saunders et.al (2009) page 597).
- Interview is when an interviewer physically meets the respondent, reads them the same set of questions in a predetermined sequence and records their response.
- Questionnaire refers to all data collection techniques in which each person is asked to respond to the same set of questions in a predetermined order.

The data collected and analysed in the first section of this research is secondary in nature, collected by ports for purposes of monitoring the performance of individual ports and their capital and labour employed and the Ministry of Transport for the purposes of monitoring the efficiency of New Zealand infrastructure and trade.

As the data is collected for the purpose other than the purpose of this research, as is the case with all secondary data, there are issues with the reliability and reporting. Therefore, the triangulation of results is carried out using another data set with further detail and collected in an environment known to the researcher.

#### **4.10 ANALYSIS METHODS**

There are a high number of analysis methods available. The most suitable method is dependent upon the data collected, the research objectives, the research process and characteristics of the data.

UNCTAD (1999) suggests that there are two different types of port performance indicators – macro port performance indicators quantify aggregate port impacts on economic activity while micro port performance indicators evaluate input/output ratio measurements of port operations. This research has already, in the industry background chapter and the literature review above, provided some detail of the importance of ports in the generation of economic and activities and the logistics importance of ports – i.e. the macro performance of ports has already been covered. The analytical components of this research concentrate on how individual New Zealand ports can improve operational productivity, service levels and capacity through the analysis of the micro port performance indicators – i.e. it concentrates on the micro performance indicators.

#### **4.11 METHODOLOGY OVERVIEW**

There are three components of the research methodology which are; data collection, analysis and reporting. All three components have two different levels of investigation – national level investigation and a detailed port investigation. The national level investigation aims to determine the existence of a relationship between volume, capacity and productivity at New Zealand's main container ports. The detailed port investigation aims to triangulate the conclusions developed by carrying out the same analysis, on a data set known to the researcher but only focusing on an individual port at a greater level of detail.

The use of secondary data brings with it drawbacks in relation to quality and reliability, therefore more detailed analysis using commercial port operational data was also completed for an individual port to triangulate the information and confirm the existence of the relationships.

The collection of data for the detailed port analysis concentrates on the Lyttelton Port of Christchurch. The data was extracted from the port operational system and checked for consistency and accuracy by the Container Terminal Managers after the completion of each vessel. Inland hub throughput data was also compiled from the financial reporting system of the inland hub business, as they bill clients directly for each container handled. This was checked by the inland hub's manager for accuracy. Between 2011 and 2013 the author also worked as an analyst for the Port of Lyttelton and gained an understanding of the data collection methods, accuracy and operational procedures of their container terminal and integrated inland hub facility. Given the data collection method, the more detailed analysis will also allow for investigation of relationships at an individual vessel exchange level, rather

than an aggregated quarterly time period.

The objectives of this report, outlined above, are focused on determining whether there is a relationship between the volume, throughput and capacity utilisation variables. To investigate the first objective of this research, regression and statistical analysis will be used on the national level and detailed port data sets. To research the second objective, analysis focuses on investigating whether there is a change in the volume, capacity utilisation and productivity trends after the introduction of an inland hub facility or a significant investment in inland hub facilities.

Both multivariate regression and simple linear regression models are used in the analysis. The multivariate regression is used where there are a number of measure types – for example for productivity where this can be measured in ship, crane or vessel productivity rate. It is used to incorporate all of measurement bases into one equation rather than displaying each of the numerous individual correlation equations for each variable. It also provides a determination of which productivity variable is influenced most by a change in volume or capacity utilisation. The simple linear regression model is used to concentrate on a particular combination of measurement types for each variable and is displayed especially where the variables have a more limited number of measurement types available.

The reporting of the analysis is completed by providing the time series plots so that the reader can visually see the trends in capacity, utilisation, volume and productivity. The reporting of the relationship between these variables is carried out by reporting the relationship (i.e. whether there is a positive or negative relationship), whether it is statistically significant and the level of the relationship. Where possible, there is an example provided to show the hypothetical change in each of the variables.

The process for the analysis, in both the macro and micro level analysis, will be:

1. Review all data set for inconsistencies and remove outliers
2. Estimate the capacity of each port will be completed using the following equations:
  - 2.1. Yard capacity will be calculated using the following equation:

*Total annual throughput capacity = the number of container slots available x the annual rate of slot turnover*

Where:
    - The number of slots available is equal to the total area of the container terminal divided by the slots per acre. The Tioga Group (2010) concluded the following storage densities for different yard operating systems: straddle carrier operations = 160 slots per acre, stacked configurations with forklifts = 200 slots per acre and gantry systems = 300 slots per hectare (RTG) or 360 for RMG. The average stacking density in the 24 U.S ports monitored was 194 slots per acre.
    - The Tioga Group (2010) suggests that the theoretical maximum annual rate of slot turnover is 70, which equates to an average dwell time of containers in the terminal at slightly over 5 days. The average slot turns per annum in the 24 U.S ports monitored was 34 slot turns per annum.
  - 2.2. The wharf/crane capacity was completed through the calculation:

*Total annual throughput capacity = the number of container cranes available x the number of crane hours available to each crane x average crane rate*

The number of cranes available will depend upon the infrastructure availability of individual ports. The number of crane hours available is 24 hours a day, 365 days a year (assuming the labour is available).
  - 2.3. Estimation will be completed under two scenarios, one at peak and one at a sustainable level, as it is unlikely that the maximum annual slot turnover or crane productivity is sustainable day in day out, although it is theoretically possible as a peak demand or loading on the system.
    - 2.3.1. The Tioga Group (2010) assumed that the sustainable container yard capacity was 80% of the peak container yard capacity, following an industry rule of thumb. The average container yard utilisation in the 24 U.S ports monitored was 50%.
3. Report throughput volume and analyse trends in volume using statistical and regression analysis
4. Using the reported throughput, calculate the capacity utilisation and analyse trends in capacity utilisation using statistical and regression analysis
  - 4.1. the utilisation rate of each port will be determined by dividing the actual throughput on an annual or quarterly basis by the available wharf and yard capacity at the corresponding point in time.
5. Report productivity statistics and analyse trends in productivity using statistical and regression analysis
  - 5.1. Productivity analysis will be reported and analysed in terms of wharf/crane productivity. The following productivity measures will be used in the analysis:
    - 5.1.1. Crane Rate – the average number of containers handled by a single crane for every hour that it is used to load or discharge a vessel. The crane rate is calculated by dividing the total container handled by the elapsed crane rate. This measure excludes all operational and non-operational delays such as wind, hatch lids and lashing tasks, as outlined by Figure 2.4.
    - 5.1.2. Ship Rate – the average number of containers handled per hour, across all cranes employed, for every hour that cranes are used to load or discharge a vessel. The ship rate excludes all operational and non-operational delays. It is calculated by multiplying the crane rate by crane intensity. Crane intensity is measure of the number of cranes

employed to load or discharge a vessel.

5.1.3. Vessel working rate – the average number of containers handled for every hour that labour is employed on the berthed vessel – i.e. the total number of containers handled divided by the elapsed labour time. The vessel working rate includes all operational and non-operational delays and therefore the reported productivity figure is typically lower than ship rate figure.

6. Investigate the existence of relationships between volume, capacity utilisation and productivity

6.1. Regression analysis will be used with statistical tests indicating the strength and confidence of any relationships.

7. Investigate whether these relationships change when an inland hub facility is introduced or altered

7.1.1. In testing for the relationship or correlation between the volume or productivity of a port with the use of inland hubs regression and statistical analysis will be completed pre and post introduction of, or changes to, inland hubs to determine whether there is a change in the relationship or correction between portside and inland hub facilities.

The following table summarises the approaches outlined in the research onion from Saunders et.al 2009 and against the approach taken in this research.

Layer	Approaches	Approach used
Philosophy	Positivism, Interpretivism, Realism, Pragmatism	Positivism
Approach	Deductive, Inductive	Deductive
Strategy	Experiment, Survey, Case Study, Action Research, Grounded Theory, Ethnography, Archival research	Components of the experiment, survey and case study
Choice	Mono, mixed or multi methods	Quantitative with multiple methods of data collection and analysis
Time horizons	Cross Sectional, Time series, pooled cross section, panel data	Panel data set
Data Collection	Sampling, Secondary data, Observation, Interviews, Questionnaires	Secondary

**Table 4.6 Overview of the Research Approach used based on Saunders et.al 2009 Research Onion**

This research is conducted under a deductive approach where the theory or hypothesis is already developed and then the data is collected and analysed to determine whether the theory or hypothesis holds given the parameters and variable of the data analysis. The hypotheses for the analysis are:

1. The relationship between volume and capacity utilisation will be positive (i.e. an increase in volume results in an increase in capacity utilisation)
2. The relationship between volume and productivity will be negative (i.e. an increase in volume results in a decrease in productivity)

3. The relationship between capacity utilisation and productivity will be negative (i.e. an increase in capacity utilisation results in a decrease in productivity)
4. The use of inland hubs will improve the productive ability of the associated seaport (i.e. after the commissioning of the inland hub the relationship between volume and capacity utilisation will be less significant and the relationship between capacity utilisation and productivity will be less significant)

#### **4.12 STRENGTHS, WEAKNESSES AND LIMITATIONS**

The strength of this research methodology is that it uses data and analysis techniques which are comparable with international literature and industrial publications. The statistical analysis also provides a high level of detail as to the level and significance of the relationships between variables and the impacts associated with a change in any of the variables.

Typically data available for this research is secondary data – obtained via industry and government publication of port performance. Another strength of the research is that it triangulates the results of the data analysis of secondary data by carrying out detailed analysis on an individual port.

The weakness of the approach is that it concentrates on the analysis of volume, capacity utilisation and productivity variables. It does not include the analysis of other factors which may impact on the performance of the container terminal, such as the financial and human elements.

A limitation of the research is the use of secondary data. The use of secondary data brings with it drawbacks in relation to quality and reliability. Therefore, as detailed above, more detailed analysis using commercial port operational data (which has been checked for accuracy by a number of parties) was also completed for an individual port. This allowed the information and results to be triangulated, and the existence and significance of relationships confirmed.

The second limitation is that the productivity data is provided by each individual port for publication without the ability for the Ministry of Transport or another third party to check for accuracy (with the exception of a sense check in comparison to the previous reported figures and the reported figures of other ports). This is especially important given each port has an incentive to report figures which are as high as possible as it is the single New Zealand publication which allows cargo owners and shipping lines to compare the productivity of New Zealand ports on a quarterly basis.

The productivity, volume and capacity utilisation measures used in this research are directly

comparable to the information published by the Australian Bureau of Statistics on Australian port productivity and other international studies, such as Tioga (2006) on large American ports. However, another limitation of this data set is that the port productivity data is produced only for the productive ability of a ports cranes – i.e. the crane, ship and vessel productivity. It does not provide information on berth productivity per metre, productivity of yard equipment or the productive ability of a port to handle demand from land transport operations which is typically published by international reports and is provided on a quarterly basis for Australian container ports by the Australian Bureau of Statistics.

#### **4.13 ETHICAL OR CONFIDENTIALITY ISSUES**

There are ethical issues involved in the collection of business information, in particular the business's right to confidentiality. The New Zealand logistics and supply chain industries are relatively small and highly competitive where information and confidentiality are both highly important. A lot of industries and businesses are unlikely to provide full information in order to preserve their confidentiality.

Therefore, only publically available information is used during the national level investigation so as to not bias the analysis towards one or two organisations which provide further information. Non-publically available information is only used as a form of validation and triangulation in the detailed port analysis.



## **5 NATIONAL INVESTIGATION OF CONTAINER PORT RELATIONSHIPS**

### **5.1 INTRODUCTION**

This chapter outlines the analysis from a national overview perspective, including the data available and the analysis on capacity, throughput, utilisation and productivity and then investigates the existence of relationships between the variables.

### **5.2 DATA AVAILABLE**

There are a high number of data sources available to determine the capacity, throughput and productivity of New Zealand container ports. The main data source has a good coverage of the variables and is consistently collected on a regular quarterly basis. However, as outlined above, the data sources are secondary in nature, with secondary data prone to reliability and accuracy issues. Therefore the national analysis performed below will investigate the relationships between capacity, throughput volume and productivity for all New Zealand ports using the main data source. The high number of alternative data sources available in New Zealand will allow support, or otherwise for the investigation completed and the conclusions developed. The detailed investigation, completed in the next chapter, will triangulate any results produced.

The main data source for the national level investigation is compiled through the use of the Ministry of Transport quarterly reports titled *Freight Information Gathering System and Port Productivity Study*. This is publically available information published quarterly. The Ministry's purpose is to provide "a detailed understanding of this of New Zealand freight traffic, including volumes, export/import imbalances, and the mode of inland transport used to carry cargo to and from ports" (Ministry of Transport (2012)). The reports also provide productivity data for the container ports.

The volume information is produced for all New Zealand ports, however productivity data only includes the main container ports of Auckland, Tauranga, Napier, Wellington, Lyttelton and Otago, although these ports account for over 90% of container traffic through New Zealand ports.

The ports productivity information published quarterly is:

- The number of containers handled (measured in units)
- Crane rate – the number of containers a crane lifts on/off a container ship in an hour
- Ship rate – the number of containers moved on/off a container ship in an hour (between the berthing and sailing of a vessel)
- Vessel rate – the number of containers moved on/off a container ship in an hour while labour is employed to work the ship

Therefore the data available does concentrate on the shipside productivity. The literature review above does highlight that this is the case for the majority of research on the productivity of container ports. This is a result of the transfer function between wharf and container vessel being the largest revenue component for a container port (Productivity Commission (2012)). Literature also suggests that crane productivity is a good representation of overall container terminal productivity as it is the result of all other terminal components functioning effectively (Le-Griffin and Murphy (2006)). Kasypi. M and Shah. M (2013) suggests that high wharf or crane productivity is a measure of a good container terminal and able to attract shipping line to berth.

Other data sources such as Rockpoint Corporate Finance's Port Financial Report compilation, Statistics New Zealand's Database and individual port media releases are also used to help provide insights to changes in the variables or the existence of any relationships. These data sources are not used as a main data source as they are not regularly collected, do not provide productivity information or suffer from problems of reliability. All data available in New Zealand concentrates on only the stevedoring or wharfside productivity, rather than also including performance metrics on the land transport integration and other customer service levels.

### **5.3 CAPACITY**

The analysis of capacity is completed across both wharf capacity and land, or yard, capacity.

The wharf/crane capacity was completed through the calculation:

*Total annual throughput capacity = the number of container cranes available x the number of crane hours available to each crane x average crane rate*

The number of cranes available will depend upon the infrastructure availability of individual ports. The

number of crane hours available is 24 hours a day, 365 days a year (assuming the labour is available). Table 4.7 details the wharfside capacity for the major New Zealand container terminals.

The italicised text below traces through the calculation for Port Otago.

	Auckland	Napier	Tauranga	Wellington	Lyttelton	Otago
Cranes	8	3	6	2	3	3
Crane hours available (for each crane) (note 1)	8,760	8,760	8,760	8,760	8,760	8,760
Crane hours available (total)	70,080	26,280	52,560	17,520	26,280	26,280
Average productivity including delays (note 2)	24.83	15.31	26.54	25.19	20.97	23.99
Peak capacity (units)	1,739,784	402,343	1,394,824	441,371	551,087	630,439
Sustainable capacity (units)	1,391,827	321,875	1,115,859	353,097	440,869	504,352
Conversion factor (units:TEU) (note 3)	1.44	1.48	1.46	1.42	1.44	1.47
Peak capacity (TEU)	2,501,263	595,445	2,041,628	625,290	795,756	929,178
Sustainable capacity (TEU)	2,001,010	476,356	1,633,303	500,232	636,605	743,342

**Table 4.7 Calculation of Annual Crane Throughput Capacity for New Zealand's Main Container Terminals**

**Note 1 – Napier uses a harbour mobile crane which is typically less productive than the quay cranes used by all other New Zealand ports**

**Note 2 – based on average rates published in Ministry of Transport's port productivity statistics between 2009 Quarter 1 and 2012 Quarter 4**

**Note 3 – calculated from Ministry of Transport (2013) Freight Information Gathering System Data Report March 2013, page 18**

#### *Crane Capacity*

*Port Otago has 3 Quay-side cranes. The Ministry of Transport productivity information suggests that the average crane productivity is 29.24 moves per hour over the last two years.*

*The total crane hours available annually are: 365 days x 24hours = 8,760 multiplied by 3 cranes = 26,280.*

*If each crane was running continuously at the average crane moves the annual capacity would be 768,427 container units or 1,129,587 TEU (assuming 29.24 moves per hour and conversion factor of 1.47 (1 container unit = 1.47 TEU<sup>19</sup>) as outlined by the Ministry of Transport's 2013 Freight Information Gathering System Outputs)*

*However, the crane productivity measure recorded by the Ministry of Transport excludes normal operational delays. The Ministry of Transport reports both the vessel rate and the ship on a quarterly basis for each of the major container terminals. Port Otago's ship rate (which is a productivity measure which discounts all operational delays) is 18% higher than the vessel rate (which includes all operational delays). Therefore 18% should be deducted from the crane moves per hour to calculate the actual crane productivity including all productive and non-productive (i.e. delays) elements.*

*Therefore the actual crane productivity is 23.99 moves per hour, resulting in a capacity of 630,457*

<sup>19</sup> In this case Port Otago has a mixture of TEU and FEU use. Auckland handles a higher proportion of TEUs, therefore the conversion factor is lower at 1 container unit = 1.44 TEU.

Land or yard capacity will be calculated using the following equation:

$$\textit{Total annual throughput capacity} = \textit{the number of container slots available} \times \textit{the annual rate of slot turnover}$$

Where:

- The number of slots available is equal to the total area of the container terminal divided by the slots per acre or hectare.
- Tioga (2010) suggest that the theoretical maximum annual rate of slot turnover is 70. The average slot turns per annum in the 24 U.S ports monitored was 34 slot turns per annum.

The yard capacity calculation will be completed under two scenarios, one at peak and one at a sustainable level, as it is unlikely that the maximum annual slot turnover of 70 is sustainable day in day out, although it is theoretically possible as a peak demand or loading on the system. The sustainable container yard capacity is assumed to be 80% of the peak container yard capacity.

Drewry (2010) suggest that the global average throughput per hectare of yard is just over 20,000 TEU per annum, but large terminals are nearly 50% higher than this whilst small ones average only 8,000 TEU per hectare per annum.

Table 5.8 outlines the yard capacity and the italicised text box below traces through the calculation for Port Otago.

	Auckland	Napier	Tauranga	Wellington	Lyttelton	Otago
Terminal Area (Hectares)	46.50	10.00	30.00	10.00	14.00	15.00
Terminal Area (acres)	114.90	24.71	74.13	24.71	34.59	37.07
Stacking configuration	Straddles with forklifts in the empty container areas	Forklifts throughout	Straddles with forklifts in the empty container areas	Straddles with forklifts in the empty container areas	Straddles with forklifts in the empty container areas	Straddles with forklifts in the empty container areas
Stacking Density (slots per acre) (note 1)	180	180	180	180	180	180
Number of slots available	20,683	4,448	13,344	4,448	6,227	6,672
Assumed maximum annual slot turnover	65	66	67	68	69	70
Peak capacity (units)	1,344,375	293,561	894,026	302,457	429,666	467,028
Sustainable capacity (units)	1,075,500	234,849	715,221	241,965	343,733	373,623
Conversion factor (units:TEU) (note 3)	1.44	1.48	1.46	1.42	1.44	1.47
Peak capacity (TEU)	1,932,789	434,453	1,308,601	428,490	620,428	688,333
Sustainable capacity (TEU)	1,546,231	347,563	1,046,881	342,792	496,342	550,667

**Table 5.8 Calculation of Annual Yard Throughput Capacity for New Zealand's Main Container Terminals**  
**Source: Author's Calculations**

**Note 1 –** The straddle terminals with 1 over 2 straddles (therefore can stack three high) are assumed to have a mean stacking height of 3 if they have an empty container facility which utilises forklifts and block stacks. In the straddle yard it is highly unlikely that everything will be stacked three high as there would be no ability to access containers other than the ones located on the end of each row and stacked on top. Therefore the mean stacking height is likely

**Note 2 -** Port of Napier is the only NZ port not using straddles in the container yard

**Note 3 –** based on Ministry of Transport (2013)

#### *Land Capacity*

*Port Otago current has 15 hectares (37.07 acres) in which to handle containers.*

*U.S ports research (which is relatively conservative in comparison to what actually happens in New Zealand) suggests that the container slots per acre is approximately 160 for a straddle operation or over 200 for a mixed (forklift and straddle) operation.*

*This equates to 5,931 (i.e. 1,977 ground slots if they are stacked 3 high) total slots available at Port Otago (@160 per acre) or 7,414 (@200 per acre).*

*U.S ports research suggests that an average number of turns for each container slot is 32 with a theoretical maximum of 70 (Lyttelton Port of Christchurch currently operate close to 70 turns). Therefore the capacity of land capacity is 415,170 TEU at 160 per acre and 519,980 at 200 slots per acre.*

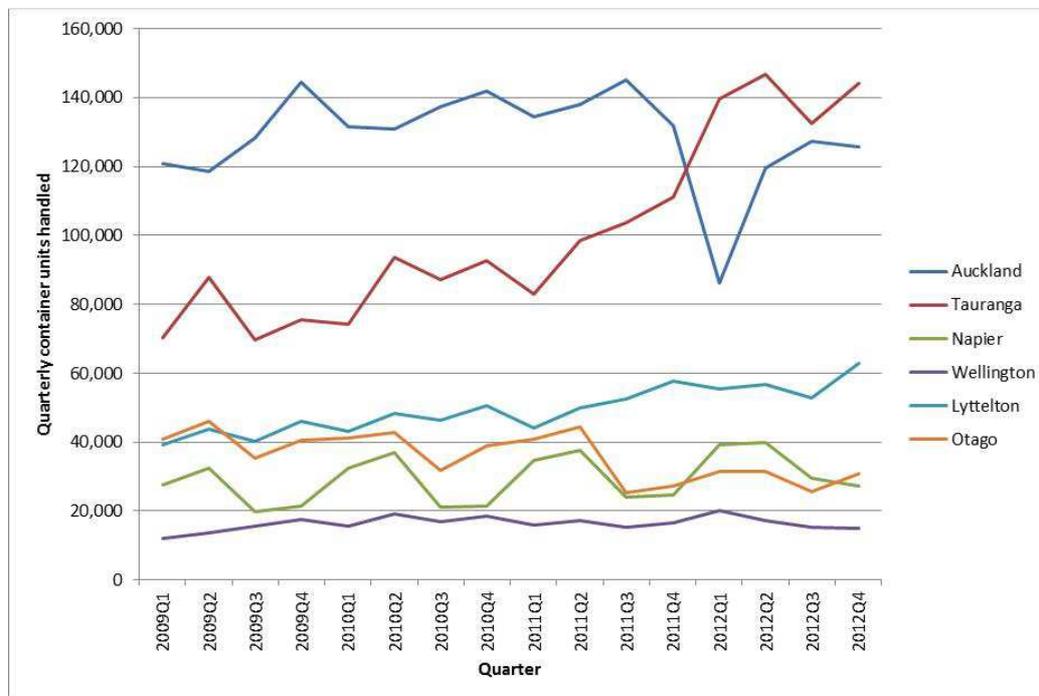
Port capacity in New Zealand is between 4.5 million and 7.25 million TEU depending upon the measurement used and timeframe of analysis (i.e. a short term peak period or a longer term sustainable capacity). 61% of yard capacity and 63% of crane capacity is contained in Auckland and

Tauranga ports and the South Island only accounts for 24% of the container capacity. For comparison, the average container yard utilisation in the 24 U.S ports monitored by Tioga (2010) was 50%.

Land capacity is significantly lower than crane capacity for all ports, reflecting New Zealand's legacy issues associated with ports that have been constructed in locations where cities have formed around them and it is now difficult and costly to reverse the problem.

## 5.4 THROUGHPUT AND UTILISATION

Time series plots for container volumes are provided in Figure 5.11 for the six largest New Zealand container ports.



**Figure 5.11 Container volumes for New Zealand's six largest container ports, Quarter one 2009 – Quarter four 2012**

Total volume of containers handled by the largest New Zealand container ports has increased steadily over the past four years, with typical seasonal spikes in the second quarter of each calendar year.

Port of Tauranga has had the largest increase in container throughput – doubling quarterly container numbers over the four year period and capturing growth and taking significant market share from Auckland. Ports of Auckland lost a lot of volume to Tauranga, especially in the first quarter of 2012 when waterfront workers went on strike and container ship lines diverted their vessels to other ports.

Table 5.9 indicates the effect of the strikes to the Ports of Auckland.

Port	Volume Q1 2012 (Container Movements)	Change from last Quarter – Q4 2011 (Container Movements)	Change from Q2 2011 (Container Movements)
Auckland	86,299	-45,524	-48,275
Tauranga	139,653	28,590	56,607
Napier	39,259	14,443	4,621
Wellington	20,188	3,690	4,256
Lyttelton	55,402	-2,251	11,460
Otago	31,407	4,187	-9,427

**Table 5.9 Market share changes associated with industrial strike action at Ports of Auckland 2012**  
**Source: Author's Calculations**

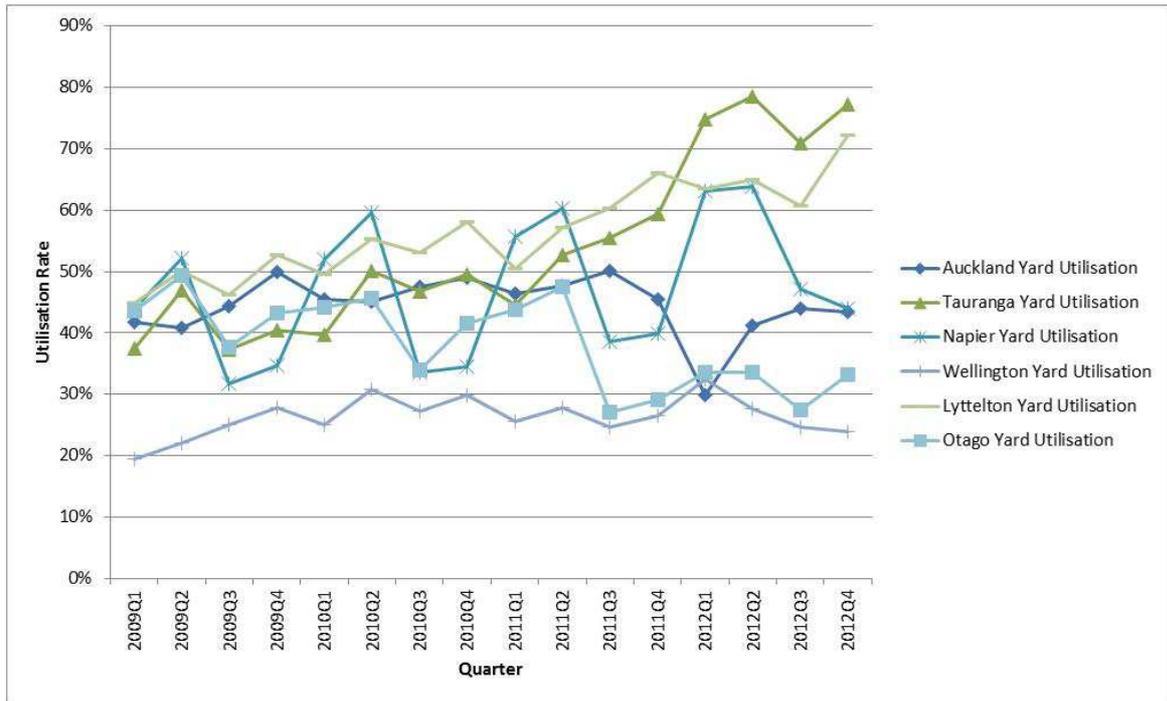
Port of Tauranga was the major beneficiary, but Napier and Wellington also had spikes in quarterly throughput for quarter one of 2012. While the impact of strikes has been temporary on the Napier and Wellington ports, the impact has been more permanent for both Auckland and Tauranga. The cumulative year on year decrease in container throughput over the last five quarters was 101,000 for Ports of Auckland while the cumulative increase for Port of Tauranga has been 185,000 – capturing both market share and growth as a result of services being permanently changed from Auckland to Tauranga.

The other port to have significant growth in quarterly container throughput is the Lyttelton Port of Christchurch, achieving a growth in quarterly throughput of over 60%. Much of this growth has been at the expense of throughput at Port Otago – their quarterly throughput has declined by 24%.

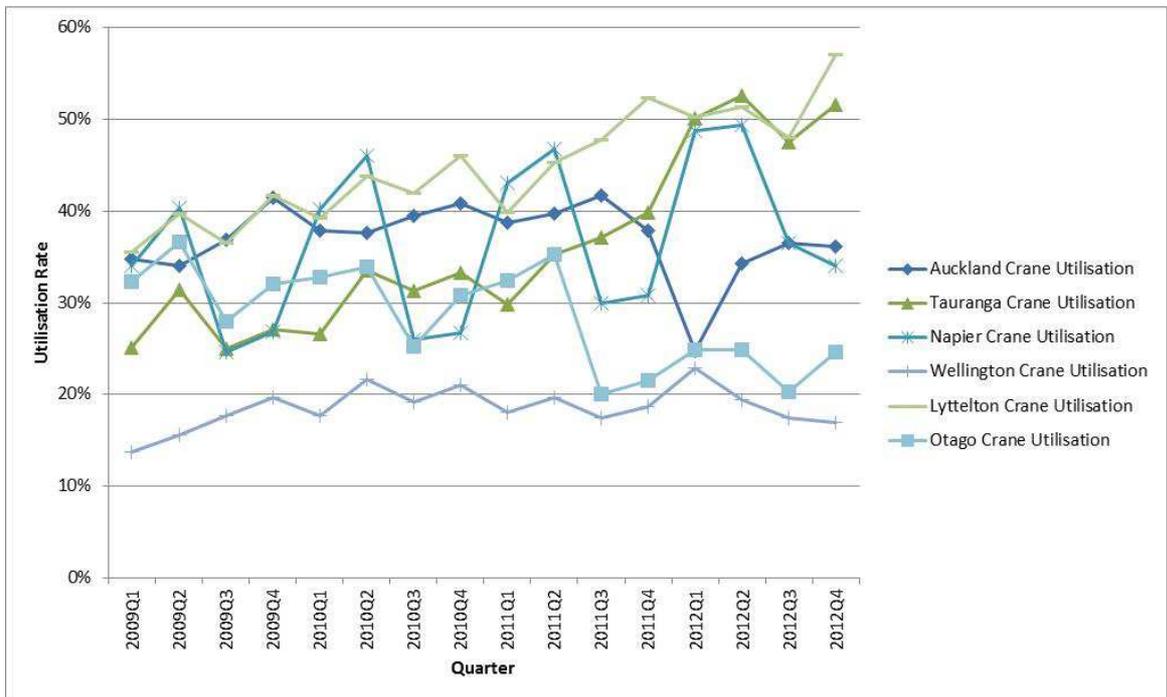
It is evident that the majority of growth is focused towards the Port of Tauranga in the North Island and Lyttelton Port of Christchurch in the South Island. These ports, as outlined by Rockpoint (2010) big ship report are also in the best position to cater for larger vessels and are the likely victors from port rationalisation.

## **5.5 UTILISATION**

Based on the quarterly throughput and the available land and crane capacities calculated in Table 5.8 and Table 4.7, it is possible to plot land and crane capacity utilisation on a quarterly basis as depicted in Figure 5.12. This figure assumes sustainable, rather than peak, loadings.



**Figure 5.12 Utilisation of Yard Capacity for New Zealand’s major container terminals under sustainable loadings between Quarter 1 2009 and Quarter 4 2012**



**Figure 5.13: Utilisation of Crane Capacity for New Zealand’s major container terminals under sustainable loadings between Quarter 1 2009 and Quarter 4 2012**

For all ports the utilisation rate for yard is higher than that of the crane utilisation, reflecting a relative shortage of land in most cases, which is in line with the Auckland Regional Holdings (2009) report on the Optimisation of the New Zealand Port Industry. They outlined that all ports except Tauranga have a shortage of land which may restrict future growth.

In the cases of highest utilisation, both ports (being Tauranga and Lyttelton) have signalled to the market the purchase of new cranes and the increasing uptake of land since this data.

The Port of Tauranga has expanded its MetroPort inland port operations in Auckland<sup>20</sup>. It has also recently extended the container wharf and purchased a new crane. Lyttelton has signalled to the market that a new ship-to-shore container gantry crane has been purchased and will be in use by 2014<sup>21</sup> and that work on the reclamation at Te Awaparahi Bay, in the eastern area of the Port has progressed well with the reclaimed area approximately 4.0 hectares as at September 2013.

Given the number of references in the literature review and industry background to the constrained capacity of the ports in New Zealand, the utilisation figures reported here are low in comparison to international examples. The reported utilisation figures for the larger ports are however higher than the figures which literature suggests results in congestion and declining productivity.

## **5.6 PRODUCTIVITY**

The time series plots for crane cranes, ship rates and vessel rates are provided below for the six largest New Zealand container ports, analysed between quarter one 2009 and quarter four 2012

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<sup>20</sup> Retrieved from <http://www.transportintelligence.com/news/port-of-tauranga-acquires-gateside-industrial-park-from-goodman/10569/> on 7 September 2013 at 12:41pm

<sup>21</sup> Retrieved from <http://lpc.co.nz/TempFiles/TempDocuments/2013%20Media%20Releases/NZX%20Release%20LPC%20Announces%20Further%20Investment%20at%20Container%20Terminal%2007%20June%202013.pdf> on 7 September 2013 at 12:41pm

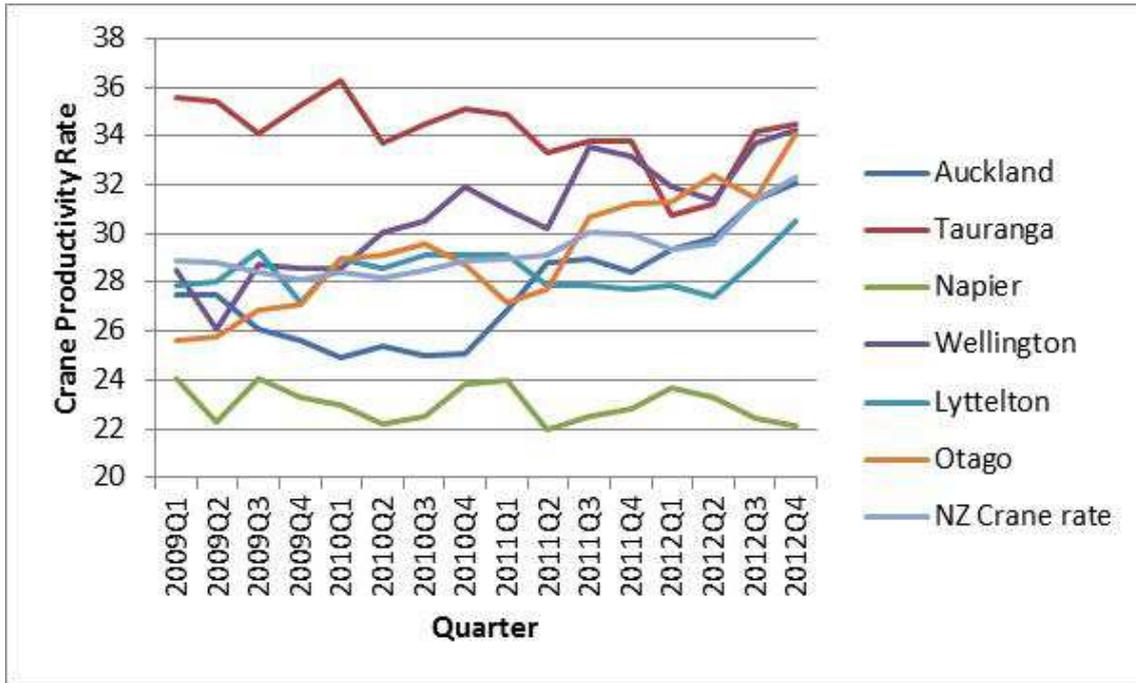


Figure 5.14 Crane productivity rates for New Zealand's six largest container ports, Quarter one 2009 – Quarter four 2012

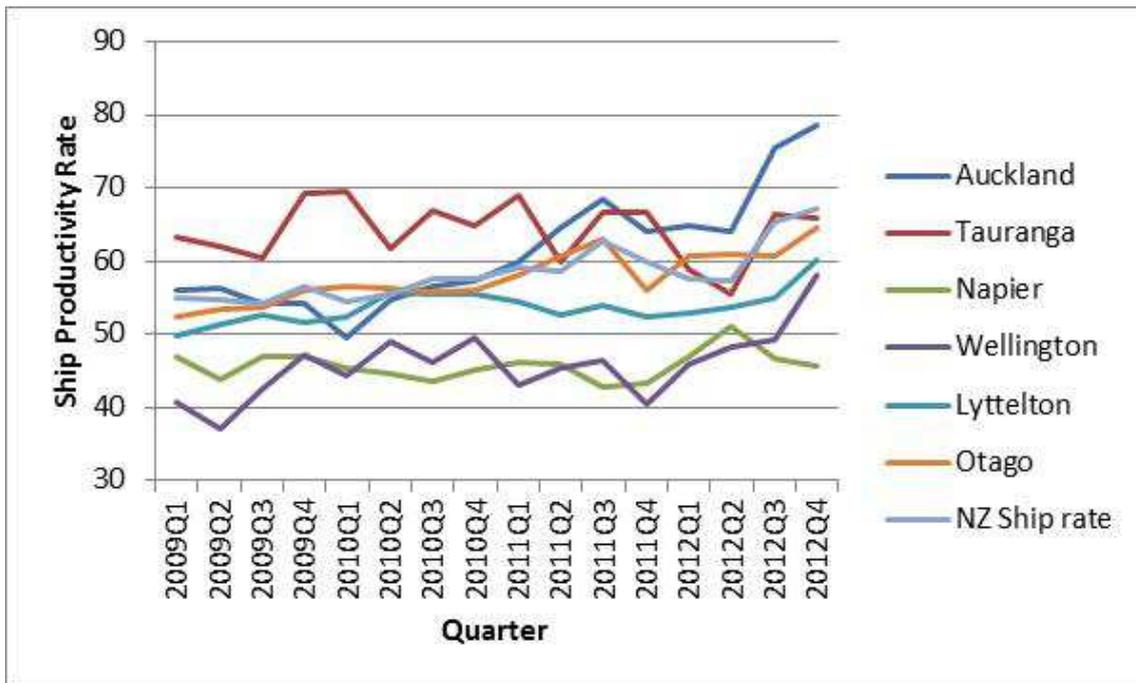
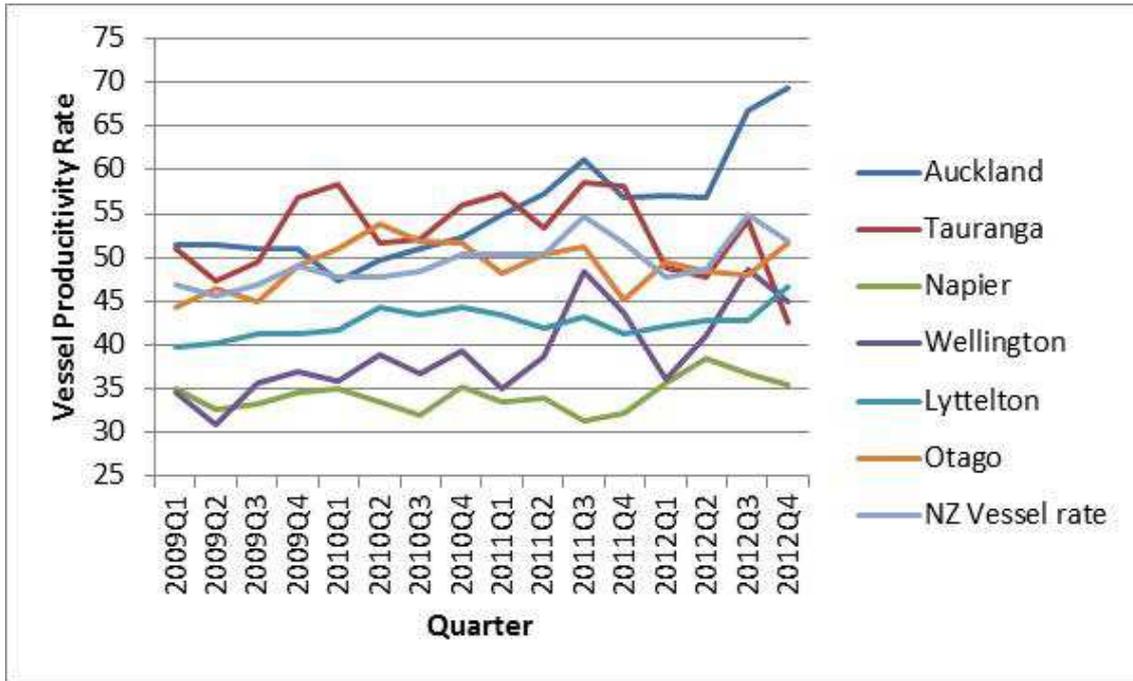


Figure 5.15 Ship productivity rates for New Zealand's six largest container ports, Quarter one 2009 – Quarter four 2012



**Figure 5.16 Vessel productivity rates for New Zealand’s six largest container ports, Quarter one 2009 – Quarter four 2012**

Over the majority of the time period Port Tauranga had the highest crane, ship and vessel productivity rates across New Zealand container ports. However, since quarter one 2009, the start of the data series, individual crane productivity has been in decline, particularly in quarter one 2012 as strike action occur in Auckland and large amounts of volume shifted quickly towards the Port of Tauranga. Crane productivity has subsequently recovered to rates similar to before the strike action.

Ship and vessel productivity rates for the Port of Tauranga have been relatively consistent over the time period, with the exception of the decline in vessel productivity rate since the final quarter of 2011. This indicates that since Tauranga has gained increased growth in market share and volume as a result of Auckland’s strike action, the individual crane rate has declined and there has also been a general increase in the portion of non-productive time due to higher utilisation, congestion and non-productive moves associated with organising container yards which are stacked higher and with greater density.

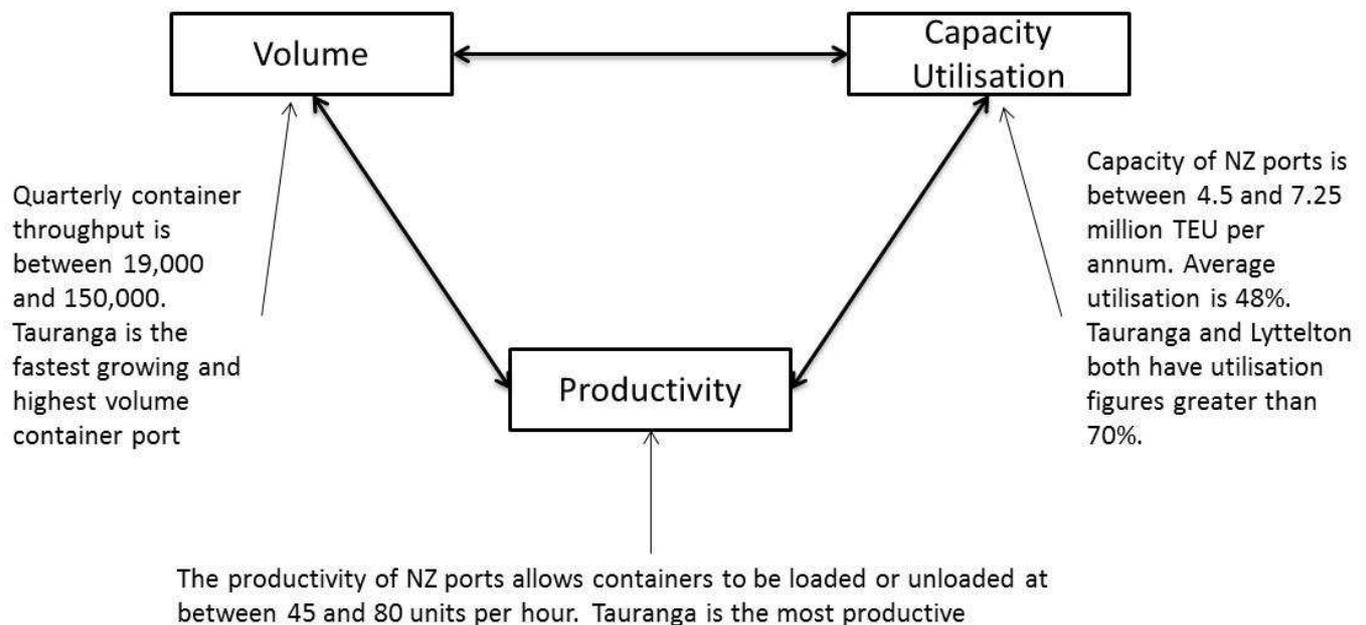
What is evident from the time series plots is that Auckland’s crane, vessel and ship productivity has been increased and sharply rose after the loss of volume to other North Island ports.

The case for Wellington is similar to that of Tauranga’s – strike action meant immediate productivity took a hit – however Wellington has bounced back in a faster manner.

It is interesting to compare and contrast the rates of Wellington and Napier ports, which have similar volumes, are located close to each other, but have different infrastructure in place. There is a concentration in Wellington on a single crane port quayside crane which has resulted in a high crane rate and low vessel rates. Napier on the other hand, has a low crane productivity from each of its harbour mobile cranes but high vessel and ship are comparable due to the concentration on a higher number of cranes (i.e. a higher crane intensity). In terms of the commercial impact – Napier are likely to have occurred less capital cost impact and running costs however their labour costs are likely to be higher due to the requirement to run further labour gangs for each crane in comparison to Wellington.

From the time series data it can be said that South Island ports are generally less productivity compared to the New Zealand average across the three productivity measures reported. This is especially the case if Napier was to be excluded from the crane rate calculation due to their differences in infrastructure.

Before the relationships between the variables are investigated, the diagram below provides a summary of the key variables:



**Figure 5.17: Diagrammatic Summary of New Zealand Container Port Variables used in this Investigation**

## 5.7 THE RELATIONSHIP BETWEEN VOLUME, CAPACITY UTILISATION AND PRODUCTIVITY

The objective of this research is to investigate the throughput volume, capacity utilisation and productivity of New Zealand ports, as well as the relationship between the variables. The volume, capacity utilisation and productivity trends of New Zealand ports have been outlined and investigated above. The analysis below provides an investigation of the relationship between the three variables, around the multiple different measurement bases (e.g. crane utilisation vs. yard utilisation or crane productivity rate vs. vessel productivity rate).

The analysis below concentrates on determining relationships between each of the variables. To determine the existence, size and significance of the relationships both multivariate regression and simple linear regression models are used. The multivariate regression is used where there are a number of measure types. It is used to incorporate all of measurement bases into one equation rather than displaying each of the numerous individual correlation equations for each variable. The simple linear model is used to concentrate on a particular combination of measurement types for each variable and is displayed especially where the variables have a more limited number of measurement types available. The detailed results of all statistical analysis completed are contained in Appendix 1.

The first relationship investigated in the analysis is the relationship between throughput volume and utilisation. Time series trends in both volume and capacity utilisation have been outlined above for all of New Zealand's major container ports. The throughput volume data is modelled in terms of container units, irrespective of whether they are twenty or forty foot containers. Capacity utilisation is measured in terms of crane capacity and yard capacity utilisation.

Simple linear regression was completed across the following relationships for each port:

$$\text{Crane utilisation} = B * \text{Volume}$$

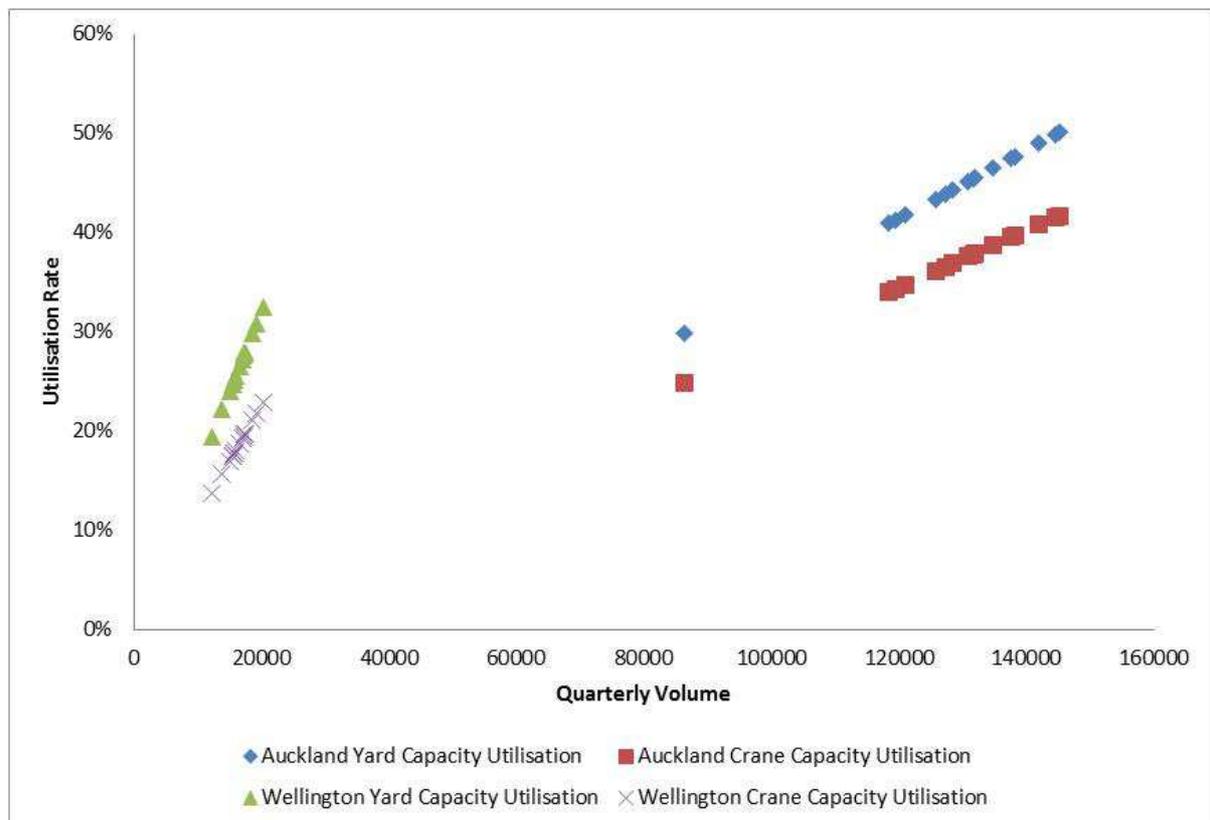
$$\text{Yard utilisation} = B * \text{Volume}$$

The results of the simple linear regressions are provided in Appendix 1. The  $B$  is the parameter vector, it is what is being estimated through this analysis and is an outline of the existence and strength of an relationship between the two variables (the variables in this case are utilisation and volume).

For crane utilisation, the volume change has the greatest impact on Wellington and Napier and the least impact on Auckland and Tauranga. This is due to the fact that Wellington has a low number (2) of productive cranes and Napier has three less productive cranes in comparison to Auckland's eight cranes and Tauranga's six, both with relatively high crane productivity per hour available.

For yard utilisation, the volume change has the greatest impact on Wellington, Napier, Otago and Lyttelton due to their lack of land available and the least impact on Auckland and Tauranga.

Figure 5.18 quickly illustrates the difference in relationships between Auckland and Wellington ports.



**Figure 5.18 Correlation between Volume and Capacity for Auckland and Wellington ports**

The steepness of the Wellington data plots relative to Auckland data plots indicates the greater impact of volume changes on capacity utilisation for the smaller New Zealand ports. However, the t-stats and the p-values are low and indicate that the variables are not statistically significant at the 95% confidence level. This means that we cannot be certain to a 95% confidence level that the variable is not actually zero. However, the small sample size of the data set is an inherent problem in this case, where an outlier has the potential to skew the estimates from a small data set – i.e. any point that differs a lot from the rest will have a disproportionately large effect on the estimated regression.

The second investigation component is the relationship between utilisation and productivity. Capacity utilisation is measured in terms of crane capacity and yard capacity utilisation. Productivity meanwhile is measured in terms of crane, ship and vessel productivity rates. Because there are multiple measures for each of the variables, multivariate regression models were used.

The first multivariable regression model used utilisation as the dependent or 'y' variable in order to investigate which type of productivity impacted the most on the utilisation of yard or crane. The multivariate equations were therefore:

$$\text{Crane Utilisation} = B1 * \text{Crane Productivity} + B2 * \text{Ship Productivity} + B3 * \text{Vessel Productivity}$$

$$\text{Yard Utilisation} = B1 * \text{Crane Productivity} + B2 * \text{Ship Productivity} + B3 * \text{Vessel Productivity}$$

The results are outlined in Table 5.10 and Table 5.11.

	<i>B1</i>	<i>B2</i>	<i>B3</i>	<i>Significance Level of F-value</i>
Auckland	-0.029	-0.007	0.018	0.026
Tauranga	-0.068	0.016	-0.010	0.002
Napier	-0.045	0.021	0.004	0.221
Wellington	0.007	0.002	-0.003	0.345
Lyttelton	-0.065	0.056	-0.034	0.001
Otago	-0.020	0.000	0.007	0.002

**Table 5.10 Multivariate correlation analysis results - crane utilisation and productivity - New Zealand's major container terminals**

	<i>B1</i>	<i>B2</i>	<i>B3</i>	<i>F-value</i>
Auckland	-0.034	-0.008	0.022	0.026
Tauranga	-0.102	0.024	-0.015	0.002
Napier	-0.059	0.027	0.006	0.221
Wellington	0.009	0.002	-0.005	0.345
Lyttelton	-0.082	0.071	-0.043	0.001
Otago	-0.027	0.000	0.009	0.002

**Table 5.11 Multivariate correlation analysis results - yard utilisation and productivity - New Zealand's major container terminals**

The interesting component of the results is the existence of both positive and negative relationships across the different measurement techniques and variables. A negative B variable and therefore relationship suggests that as crane or yard utilisation increases the productivity of the crane or cranes decreases. Whereas a positive relationship indicates that an increase in utilisation results in an increase in productivity.

The largest impact upon crane and yard utilisation is how fast each crane is working individually (as shown by the crane productivity rate) rather than how fast the cranes are collectively working together to exchange containers on a vessel – i.e. the crane rate has a larger impact on utilisation than the ship or vessel productivity rate.

There is also a difference in the relationship across the major container terminals. An increase in crane utilisation makes Wellington significantly more productive whereas it significantly decreases the productivity of Auckland's individual cranes. An increase in yard utilisation makes Wellington and Lyttelton more productive whereas it significantly decreases the productive ability of Auckland, Tauranga, Napier and Otago's individual cranes.

This is perhaps due to Wellington's concentration on the smaller number of cranes they own in relation to their total throughput – i.e. Wellington owns two quayside cranes and has an approximate annual TEU throughput of 100,000 (i.e. 50,000 TEU per crane) whereas Auckland has 8 cranes with throughput eight times that of Wellington.

It could also be indicative of the typically low utilisation of total crane hours or yard area at Wellington in comparison to Auckland - the increased repetition increases associated with increased utilisation also increases proficiency – i.e. practice makes perfect. Whereas for Auckland they already operate at a higher utilisation and proficiency

It may also indicate how ports respond to increased volume and utilisation. If there is an increase in utilisation Wellington may respond by increasing labour and capital (in the form of straddles or forklifts) to keep crane productivity high, whereas Auckland may choose to decrease productivity in order to minimise labour costs, or Auckland may bring an additional crane into the servicing of the vessel.

The significance of the F-value column indicates the statistical significance of the relationship in totality. The values reported indicate the level of error prevalent in the equation. Therefore a value in this column of 0.05 indicates that there is a 5% error prevalent, or a high level of confidence in the model predictions with the confidence level of 95%.

The confidence levels of the Napier and Wellington equations are lower than the other major container terminals, indicating the more erratic nature of the quarterly data for the Napier and Wellington ports due to their smaller baseline throughput volumes and capacity utilisation.

The second multivariable regression model used productivity as the dependent or 'y' variable in order to investigate which type of utilisation impacted the most on productivity. However, in this multivariate equation throughput volume is also included in order to determine whether volume or utilisation is the most significant contributor to changes in productivity.

The multivariate equations are therefore:

$$\text{Crane Productivity} = B1 * \text{Crane Utilisation} + B2 * \text{Yard Utilisation}$$

$$\text{Ship Productivity} = B1 * \text{Crane Utilisation} + B2 * \text{Yard Utilisation}$$

$$\text{Vessel Productivity} = B1 * \text{Crane Utilisation} + B2 * \text{Yard Utilisation}$$

High correlation between crane and yard utilisation figures results in the multivariate equations presenting multicollinearity<sup>22</sup>, meaning that the results for individual variables (i.e. B1 or B2) maybe highly inaccurate. Simple linear regression was therefore completed across each of the individual measurement functions for each variable, with the results provided in the Appendix 1; Regression Analysis Outputs.

The simple linear relationships between capacity utilisation and productivity provided interesting information– an increase in crane or yard utilisation made Wellington and Lyttelton significantly more productive whereas it significantly decreases the productive ability of Auckland, Tauranga and Otago. Napier was unique, in that depending on the basis used to measure productivity or capacity utilisation

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<sup>22</sup> Multicollinearity is a statistical phenomenon in which two or more predictor variables in a multiple regression model are highly correlated, meaning that one can be linearly predicted from the others with a non-trivial degree of accuracy. In this situation the coefficient estimates may change erratically in response to small changes in the model or the data. Multicollinearity does not reduce the predictive power or reliability of the model as a whole, at least within the sample data themselves; it only affects calculations regarding individual predictors.

the relationship could be positive or negative.

The final relationship investigated in the analysis of port variables is the relationship between throughput volume and productivity. Time series trends in both volume and capacity utilisation have been outlined above for all of New Zealand's major container ports. The throughput volume data is modelled in terms of container units, irrespective of whether they are twenty or forty foot containers. This analysis does not unduly penalise those ports focusing on either 20 foot containers or 40 container units as all New Zealand ports have twin lift capability (i.e. they can lift two twenty foot containers simultaneously) on both their straddles and cranes. Productivity meanwhile is measured in terms of crane, ship and vessel productivity rates.

Simple linear regression was completed across the following relationships for each port:

$$\text{Crane rate} = B * \text{Volume}$$

$$\text{Ship rate} = B * \text{Volume}$$

$$\text{Vessel rate} = B * \text{Volume}$$

Statistical results are provided in the Appendix 1; Regression Analysis Outputs.

An increase in container throughput volume increases the crane productivity of the Wellington significantly and Lyttelton to a smaller degree while it significantly decreases Otago's.

In terms of statistical significance, Auckland, Napier, Wellington and Lyttelton have B values which are statistically significant at the 95% confidence level. There is, therefore, more confidence in the estimates produced for these ports.

An increase in container throughput volume increases the ship productivity of the Wellington significantly and Lyttelton to a smaller degree while it significantly decreases Otago's.

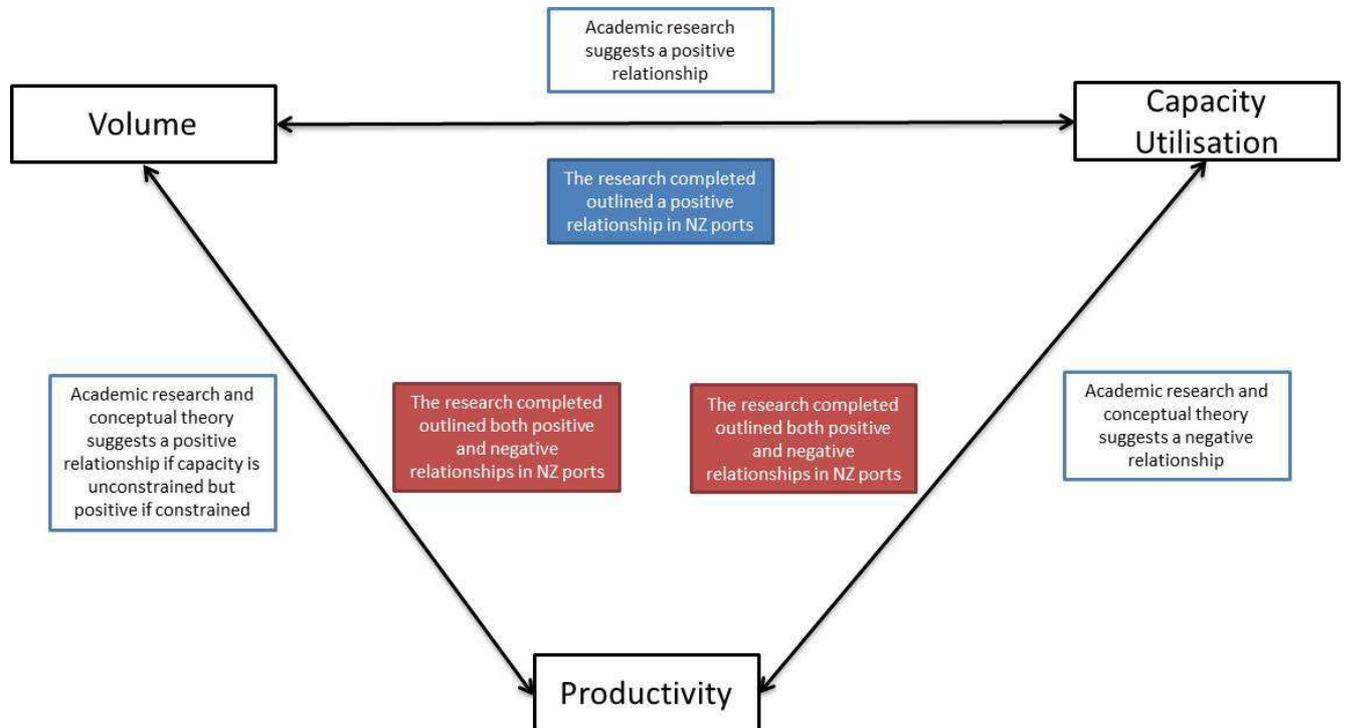
In terms of statistical significance, Auckland, Tauranga, Napier and Wellington have B values which are statistically significant at the 95% confidence level. There is, therefore, more confidence in the estimates produced for these ports.

An increase in container throughput volume increases the ship productivity of the Wellington and Napier significantly and Lyttelton to a smaller degree while it significantly decreases Auckland, Tauranga and Otago's.

In terms of statistical significance, Auckland, Tauranga, Napier, Wellington and Otago have B values which are statistically significant at the 95% confidence level. There is, therefore, more confidence in

the estimates produced for these ports.

The diagrammatic overview below summarises the results of this investigation against the expected hypotheses.



**Figure 5.19: Summary of Investigation Results against the Expected Hypotheses**

Therefore, in summary most of the investigation confirmed the hypothesis and produced relationships similar to the conceptual and academic models reviewed. However in some cases (Wellington in particular) the results were opposite to the hypotheses.

### 5.8 THE RELATIONSHIP BETWEEN PORT PRODUCTIVITY, VOLUME AND THE USE OF INLAND HUBS

One objective of this research is to investigate the throughput volume, capacity utilisation and productivity of New Zealand ports, as well as the relationship between the variables. Another objective is to investigate how ports develop and use inland hubs to positively influence these variables and relationship.

The following inland hubs are assumed in the analysis:

- Ports of Auckland – Wiri Inland Container Depot – Opened, prior to the start of the data series however, in Quarter 1 2010 rail link directly linking the inland port to the seaport was opened.<sup>23</sup>

<sup>23</sup> [http://www.poal.co.nz/facilities\\_services/facilities/inland\\_port.htm](http://www.poal.co.nz/facilities_services/facilities/inland_port.htm) retrieved at 6:12pm on 11 September 2013

- Port of Tauranga – MetroPort Auckland - was opened in 1999<sup>24</sup>, prior to the start of the data series. However in March 2010 it expanded to include Tapper Transport, an inland port and warehousing facility with a throughput of 90,000 Auckland TEUs<sup>25</sup>.
- Lyttelton Port – CityDepot Limited – was opened prior to the start of the data series. However, this will be investigated further in the detailed port analysis below.
- Port Otago – Fonterra opened a 16.45 hectare dry and cool storage facility in Mosgiel, linked to the port by rail Mosgiel Inland Hub <sup>26</sup>, with product being stored in there in June 2010<sup>27</sup>. It must be noted that in the time period the Te Rapa Inland Port in Hamilton has also been opened and currently caters for a large volume of Fonterra product. However, it is port agnostic unlike the inland hubs mentioned above, and is a solution developed by the exporter rather than a solution developed by a port aimed at developing the market share, volume or productivity of a particular port<sup>28</sup>.

The purpose of this section of the analysis is to determine the impact on volume and productivity of using inland hubs, also known as inland container terminals. As discussed throughout other chapters, Auckland industrial strikes in Quarter 4 2010 and Quarter 1 2011, significantly altering the throughput volumes. As the strikes were at a similar time to the changes in inland hubs as mentioned, it is difficult to determine whether the changes in volume of each of the ports pre and post hub introduction are attributable to the use of inland hubs.

Therefore, the analysis here concentrates on the changes in productivity as a result of the changes in inland hubs. The equation analysed in below is:

$$\text{Vessel rate} = B * \text{Volume}$$

Rather than discussing the figures produced directly from the equations, it is easier to convert them

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<sup>24</sup> <http://www.teara.govt.nz/en/photograph/7119/metroport-auckland> and [www.port-tauranga.co.nz](http://www.port-tauranga.co.nz) retrieved at 7:23am on 12 September 2013

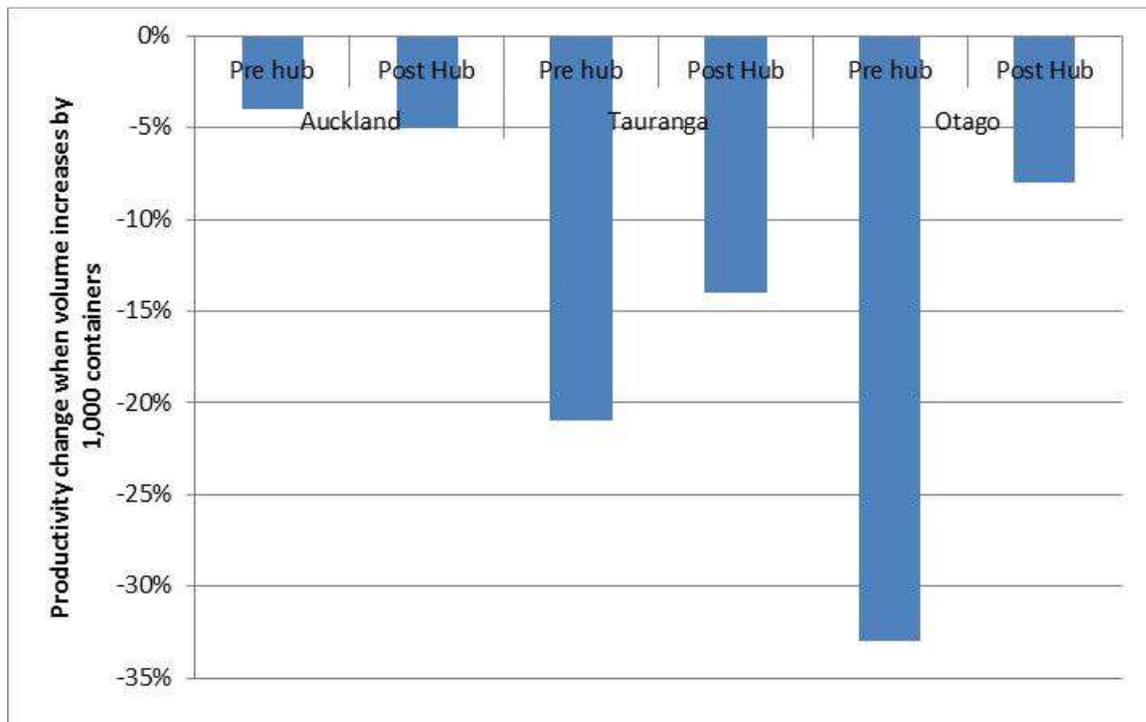
<sup>25</sup> "Tapper Akl freight hub sold to Port of Tauranga for \$15m". *The New Zealand Herald*. 18 March 2010. Retrieved 6 September 2013.

<sup>26</sup> <http://www.nbr.co.nz/article/fonterra-unveils-huge-new-mosgiel-site-37884> retrieved 6 September 2013 at 6:21am

<sup>27</sup> <http://www.rmtunion.org.nz/publications/documents/TTW2-FINAL.pdf> retrieved 6 September 2013 at 6:25am

<sup>28</sup> The impact on productivity of an inland hub being port agnostic or dedicated to a particular port is untested in this research and is identified as further research.

into a figure which illustrates the ability of each port to handle the impact of an increase in container throughput of 1,000 containers. Figure 5.20 simplistically outlines the changes in port relationship pre and post introduction of an inland hub facility when converted to a change in container throughput of 1,000 units.



**Figure 5.20: Productivity change when volume increases by 1,000 containers**

The graph shows that the changes in inland hubs had a positive benefit for the Tauranga and Otago ports but a detrimental impact on the Ports of Auckland. It must be noted that In terms of statistical significance, all the equations have B values which are statistically significant at the 95% confidence level.

Port of Tauranga and Otago had positive impacts after the introduction of inland hubs – that is, after inland hubs are introduced they are able to hold productivity higher when faced with volume increases, this is especially the case for Port Otago. In the case of Port Otago an increase in container volume resulted in a decrease in productivity of 33% (or a 9.57 containers per hour for each crane, assuming an initial crane productivity of 29 moves per hour). However, post introduction of inland hub facilities an increase in container volume of 1,000 units lead to a decrease in crane productivity of 7.8% (2.62 containers per hour).

Ports of Auckland, on the other hand, are less able to handle increasing volumes post introduction of

the inland hub. Pre inland hub use an increase in container throughput volume of 1,000 decreased crane productivity by 4.4%, whereas after the introduction of inland hub facilities the negative impact was larger at 4.9%. The case for Auckland is opposite of the relationship expected from the review of conceptual and academic models.

## **5.9 FINDINGS**

In order to provide discussion around the objectives identified and the literature studied, the analysis presented in this chapter focused on investigating the trend in throughput volume, capacity utilisation and productivity as well as the relationship between each of these variables. It is also presented an analysis focused on determining whether the use of inland hubs impacted on the volume, capacity utilisation or productivity of the port.

At the national level data was readily available through the Ministry of Transport's Freight Information Gathering System and Port Productivity Monitoring which provided quarterly information on the volume of throughput and the productivity of New Zealand's main container terminals.

### **Capacity, Volume and Utilisation**

National container port capacity in New Zealand is between 4.5 million and 7.25 million TEU<sup>29</sup> depending upon the measurement used and timeframe of analysis (i.e. a short term peak period or a longer term sustainable capacity). A majority of this capacity, however, is contained in the Upper North Island, with 61% of yard capacity and 63% of crane capacity held by Auckland and Tauranga ports.

Land capacity is significantly lower (and therefore land capacity utilisation significantly higher) than crane capacity for all ports, reflecting New Zealand's legacy issues associated with ports that have been constructed in locations where cities have formed around them and it is now difficult (politically and environmentally) and costly to reverse the problem through expansion or land reclamation.

The total volume of containers handled by the largest New Zealand container ports has increased steadily over the past four years, with typical seasonal spikes in the second quarter of each calendar year and the largest growth in containerised volumes being through Port of Tauranga in the North Island and Lyttelton Port of Christchurch in the South Island.

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<sup>29</sup> As calculated in Table 4.7 and Table 5.8 above.

## **Productivity**

Over the majority of the time period studied Port of Tauranga had the highest crane, ship and vessel productivity rates across New Zealand container ports. However, since quarter one 2009, the start of the data series, individual crane productivity has been in decline, particularly in quarter one 2012 as strike action occur in Auckland and large amounts of volume shifted quickly towards the Port of Tauranga. Crane productivity has subsequently recovered to rates similar to before the strike action.

It is interesting to compare and contrast the productivity rates of Wellington and Napier ports, which have similar volumes, are located close to each other, but have different infrastructure in place. There is a concentration in Wellington on an individual single crane port quayside crane, rather than a collection of cranes, which has resulted in a high crane rate and low vessel rates. Napier on the other hand, has a low crane productivity from each of its harbour mobile cranes but high vessel and ship productivity rates are in line with the other New Zealand ports through the use of more cranes (i.e. a higher crane intensity). In terms of the commercial impact – Napier are likely to have occurred less capital cost impact and running costs however their labour costs are likely to be higher due to the requirement to run further labour gangs for each crane in comparison to Wellington.

From the time series data it can be said that South Island ports are generally less productivity compared to the New Zealand average across the three productivity measures reported. This is especially the case if Napier was to be excluded from the crane rate calculation due to their differences in infrastructure.

## **Relationships**

### Volume and Capacity Utilisation

Changes in container throughput volumes had different impacts on each of New Zealand's container ports due to the differences in infrastructure development across both crane and yard infrastructure.

A volume change impacts significantly on the crane capacity utilisation in Wellington and Napier, due to Wellington having only two quay side container cranes (compared to Tauranga's six and Auckland's eight) and Napier's three harbour mobile cranes (which are on average less productive). On the other hand, changes in container throughput volume has a significant impact on Otago and Lyttelton due to their lack of land available. It must be noted that the reasons for Auckland and Tauranga not featuring here is because their available capacity is significantly greater than that of the other New Zealand ports. Therefore, an increase in throughput of 1,000 container per annum has a

greater impact on the capacity of the smaller ports because represents a large portion of total throughput.

In the analysis completed, changes in volume had the greatest impact on yard capacity, due to the fact that the crane capacity is typically higher than the yard capacity across New Zealand's container ports.

#### Capacity Utilisation and Productivity

The relationship between capacity utilisation and productivity provided interesting information– an increase in crane or yard utilisation made Wellington and Lyttelton significantly more productive whereas it significantly decreases the productivity of Auckland, Tauranga and Otago. Napier was unique, in that depending on the basis used to measure productivity or capacity utilisation the relationship could be positive or negative.

#### Productivity and Volume

The relationship between volume and productivity follows that of the relationship between utilisation and productivity, in that an increase in throughput makes Wellington and Lyttelton significantly more productive whereas it significantly decreases the productivity of Auckland, Tauranga and Otago.

However, in the case of the productivity and volume relationship Napier's relationship is positive across all variables.

#### **The relationship between port productivity, volume and the use of inland hubs**

The national level analysis concentrated on the changes in productivity as a result of the changes in inland hubs. It showed that infrastructure upgrades in inland hubs had a positive benefit for the productivity of Tauranga and Otago ports but a detrimental impact on the Ports of Auckland.

## **6 DETAILED INVESTIGATION OF CONTAINER PORT RELATIONSHIPS**

### **6.1 INTRODUCTION**

This chapter concentrates on a single port, Lyttelton Port of Christchurch, and conducts analysis on more detailed information to triangulate the findings developed as part of the national level investigation.

### **6.2 DATA AVAILABLE**

Lyttelton Port of Christchurch (LPC) is New Zealand's third-largest deep-water port. It is located just outside the Christchurch city, New Zealand's second largest city and the largest city in the South Island. The port's Lyttelton Container Terminal provides specialised cargo-handling and stevedoring services for general and refrigerated containers.

CityDepot, the Lyttelton port's inland port at Woolston, provides an extensive container repair, wash and storage facility. CityDepot is located six kilometres from the main port and has the capacity to store up to 7,000 TEUs.

The data used for the detailed analysis was produced from the port operational system and checked for consistency and accuracy by the Container Terminal Managers after the completion of each vessel. Inland hub throughput data was also compiled from the financial reporting system of the inland hub business, as they bill clients directly for each container handled. Between 2011 and 2013 the author also worked as an analyst for the Port of Lyttelton and gained an understanding of the data collection methods, accuracy and operational procedures of their container terminal and integrated inland hub facility. Given the data collection method, the more detailed analysis will also allow for investigation of relationships at an individual vessel exchange level, rather than an aggregated quarterly time period.

For this research, the Lyttelton Port has allowed the use of detailed data collected from their terminal operating system on each vessel exchange in the container terminal since August 2001. The compiled includes:

- The number of TEUs exchanged per vessel visit
- The number of containers exchanged per vessel visit

- It must be noted that there in a very small percentage of the sample size, the container units of the vessel exchange were not reported. In these cases the units exchanged has been calculated based on the average TEU/unit conversation factor of the data set
- Start time and finish time of labour – i.e. time of labour boarding and leaving the vessel
- Crane hours

This allows the calculation of the standard stevedoring productivity measures of crane rate, crane intensity, ship rate and vessel rate. This data has been manually entered for multiple periods.

Outliers in the data set were taken out were:

- Crane intensity was greater than the cranes available
- Total crane hours for a vessel exchange less than one hour

The port has also allowed the use of information captured from the operating system used in the inland container depot, which includes detailed monthly breakdowns of container throughput by type. The difference, however, is that the data reported from the inland hub is the number of containers through the site, totalled on a monthly basis. The total throughput is the number of containers entering or exiting the site. It does not include the number of container repairs, washes or inspections.

### **6.3 THROUGHPUT DEMAND**

The Lyttelton Port of Christchurch has experienced strong growth over the past 4 years. Over the past 10 years containerised throughput has grown at a compound annual growth rate of 10.4%<sup>30</sup>.

In order to handle this growth the port has worked hard to service more vessels every month with a greater average container exchange per vessel – i.e. there are more vessels carrying more containers. This is evident in Figure 6.21 and Figure 6.22.

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<sup>30</sup> Based on information published in Annual Financial Reports released by Lyttelton Port of Christchurch

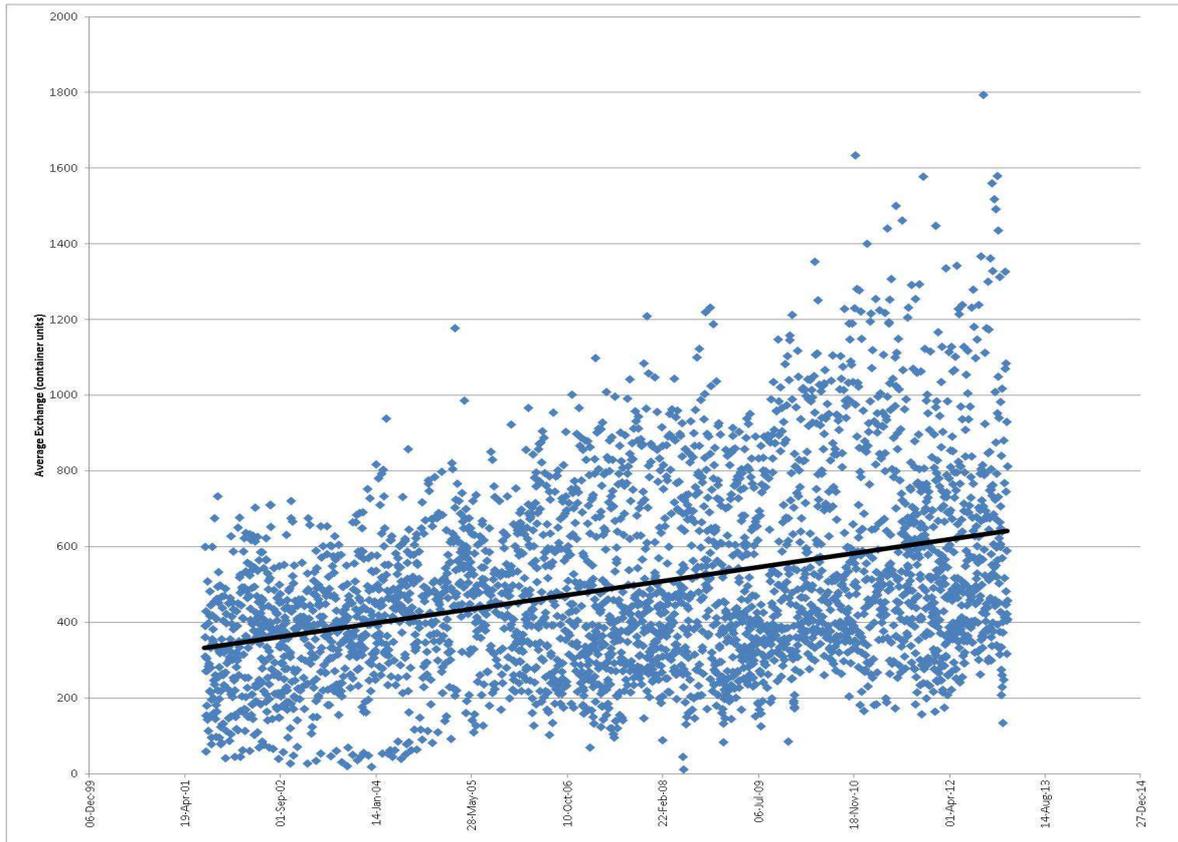


Figure 6.21 Average Vessel Container Exchange at Lyttelton Port of Christchurch between August 2001 and January 2013

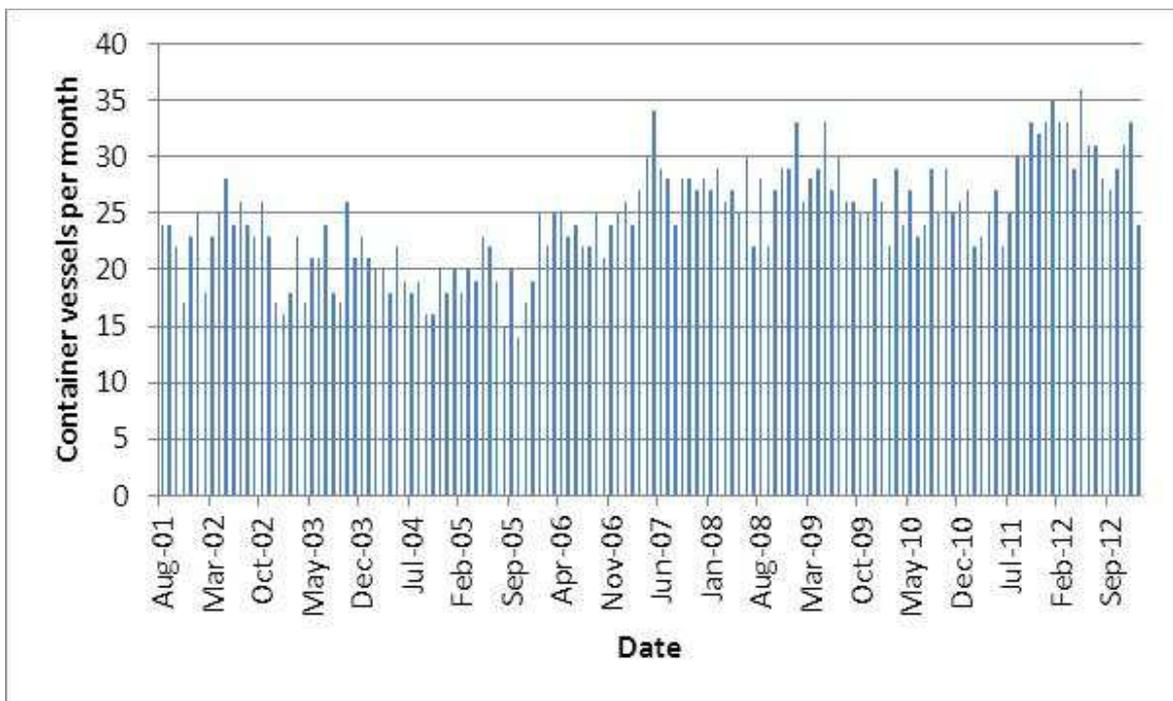


Figure 6.22 Container Vessel Calls per Month at Lyttelton Port of Christchurch between August 2001 and January 2013

## 6.4 CAPACITY AND UTILISATION

The same capacity calculations used in the national overview were applied to the Lyttelton Port of Christchurch information, except that rather than completing the analysis on a quarterly basis it was completed on a daily basis due to increased information availability.

In terms of crane capacity available, the Lyttelton Port of Christchurch had 2 crane up until 15 September 2006<sup>31</sup>, when a new port quay crane was commissioned. In calculating the daily crane capacity the number of cranes is multiplied by 24 hours in a day multiplied by the average crane productivity rate including delays (which as outlined in the national overview is 20.97 for these calculations). Therefore the daily crane capacity is 1,007 or 1,510 container units, depending on whether two or three cranes are in operation.

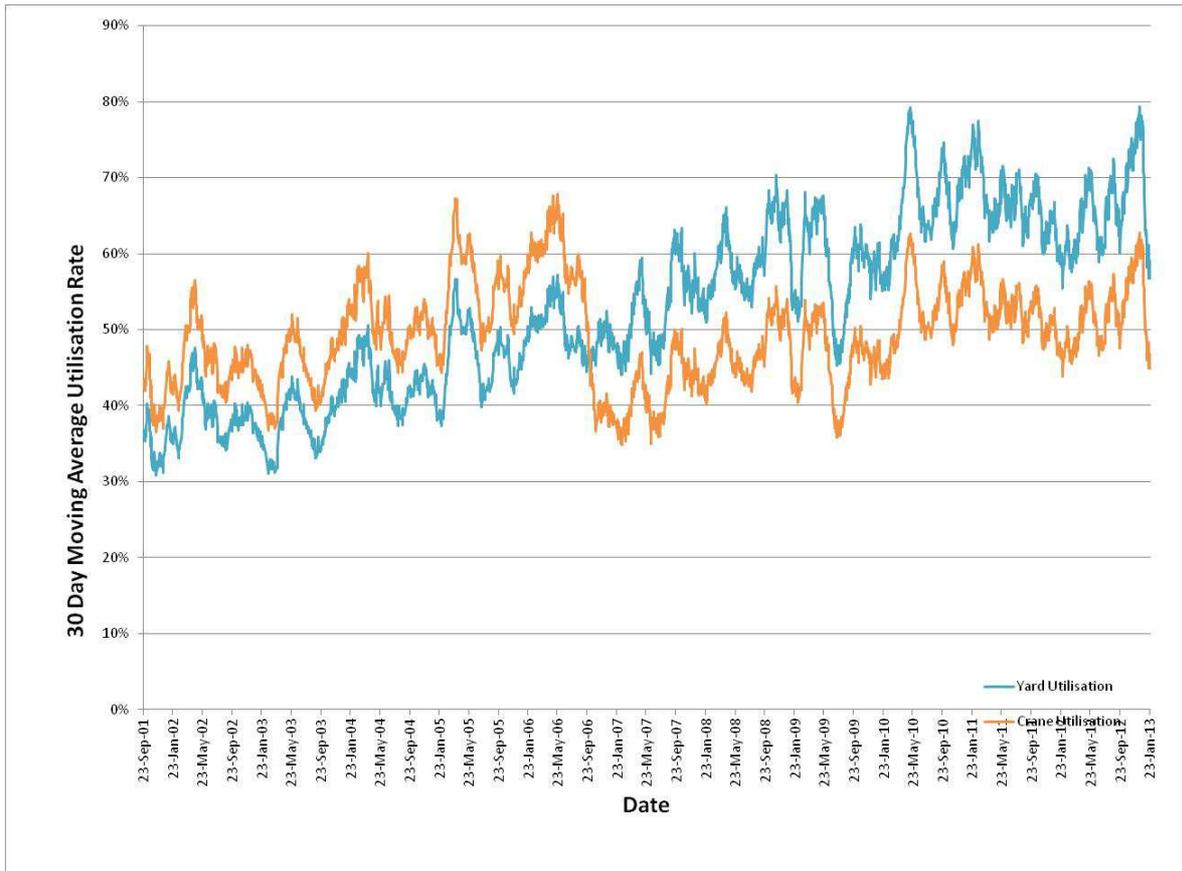
The peak yard capacity of 435,893 containers used above in the national overview is used here but converted to a daily capacity of 1,194 containers.

In the national overview a peak capacity and sustainable capacity was calculated, with sustainable capacity being 80% of peak capacity. Sustainable capacity was used in the national overview as the means of measuring capacity utilisation as it is assumed that it is difficult for a port to maintain peak capacity over the period of a quarter. In the detailed investigation, where the focus of the information is on a daily basis, the peak capacity measurement is used as it is assumed that the port can operate at peak for the period of a day. Graphs are provided below for both peak crane and yard capacity utilisation.

The reporting system employed at the Lyttelton Port of Christchurch leads to the possibility of crane and yard capacity can be utilised at a rate greater than 1 or 100%. Vessels, and their total exchange, are reported on the day in which the labour leaves the vessel. However, a large vessel exchange may cross two or more days but all the containers are reported on the day that the labour leaves the vessel, resulting in capacity utilisation being greater than 100%. To minimise the extent of this error, a 30 day moving average was used in the data series below.

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<sup>31</sup> Lyttelton Port of Christchurch internal information

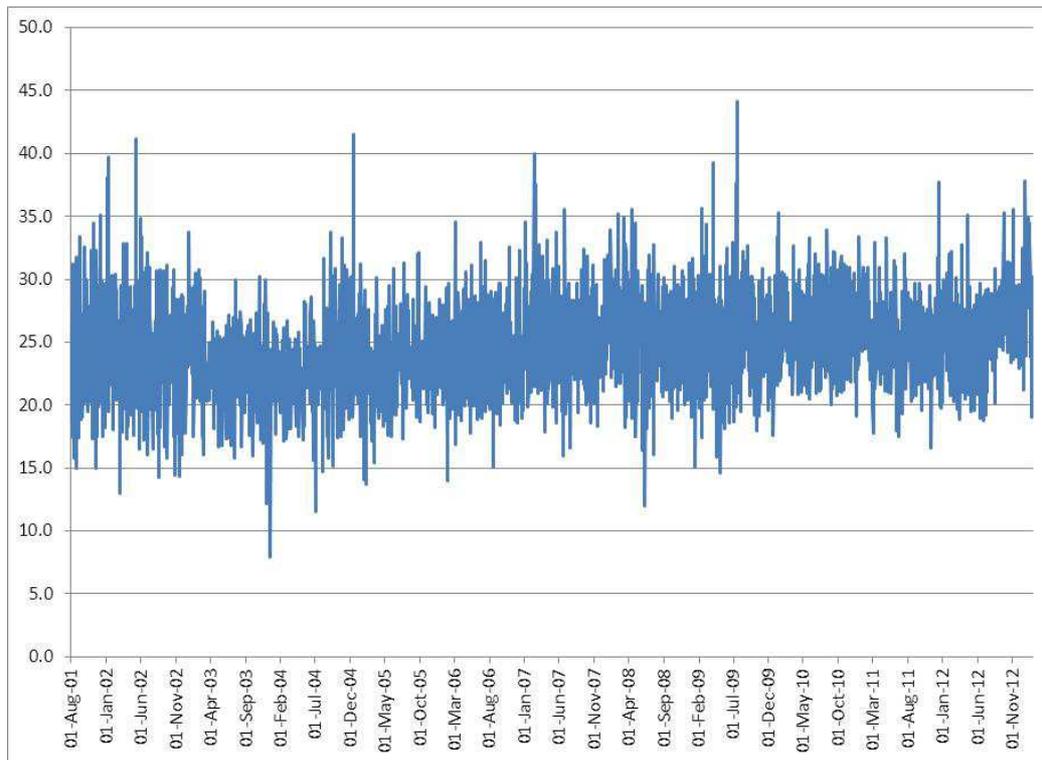


**Figure 6.23: 30 day moving average Utilisation of Peak Crane or Yard Capacity for Lyttelton Port of Christchurch container terminal between August 2001 and January 2013**

There is a very high correlation between yard and crane utilisation. Yard capacity utilisation has a general increasing trend and over the last two years. Crane capacity utilisation, on the other hand has remained relatively stable, however there are two distinct periods, pre 2006 when there were two cranes and post 2006 when there were three cranes. Leading up to the additional crane being commissioned the trend was of increasing crane utilisation. After the purchase of the additional crane there has been a slow and steady increase in crane utilisation but the crane utilisation has not yet reached the levels leading up to the crane commissioning. Since the crane purchase the more significant concern for the port is the yard capacity utilisation, which is high and has been a level which the literature suggests should result in congestion for significant periods between 2010 and 2013.

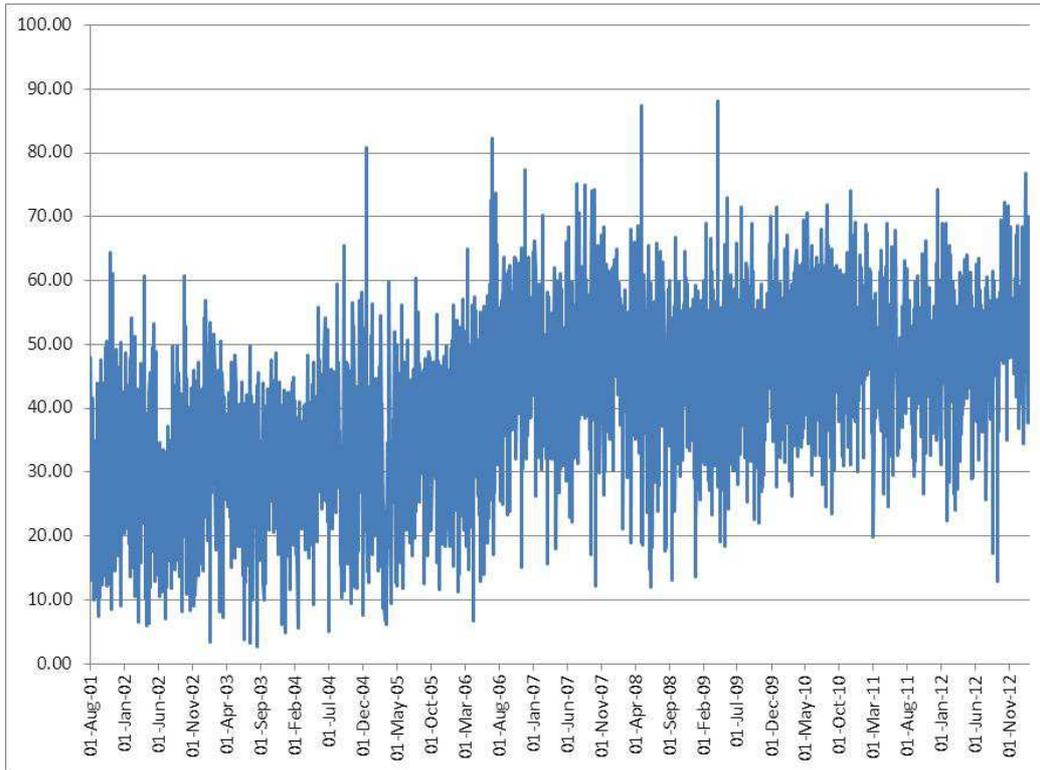
## 6.5 PRODUCTIVITY

Overall trends in productivity over the time period are outlined in Figure 6.24 and Figure 6.25 for crane, ship and vessel productivity measures as well as the crane intensity.



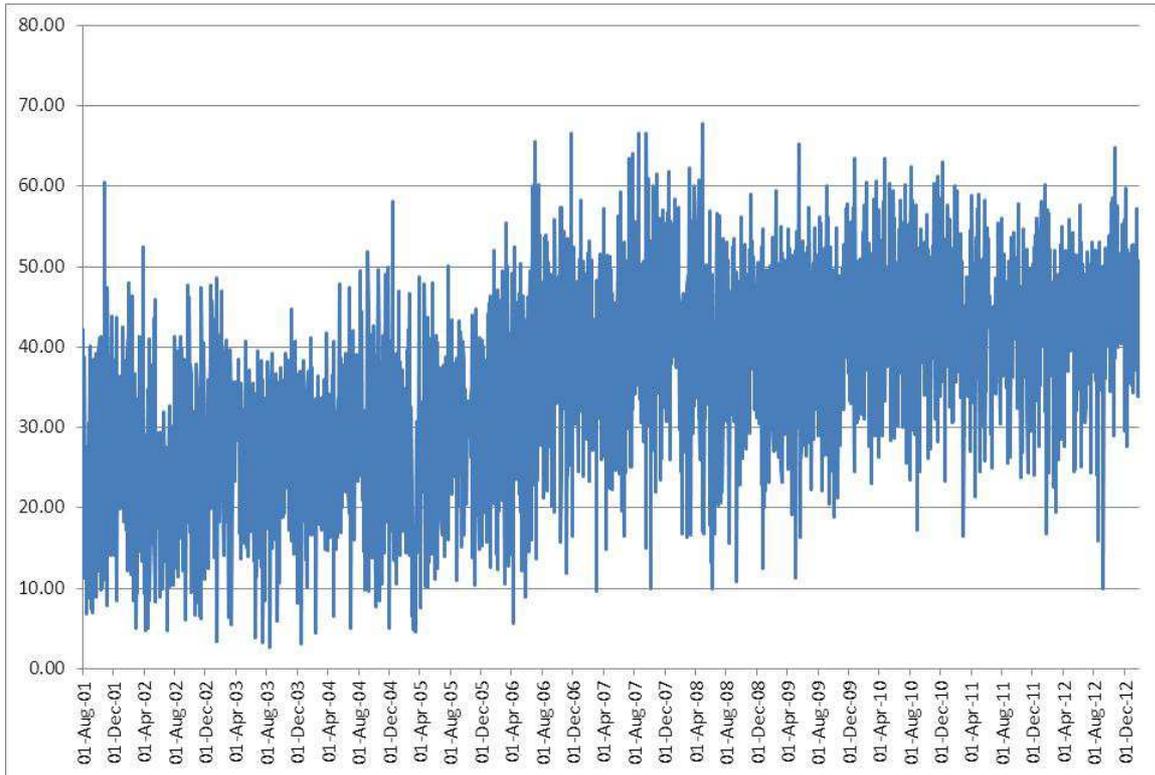
**Figure 6.24 Crane productivity rates for Lyttelton Port of Christchurch Container Terminal, August 2001 – January 2013**

The crane rate for each individual crane has stayed the relatively static with the increased units and average vessel exchange, however the crane intensity has increased after the crane purchase in 2006, which is evident in the step change in the crane intensity time series graph (Figure 6.24). The increased crane intensity, along with the small increase in crane productivity, has resulted in an increase in the ship and vessel productivity rates.



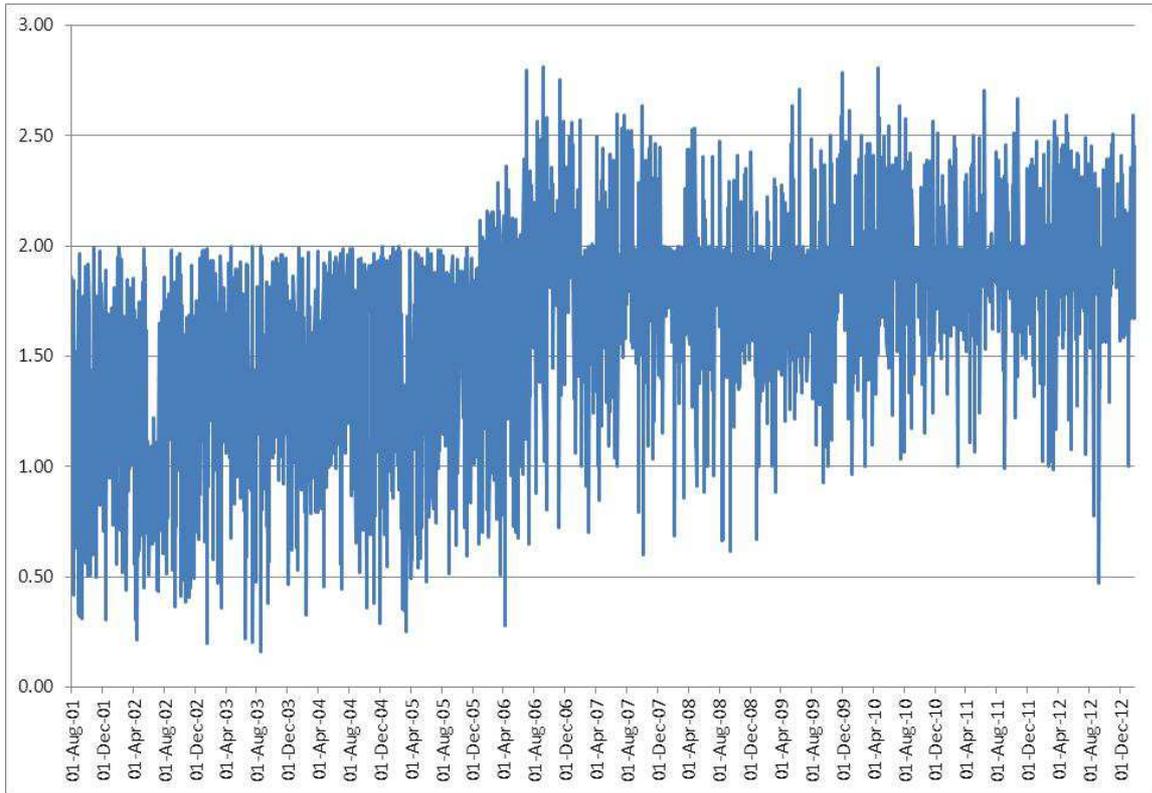
**Figure 6.25 Ship productivity rates for Lyttelton Port of Christchurch Container Terminal, August 2001 – January 2013**

Ship productivity (Figure 6.25) and vessel productivity (Figure 6.26) have both been upward trending over the time period, as can be seen by the time series figures. As the vessel productivity includes operational delays and the ship productivity does not, and the vessel rate is growing faster than the ship rate, it can be assumed that the non-productive elements (i.e. the delays) have reduced throughout the time period.



**Figure 6.26 Vessel productivity rates for Lyttelton Port of Christchurch Container Terminal, August 2001 – January 2013**

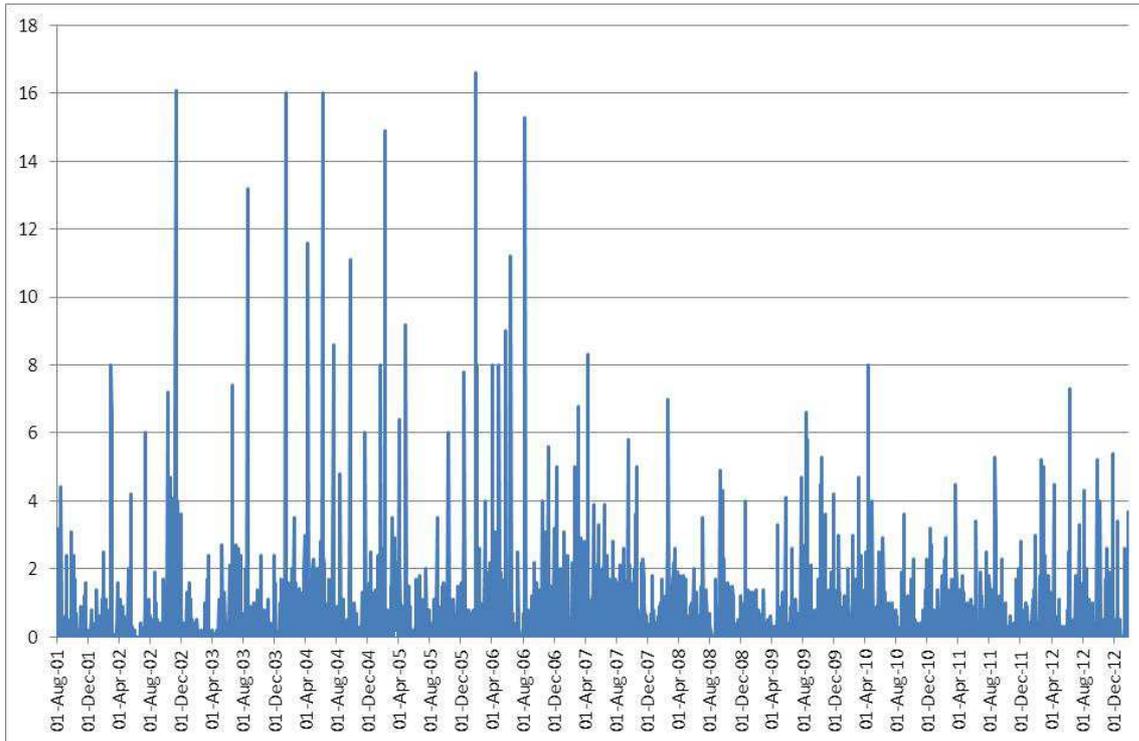
Figure 6.27 outlines how the port is using their cranes – the crane intensity. Crane intensity is a proxy for the average number of cranes used per ship (Ministry of Transport 2012). It is calculated by dividing the crane hours by the labour hours spent on each vessel exchange carried out.



**Figure 6.27 Crane Intensity for Lyttelton Port of Christchurch Container Terminal, August 2001 – January 2013**

Crane intensity prior to the new, third, crane being operationalised in 2006 was close to two for very long periods – that is on nearly every vessel exchange both cranes were being used continuously while the vessel was in port. This would have put significant pressure on each of the port’s cranes to perform. After 2006 the port then has three cranes but the crane intensity oscillates between 2 and 2.5, relieving pressure on each of the individual cranes.

Figure 6.28 then outlines how often the cranes are breaking down and causing operational delays and reductions in productivity.



**Figure 6.28 Crane Breakdown Hours per Vessel Call for Lyttelton Port of Christchurch Container Terminal, August 2001 – January 2013**

Crane breakdowns have dramatically decreased since the end of 2006, the same time as the new crane installation being operationalised. The new crane and the reduction in crane break down also corresponds with a step change increase in the vessel productivity and smaller increases in crane and ship productivity rates reported in Figure 6.24, Figure 6.25 and Figure 6.26 above.

A more reliable and effective crane is expected to correlate with an increase in vessel productivity rate as the calculation of vessel productivity includes all productive and non-productive elements (i.e. it includes crane breakdowns within the calculation). However, the fact that there have still been increases in crane and ship productivity (both calculations exclude non-productive elements, including crane breakdowns, from calculations) indicates that there have been benefits received outside of just the reduced breakdowns – i.e. the container terminal is generally more productive as a result of increased reliability.

## **6.6 THE RELATIONSHIP BETWEEN VOLUME, CAPACITY UTILISATION AND PRODUCTIVITY**

The objective of this research is to investigate the throughput volume, capacity utilisation and productivity of New Zealand ports, as well as the relationship between the variables. The volume, capacity utilisation and productivity trends the Lyttelton Port of Christchurch have been outlined and

investigated above. The relationship between the three variables has also been investigated above with a concentration at a macro or national level. Below the analysis on the relationship between volume, capacity utilisation and productivity is completed at a more micro level, with the concentration being on one port with more detailed information for analysis. All regression analysis results are included in Appendix 1.

### **The Relationship between Volume and Capacity Utilisation**

The equation analysed in this section is:

$$\text{Crane/yard utilisation percentage} = B * \text{Volume}$$

The regression analysis results are included in Appendix 1.

In the case of crane capacity, if volume increases by 1,000 containers, crane utilisation would increase by 0.836%. This is slightly higher than the results for Lyttelton produced during the national level analysis (which was an increase of in capacity utilisation of 0.0907% for an increase in volume of 1,000 containers), however in this case there is more data accuracy, which is reflected in the fact that the estimate is statistically significance (in the national overview data it was not significant at the 95% confidence level).

In the case of yard capacity on the other hand, if volume increases by 1,000 containers, crane utilisation would increase by 0.659%. This is slightly higher than the results for Lyttelton produced during the national level analysis (which was an increase of in capacity utilisation of 0.115% for an increase in volume of 1,000 containers), however it is also the case that there is more accuracy here.

Crane capacity is higher than yard capacity in the case of the Lyttelton Port. A result of this is that an increase in volume has a greater impact on yard capacity utilisation.

### **The Relationship between Capacity Utilisation and Productivity**

The sections below outline the analysis completed to determine the relationships between capacity and productivity using the two different capacity measures and three productivity measures.

The equations analysed in the investigation of these relationships are:

$$\text{Crane or ship or vessel productivity rate} = B * \text{crane or yard utilisation}$$

The regression analysis results are included in Appendix 1.

The B values from all the combinations of variable investigated are positive and significant to a high confidence level, illustrating that productivity and capacity have increased in parallel over the analysis

period. The positive nature of the variables, their value and their significance are similar to the values derived in the national overview analysis, thus confirming the relationship. The major difference between the national overview analysis and the detailed port investigation is that the B variable is significantly lower in the detailed port investigation for the relationship between productivity and crane utilisation across all the crane productivity measures. This is a result of the detailed port investigation having a more detailed view of investment in crane capacity.

Also, for the national overview analysis, the productivity figures are averages for the period of a quarter, whereas the detailed port investigation reports productivity for every vessel exchange. Therefore, there is more volatility and lower levels of statistical significance due to the difficulty in fitting a linear line close to all the data plots.

In the detailed port investigation regarding overall, the variables are higher for the impact of yard utilisation, rather than crane utilisation, on overall port productivity.

### **The Relationship between Productivity and Volume**

The sections below outline the analysis completed to determine the relationships between capacity and productivity using the two different capacity measures and three productivity measures.

#### **Volume and crane rate**

The equations analysed in the investigation of this relationship are:

$$\text{Crane/ship/vessel rate} = B * \text{Volume}$$

The regression analysis results are included in Appendix 1.

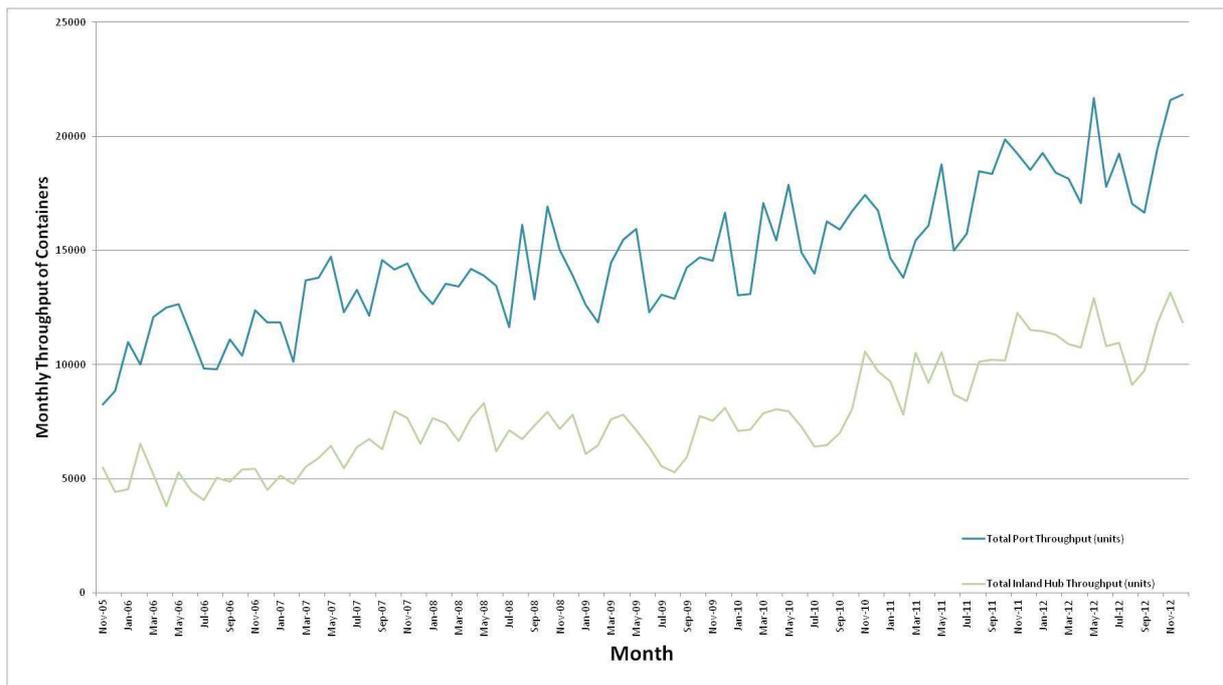
The B values for all combinations of variables analysed are positive and significant to a high confidence level, illustrating that productivity and capacity have increased in parallel over the analysis period. The positive nature of the variables and their value is similar to the values derived in the national overview analysis, thus confirming the relationship. The major difference between the national overview analysis and the detailed port investigation is that the B variable is significantly higher in the detailed port investigation for the relationship between productivity and volume across all the crane productivity measures.

The other difference is that the variables are all statistically significant in the detailed port investigation, whereas there were not in the national overview analysis. This reflects the larger data set available for the detailed analysis.

## 6.7 THE RELATIONSHIP BETWEEN PORT PRODUCTIVITY, VOLUME AND THE USE OF INLAND HUBS

As detailed above in the description of the data sources, the data provided from CityDepot for the volume of the container throughput of the inland hub is provided on a monthly basis. Therefore the daily analysis performed above is aggregated to provide for easy comparison and integration of investigation with the inland hub data.

One of the principal aims of an inland hub, as outlined in previous chapters, is to increase growth and market share by allowing a port to extend its hinterland capture area. The analysis of inland hubs and their relationship with the shipside container terminal first of all concentrates on the throughput volume of each facility. It must be noted in the case on CityDepot, it is very close to the seaport (less than 10 minutes' drive) which is typically different that the inland hub facilities outlined in international operational and theoretical examples. The throughput of each facility is outlined in the time series plot below



**Figure 6.29 Time Series Plot of Lyttelton Container Terminal and CityDepot Inland Port Throughput volumes between November 2005 and November 2012**

The above series indicates that there is some correlation in the two variables, especially in the second half of the series. This is modelled with equation being:

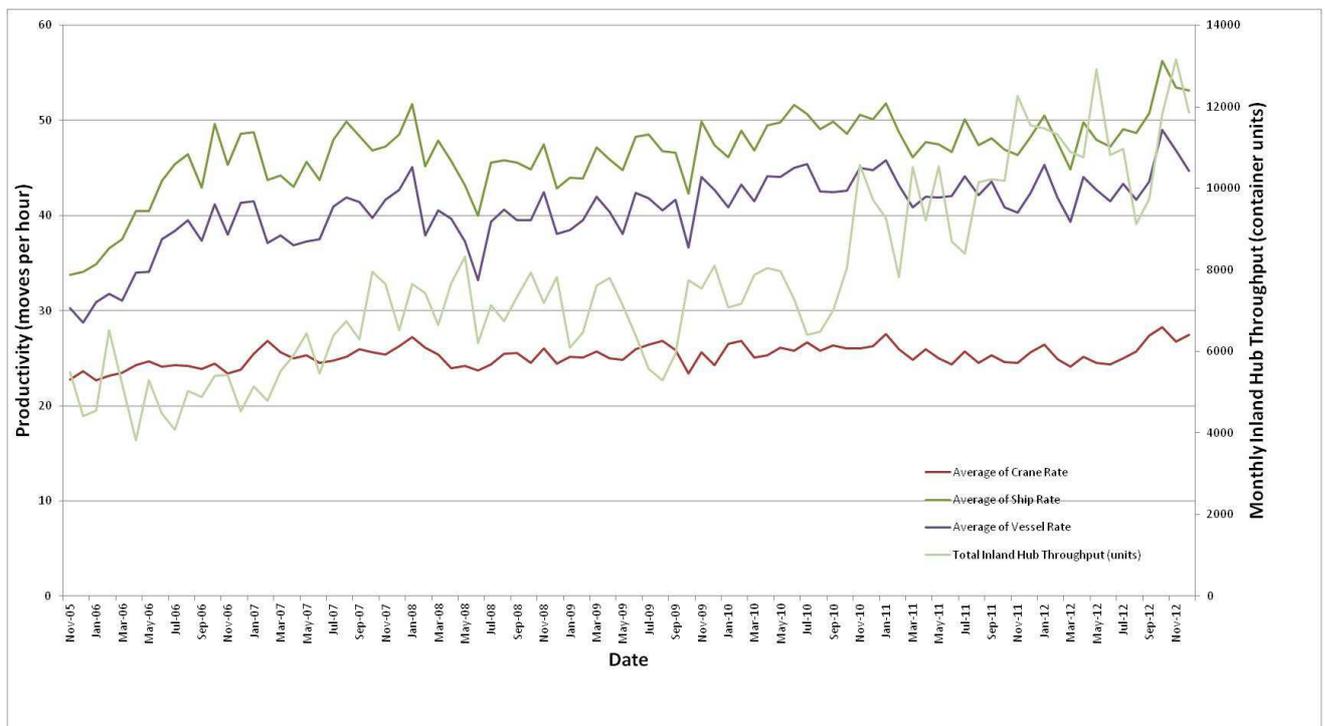
$$\text{Port Volume} = B * \text{Inland Hub Volume}$$

The regression analysis results are included in Appendix 1.

The variable for the relationship between inland hub volume and the port volume is positive and significant, illustrating that there is a relationship where an increase in volume at the inland hub also increases the volume at the port. This makes sense as both operations are owned by the Lyttelton Port of Christchurch and there are financial incentives for the integration of the two operations.

However, what is interesting about the variable report is that it is greater than one. That is, for example, if throughput volume increases by 1,000 at the inland hub there is an increase in port throughput of greater than 1,000. This also makes sense as the majority of inland port throughput is of empty containers, which then are also handled by the port. However, the empty containers handled by the inland hub are associated with a full container movement to and or from the port.

Another aim of an inland hub is to remove non-productive elements away from the scarce portside land to create greater efficiency and productivity. Therefore, the analysis also investigated the relationship between productivity of the Lyttelton Container Depot and the throughput volume of the CityDepot inland hub facility. The productivity of the port, using the crane, ship and vessel productivity measures, is outlined against the throughput volume of the inland hub in the time series plot below.



**Figure 6.30 Time series plot of Lyttelton Container Terminal Productivity and CityDepot Inland Port between November 2005 and November 2012**

There is some positive correlation between the productivity time series and the throughput volume of the inland hub, especially if concentration is paid to the peaks in throughput volume and how they

correlate with the peaks in ship and vessel productivity rates. This is investigated below with equation being:

$$\text{Port Productivity} = B * \text{Inland Hub Volume}$$

The regression analysis results are included in Appendix 1.

The B variable is positive and significant, indicating that as the volume of containers through the inland hub increases, so does the productivity of the portside container terminal. If the throughput volume of the inland hub increases by 1,000 over the period of a month, the productivity of the container wharf would increase by 0.987 – that is, for every hour that a crane is in operation it would be loading or unloading nearly one container more per hour.

The correlation between port productivity and inland hub volume is the highest for the vessel productivity rate. Vessel productivity rate is the only productivity rate, of the three variables used, which includes the non-productive elements of a vessel exchange, the other exclude them. As it is the highest, it indicates that an increase in inland hub volume not only increases productivity, but it also reduces the time delays/stoppages at the port.

The final relationship investigated between the port and inland hub facilities is the relationship between the volume of the inland facility and the capacity utilisation of the portside facility. This is outlined in the time series plot below (Figure 6.31) for both yard and crane capacity utilisation.

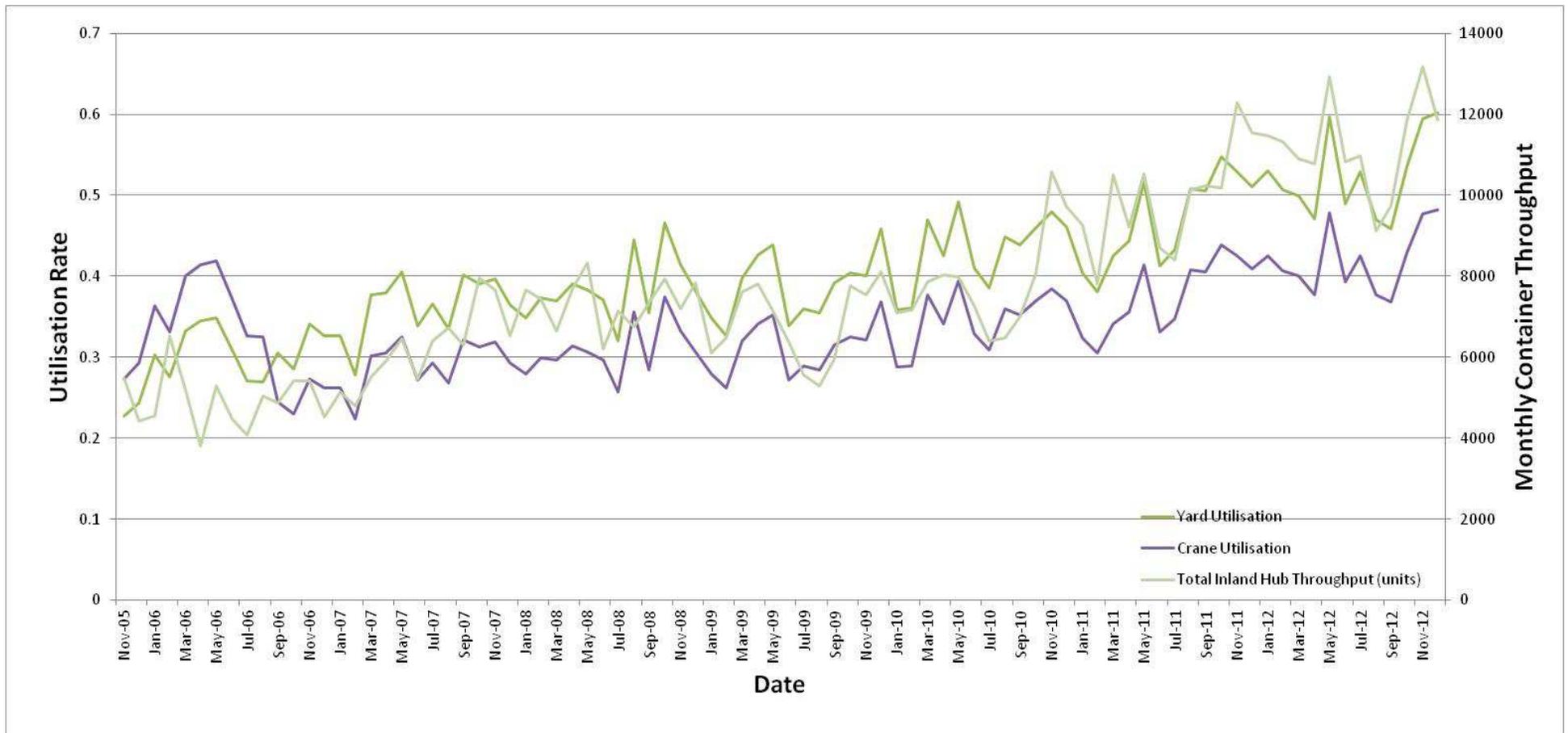


Figure 6.31 Relationship between Container Terminal Utilisation and Inland Hub Volume

Figure 6.31 indicates that there is some correlation in port capacity utilisation and inland hub throughput volume, especially in the second half of the series. This is investigated below with equation analysed being:

$$\text{Port Yard or Crane Capacity Utilisation} = B * \text{Inland Hub Volume}$$

The regression analysis results are included in Appendix 1.

The variables are positive and statistically significant, indicating that if the throughput volume of the inland facility increased it is associated with an increase in the capacity utilisation of the portside container terminal yard or cranes. There is a greater impact on yard utilisation from an increase in throughput volume, due to the capacity of the yard being significantly less than the combined crane capacity.

Inland hubs are used as a means of reducing the pressure on the productive and high value land at the port side. However, the more the port pushes throughput towards the inland hub, the higher the capacity utilisation is. This is perhaps explained by the above relationship between volume at the two facilities. A majority of inland port throughput is of empty containers, which then are also handled by the port. However, the empty containers handled by the inland hub are usually associated with a full container movement to and or from the port.

In the case of the CityDepot inland hub, its close proximity to the seaside terminal further integrates its functionality as during spikes in demand both facilities can respond immediately to utilise capacity over both facilities. This is different than the other New Zealand inland hubs studied, and many international examples, that are set up close to the hinterland market (to increase the geographical reach of the port) or at the other end of a busy transport spine (to allow transport to be completed in off peak or congested times).

## **6.8 FINDINGS**

In order to provide discussion around the objectives identified and the literature studied, the analysis presented in this chapter focused on investigating the trend in throughput volume, capacity utilisation and productivity as well as the relationship between each of these variables. It is also presented an analysis focused on determining whether the use of inland hubs impacted on the volume, capacity utilisation or productivity of the port.

At the detailed level, vessel exchange size, frequency and productivity of individual vessels was obtained from Lyttelton Port's container management system. The throughput of CityDepot, Lyttelton Port of Christchurch's Inland Container Depot, was provided on a monthly basis.

In the detailed analysis, which is completed over a longer time period, yard capacity has a general increasing trend and over the last two years there have been regular occurrences of a yard utilisation greater than 100%. Leading up to the additional crane being commissioned the trend was of increasing crane utilisation and regular periods where crane utilisation exceeded 100%. After the purchase of the additional crane there has been a slow and steady increase in crane utilisation but the crane utilisation has not yet reached the levels leading up to the crane commissioning of the third crane.

The conclusions of the national and detailed investigation are aligned in that they depict a high level of utilisation across New Zealand ports, one that is increasing due to the high growth in containerised throughputs.

The interesting finding from the detailed analysis was that vessel productivity grew faster than ship productivity over the time period studied. As the ship productivity discounts delays and the vessel productivity does not, it can be assumed that the non-productive elements (i.e. the delays) have reduced throughout the time period, as a result of a dramatic reduction of crane brakes downs after the purchase of the new crane in 2006.

The crane rate for each individual crane has stayed the relatively static with the increased units and average vessel exchange, however the crane intensity has increased after the crane purchase in 2006, which is evident in the step change in the crane intensity time series graph. The increased crane intensity, along with the small increase in crane productivity, has resulted in an increase in the ship and vessel productivity rates.

## **6.8.1 Relationships**

### **6.8.1.1 Volume and Capacity Utilisation**

The detailed analysis confirmed the positive relationship between volume and capacity provided in the national level investigation. However, with more accuracy and analysed at a shorter timeframe (days rather than quarters) the impact of volume on utilisation is slightly higher in the case of the detailed analysis.

### **6.8.1.2 Capacity Utilisation and Productivity**

The relationship between capacity utilisation and productivity provided interesting information— an increase in crane or yard utilisation made Wellington and Lyttelton significantly more productive whereas it significantly decreases the productive ability of Auckland, Tauranga and Otago. The detailed port investigation confirmed the relationship for the Lyttelton Port of Christchurch, as the variables and their significance were similar.

The major difference between the national overview analysis and the detailed port investigation is that the B variable is significantly lower (i.e. high utilisation or changes in utilisation have a less significant impact on productivity) in the detailed port investigation for the relationship between productivity and crane utilisation across all the crane productivity measures. This is a result of the detailed port investigation having a more detailed view of investment in crane capacity as well as the difference in time periods studied.

### **6.8.1.3 Productivity and Volume**

The relationship between volume and productivity follows that of the relationship between utilisation and productivity, in that an increase in throughput makes Wellington and Lyttelton significantly more productive whereas it significantly decreases the productive ability of Auckland, Tauranga and Otago. The detailed port investigation confirmed the relationship for the Lyttelton Port of Christchurch, as the variables and their significance were similar.

The major difference between the national overview analysis and the detailed port investigation is that the B variable is significantly higher in the detailed port investigation for the relationship between productivity and volume across all the crane productivity measures.

The other difference is that the variables are all statistically significant in the detailed port investigation, whereas there were not in the national overview analysis. This reflects the larger data

set available for the detailed analysis.

#### **6.8.1.4 The relationship between port productivity, volume and the use of inland hubs**

The national level analysis concentrated on the changes in productivity as a result of the changes in inland hubs. It showed that infrastructure upgrades in inland hubs had a positive benefit for the productivity of Tauranga and Otago ports but a detrimental impact on the Ports of Auckland. This was confirmed by the detailed analysis.

It was also shown that in the case of Lyttelton Port there was a positive relationship between the throughput of the inland hub and the productivity of the shipside container terminal. Also, the fact that the correlation between port productivity and inland hub volume was the highest for the vessel productivity rate, indicates that an increase in inland hub volume not only increases productivity, but it also reduces the time delays/stoppages at the port as vessel productivity rate is the only productivity measure which includes the non-productive elements of a vessel exchange.

The detailed analysis of the relationship between inland hubs and their integrated shipside terminals also showed that there is a relationship where an increase in volume at the terminal also increases the volume at the port. This makes sense as both operations are owned by the Lyttelton Port of Christchurch and there are financial incentives for the integration of the two operations. However, what is interesting about the variable report is that it is greater than one. This is, for example, if throughput volume increases by 1,000 at the container terminal there is an increase in port throughput of greater than 1,000. This also makes sense as the majority of inland port throughput is of empty containers, which then are also handled by the port. However, the empty containers handled by the inland hub are associated with a full container movement to and or from the port.

It must be noted that the analysis of the relationship was recompleted with a concentration only on the 2012 calendar year. This was carried out to determine whether the relationships between volume, capacity and productivity were any different as Lyttelton Port of Christchurch moved further towards full capacity utilisation. There was no change in the relationships. Therefore, the relationships are the same regardless of the utilisation level.

# 7 DISCUSSION

## 7.1 INTRODUCTION

The chapter below discusses the analysis findings outlined above by relating them to the industry background and literature review previously carried out.

## 7.2 PORT PRODUCTIVITY, CAPACITY AND GROWTH

The diagrams below provide an overview of the results of the analysis, in particular a comparison of each variable against examples in the literature and the relationships between the variable observed in this research and in academic literature reviewed;

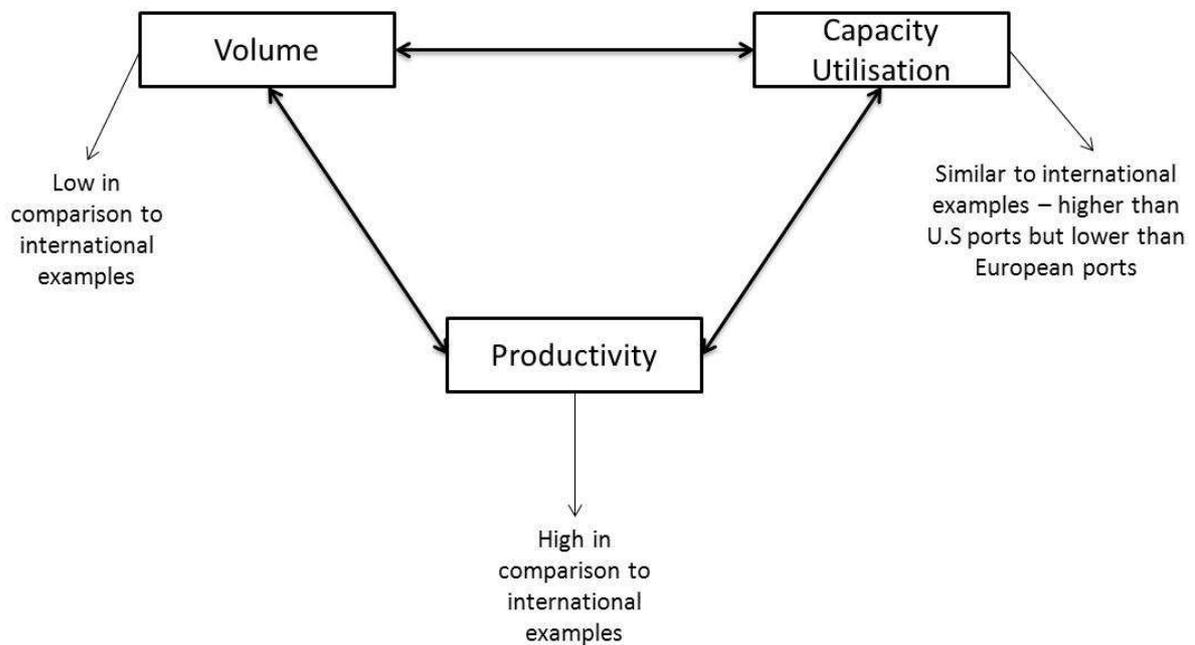


Figure 7.32: Comparison of the variable against examples in the literature

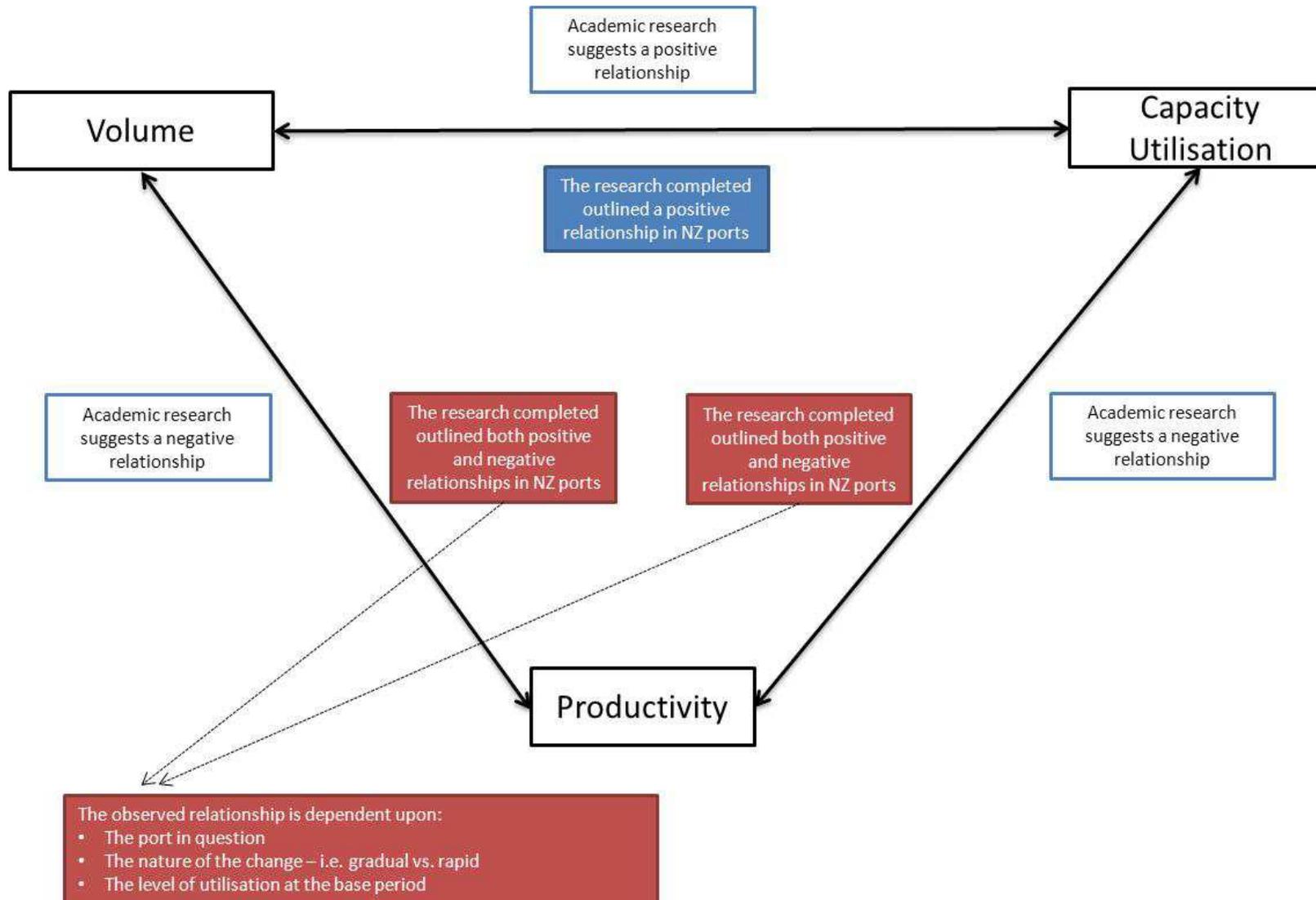


Figure 7.33: Relationships between the variables – comparison of those in the literature and those observed in this research

There are a number of methods available in academic literature and industry publications to estimate the available capacity of container terminals. This research adopted the approach that was used by Tioga (2006) in their large study of U.S port. This allowed the research results to be compared to a number of U.S ports, both large and small. The research used calculated the wharf and crane capacity of each of the New Zealand ports based on observed and reported crane productivity rates, terminal land areas and terminal operating equipment.

Port capacity in New Zealand is between 4.5 million and 7.25 million TEU<sup>32</sup> depending upon the measurement used and timeframe of analysis (i.e. a short term peak period or a longer term sustainable capacity). Land capacity is significantly lower than crane capacity for all ports, reflecting New Zealand's legacy issues associated with ports that have been constructed in locations where cities have formed around them and it is now difficult and costly to reverse the problem.

For all ports the utilisation rate for yard is higher than that of the crane utilisation, reflecting a relative shortage of land in most cases. Utilisation is high across most New Zealand ports, with the average across crane and yard utilisation being 48% for all New Zealand ports. This is typically higher than the results of U.S ports reported by Tioga (2006) but less than the European examples outlined. Tauranga and Lyttelton, both of which are forecast to be the main ports post port rationalisation (New Zealand Shipping Federation (2010)), have yard utilisation figures greater than 70%. . Academic research (in particular Haralambides (2012)) suggests once 70% port capacity utilization has been reached congestion and productivity difficulties starts to set in.

Therefore, New Zealand ports as well as international ports are struggling with the same problem of maintaining and growing capacity in the face of rapidly increasing throughput demand while maintaining productivity levels to shipping lines.

Productivity, in the port sense, is typically referred to the productive ability to load and unload container ships, which is a result of the efficiency of the entire container terminal operating system and staff. Maintaining productivity levels in loading/unloading container vessels is of the highest importance to ports as their main clients are the shipping lines, whose vessels are being loaded or unloaded.

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<sup>32</sup> Refer to Table 5.8 and Table 4.7 for further details on the information used to calculate these figures.

The productivity of New Zealand container ports was analysed in this research using the crane rate, vessel rate and ship rate productivity measures which concentrate on how many containers are moved between ship and wharf by an individual crane or collection of cranes for each crane or labour hour. This was more restrictive than some academic and industry international examples which also analyse TEU per hectare, TEU per berth and/or vessel turn times. In the New Zealand case the data is not available to carry out a wider ranging analysis of container terminal productivity.

On average, the productivity of New Zealand ports is high in relation to the ports examined and outlined in international literature. In this sense, the fact that New Zealand ports compete so hard just to survive and have smaller intertwined hinterlands may actually be beneficial, but proof of this is outside the parameters of this study.

Over the majority of the time period Port Tauranga had the highest crane, ship and vessel productivity rates across New Zealand container ports. Much has been made of the Port of Tauranga's non-unionised labour force (all other New Zealand ports employ union controlled staff), economies of scale (vessel exchanges are typically higher than other New Zealand ports), high crane technology and good road and rail land transport connections<sup>33</sup>. Whether it is one or a combination of these factors that results in the high throughput growth and high productivity levels is unknown and an investigation is outside the scope of this research.

From the analysis performed it can also be said that South Island ports are generally less productive compared to the New Zealand average across the three productivity measures reported. This is especially the case if Napier was to be excluded from the crane rate calculation due to their differences in infrastructure<sup>34</sup>. This poses the question of whether New Zealand importers and exporters should be looking to hub or tranship products through large North Island ports like Tauranga in order to gain productivity improvements.

The Port of Tauranga has the aspiration of being New Zealand's single hub port and has purchased a half stake in PrimePort Timaru to allow the opportunity to marshal South Island cargo to be transhipped over Port of Tauranga. The Timaru location has latent capacity and has the potential to again attract throughput volumes from large exporters in close proximity which currently export out of

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<sup>33</sup> This comment has been based of discussions with Managers in other New Zealand Container Ports.

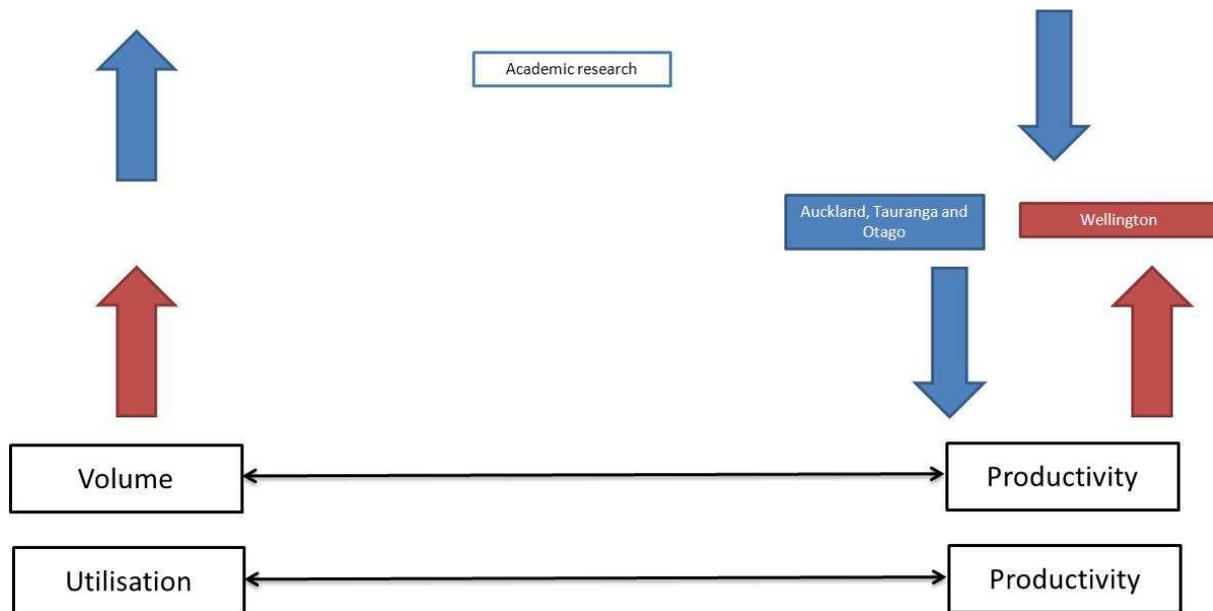
<sup>34</sup> Port of Napier uses Harbour Mobile Cranes which are typically less productive than the Gantry Cranes uses by all other New Zealand ports featured in this research.

Lyttelton Port. While this research suggests that productivity benefits are likely if growth in throughput volumes were to be transhipped through North Island ports rather than be directly exported via Port of Lyttelton or Port Otago, further investigation, outside this research, needs to be completed to determine the full costs and benefits. The only problem with the suggestion that further throughput volumes should be diverted to Tauranga is that since quarter one 2009 individual crane productivity has been in decline at Tauranga, particularly in quarter one 2012 as strike action occur in Auckland and large amounts of volume shifted quickly towards the Port of Tauranga. There has also been a general increase in the portion of non-productive time.

Ports of Auckland's crane, vessel and ship productivity has been increasing over the time period studied and sharply rose after the loss of volume to other North Island ports. The case for Wellington is similar to that of Tauranga's – strike action meant immediate productivity took a hit – however Wellington has bounced back in a faster manner.

The analysis performed and the commentary above indicates a negative relationship between volume or capacity utilisation and productivity. That is, if volume or capacity utilisation increases productivity will decrease. This is similar to the conclusions of academic literature which suggests that container terminal managers must balance the need to provide capacity at the terminal to allow for volume increases with keeping the productivity of the terminal high to attract new or grow existing shipping customers (Merchx (2013)).

However the case of CentrePort Wellington was different in this research. While it did experience a decrease in the productivity when it was required to respond quickly during the period of strike action at the Ports of Auckland, generally and over the totality of the time period there is a positive relationship between volume and productivity – when volume increases so does productivity – the opposite of what was expected from the study of the theoretical basis and the previous academic research. These differences and similarities to the academic literature are diagrammatically outlined below



**Figure 7.34: Diagrammatic Overview of the Relationship between Volume or Utilisation and Productivity**

The question this then poses is, as CentrePort Wellington has a positive relationship between volume and productivity, why then does not the New Zealand industry/government direct volume through the Wellington port, or undertake initiatives which seek to grow trade through the Wellington port? Given the relationships outlined above, if volume was diverted from other New Zealand ports to Wellington, the New Zealand port industry overall would be more productive. This may also provide an opportunity to increase the resilience of New Zealand's supply chain and port industries. This is a contrasting view to the industry's current view of either a single New Zealand hub port or a rationalised port structure with one major port in each of the North and South Islands, of which Wellington is not the recommended port for the North Island.

One reason this is not occurring may be due to the inland origin and destination of containerised freight. As part of this research a review of each of the major New Zealand trade industries was undertaken and concluded that there is a relatively low concentration of import and export industries located in the Wellington region. Therefore the inland transport leg to get cargo to and from the Wellington port is low and costly. However, this does not mean that the theory of pushing cargo towards Wellington to generate industry productivity increases should not be investigated. Although when the initiatives which seek to grow trade through the Wellington port and increase New Zealand productivity are evaluated, they must be evaluated alongside other initiatives to increase port productivity such as new crane or terminal equipment in other large container terminals, which may be more economical than diverting trade towards CentrePort Wellington.

The analysis shows that the capacity utilisation of CentrePort Wellington is low across the both the land and crane assets. While there is currently a positive relationship between volume and capacity, it could be expected that when capacity utilisation increases above 70% the nature of the relationship could change and even turn negative. This is another reason for not diverting trade towards CentrePort Wellington. Therefore, perhaps Tauranga and Auckland are at the more developed end in terms of terminal infrastructure and that is the reason why they have negative relationships between volume/capacity and productivity.

The comparison of terminal infrastructure and productivity between Wellington and Napier ports shows that CentrePort Wellington has developed infrastructure that is comparable to a large international terminal while Napier uses less advanced infrastructure in the harbour mobile cranes, however their productivity levels are of a similar level. Wellington and Napier ports have similar volumes, are located close to each other, but have different infrastructure in place. There is a concentration in Wellington on a single crane port quayside crane which has resulted in a high crane rate and low vessel rates. Napier on the other hand, has low crane productivity from each of its harbour mobile cranes but high vessel and ship productivity rates are comparable due to the concentration on a higher number of cranes (i.e. higher crane intensity) as well as innovative methods of handling empty containers. In terms of the commercial impact – Napier is likely to have incurred less capital cost impact and running costs however their labour costs are likely to be higher due to the requirement to run further labour gangs for each crane in comparison to Wellington.

Wellington is no less developed than the Auckland or Tauranga ports, it is just at another point in its asset utilization compared to the larger New Zealand ports. This then suggests that, in New Zealand, the relationship between productivity and volume or capacity utilization changes dependent upon the level of utilization.

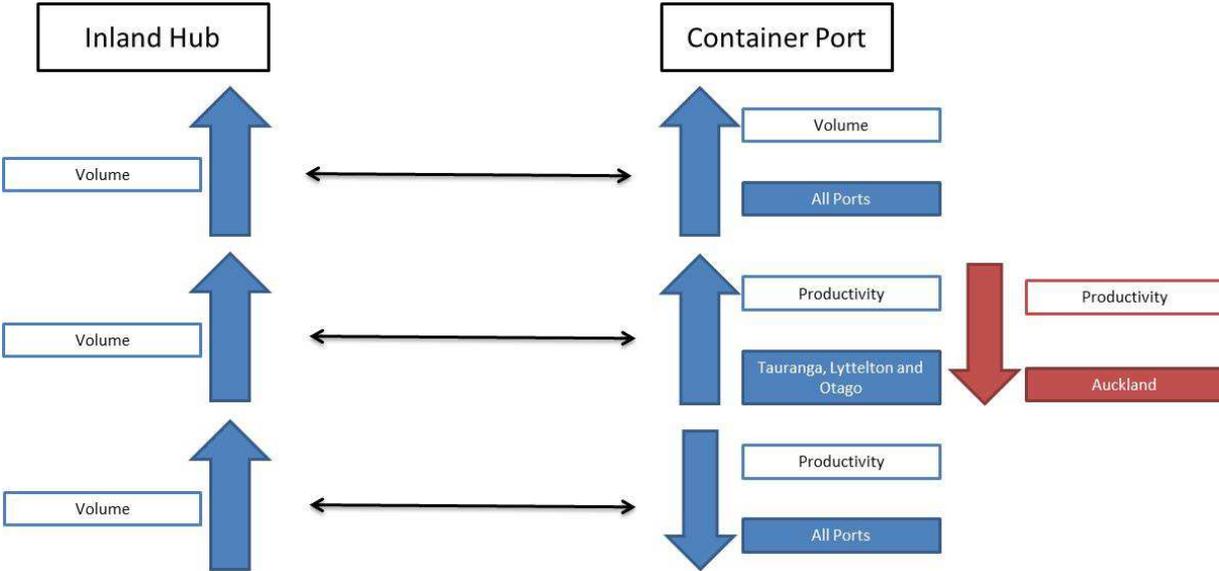
The analysis has shown the benefit of investment in infrastructure. Port infrastructure is expensive and has long payback periods, however there are significant benefits from increasing investment in container terminal infrastructure. In 2006 Lyttelton Port of Christchurch invested in a new quay crane. Since the introduction of this crane, crane breakdowns have dramatically decreased. In terms of productivity, the crane installation completion resulted in a step change increase in the vessel productivity but only smaller increases in crane and ship productivity rates. This is to be expected as crane and ship productivity rates exclude any non-productive elements in the calculation of

productivity – therefore crane breakdowns never entered into calculations. However, the fact that there have still been increases in crane and ship productivity indicates that there have been benefits received outside of just the reduced breakdowns – i.e. the container terminal is generally more productive as a result of increased reliability.

### 7.3 INLAND PORTS

As discussed throughout the research the New Zealand ports studied have a shortage in available terminal land areas. There have been investment inland terminal facilities by New Zealand ports to provide increased storage area at a cost less than expensive land reclamation. However, some ports have also invested in inland terminal facilities as a means of entering a competitor's hinterland area and growing market share.

The research showed that infrastructure upgrades in inland hubs had a positive benefit for the productivity of Tauranga and Otago ports but a detrimental impact on the Ports of Auckland. In the detailed analysis of the relationship between inland hubs and their integrated shipside terminals, it was shown for the Lyttelton Port of Christchurch that there was a positive relationship between the throughput of the inland hub and the productivity of the shipside container terminal. An increase in inland hub volume not only increases productivity, but it also reduces the time delays/stoppages at the port. This is consistent with the theoretical underpinnings and previous academic literature. These relationships are outlined diagrammatically below.



**Figure 7.35: Diagrammatic Overview of the Relationship between Inland Hub Use and Container Terminal Performance**

Therefore the inland hubs are being used as both a means of increasing operational effectiveness by increasing land area, decreasing infrastructure utilisation of wharfside equipment and increasing productivity as well as a means of competing against other New Zealand ports.

The relationships covered in this, and other international research such as Tioga Group (2010), are occurring over a number of years and therefore have suitable time to adjust. As an example, the productive ability of the Lyttelton Port has increased over time. However, this does not mean that Lyttelton could handle sharp increases in volume while maintaining productivity. The impact of strike action provide a good case study for determining what would happen if New Zealand ports needed to quickly respond so sudden changes in volume.

Strike action by the labour force in Auckland at the end of 2012 provides a perfect test of the relationship between productivity, capacity and volume as it illustrated a quick shift in volume – immediately large amounts of freight diverted Auckland for other North Island ports. Large volume increases at the Port of Tauranga resulted in falls in crane productivity and vessel and ship productivity.

Finally, while this research provides important analysis and insights into relationships between volume, capacity and productivity, it is important to note that there are also other factors involved in maximising the performance of a container port. Something that is missing from the quantitatively based research is the health and safety risk involved in operational container ports. Container ports typically involve a high health and safety risk relative to other industries or workplaces. Container terminal managers must insure that their desire to increase throughput volume and productivity does not unnecessarily place workers in further danger.

An example of this is at the Lyttelton Port of Christchurch. Throughout the 2013 year the port released press statements on this increased throughput growth, high productivity and increasing revenues. The 2013 Annual Financial Report<sup>35</sup> highlighted the high growth rate and record container throughput. However in the 10 month period to September 2014 three fatalities and multiple accidents have occurred within the Lyttelton Port operational area, in a time when trucking customers suggested on numerous occasions that landside congestion was placing increased risks –The Press newspaper reported that “Other drivers, who no longer work at the port, have told The Press of a “below average”

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<sup>35</sup> <http://lpc.co.nz/TempFiles/TempDocuments/Annual%20Reports/LPC-Annual-Report-2013-web.pdf> retrieved 21 September 2014 at 10:32am.

truck fleet, congested facilities and an environment where workers' health and safety concerns are not taken seriously enough<sup>36</sup>.

#### **7.4 CONTRIBUTION OF THIS RESEARCH TO THE ACADEMIC AND INDUSTRIAL LITERATURE**

This research contributes to New Zealand logistics and supply chain academic literature by providing the first statistical analysis on the relationship between volume, capacity and utilisation and moves the field of research beyond the typical study of the need, or otherwise, for larger ships in New Zealand and which ports are most suited to be big ship capable.

This study also progresses New Zealand research by providing a link between the use of inland port facilities and the productivity of wharfside operations. As outlined in other chapters, the link between Port of Tauranga's inland hub facilities and volume growth has previously been studied, however, this research provides a link for the productivity elements and expands analysis to further New Zealand ports and allows for the comparison of inland hub facilities across the country.

This research provides insight to the investment decisions which are likely to come to bear in the medium term future within the New Zealand trade and logistics industry. It is important that research such as this be used in considering the holistic infrastructure decisions impacting upon the future of New Zealand ports as industry led publications are typically completed by a small section of industry in order to benefit the future of their particular business or in an attempt to lower their total supply chain costs<sup>37</sup>.

The research is also important as it identifies potential opportunities to improve productivity in the New Zealand port industry, an industry which has been outlined above as vital to the success of the New Zealand economic performance as it facilitates trade and access to the global market.

In a more global setting, this research is also important. Typically academic literature on container ports is focused on large American or European container ports. It shows that, potentially, the relationship between productivity and volume or utilisation may be expected to change dependent

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<sup>36</sup> <http://www.stuff.co.nz/the-press/news/hills-and-harbour/10468089/Call-for-big-changes-at-port> retrieved 21 September 2014 at 10:43.

<sup>37</sup> For example, the Shippers Council Report on the Question of Bigger Ships is completed with recommendations which benefit the large exporters which make up the New Zealand Shippers Council. It does not necessary consider the opinions or implications of the recommendations on the number of smaller exporters or the number of New Zealand importers.

upon the level of utilisation, as experienced between the different volume/utilisation levels of Auckland and Wellington ports. Also, the relationship between volume or utilisation and productivity can be positive – which is completely the reverse of the conclusions made throughout conceptual studies and academic literature.

It also provides evidence that having regional ports with intertwined highly competitive hinterland activities maybe a good thing, even though there is some duplication in assets, as it promotes an industry focused on winning business based on productivity and cost. It is important that this highly competitive domestic supply chain is maintained while the industry moves through a phase of rationalisation and fewer ports are handling increasing container volumes. This will keep the focus of the industry on productivity improvements.

Finally, it shows that inland port facilities can be used as a means to improve the productivity of wharfside operations.

## **7.5 STRENGTHS, WEAKNESSES AND LIMITATIONS**

The strength of this research methodology is that it uses data and analysis techniques which are comparable with international literature and industrial publications. The statistical analysis also provides a high level of detail as to the level and significance of the relationships between variables and the impacts associated with a change in any of the variables. Typically data available for this research is secondary data – obtained via industry and government publication of port performance. Another strength of this research is that it triangulates the results of the data analysis of secondary data by carrying out detailed analysis on an individual port.

The first limitation of the research is the use of secondary data. The data is compiled through the use of the Ministry of Transport quarterly reports titled *Freight Information Gathering System and Port Productivity Study*.

The second limitation is that this productivity data is provided by each individual port. The Ministry of Transport then compiles and publishes the information. There is limited ability for the Ministry of Transport or any other third party to check for accuracy (with the exception of a sense check in comparison to the previous reported figures and the reported figures of other ports). This is especially important given each port has an incentive to report figures which are as high as possible as it is the single New Zealand publication which allows cargo owners and shipping lines to compare the

productivity of New Zealand ports on a quarterly basis. Lyttelton and Tauranga ports are both listed on the New Zealand stock exchange and therefore have the added incentive here as a means of increasing share price through an increased in the perceived value of the port's assets.

The use of secondary data brings with it drawbacks in relation to quality and reliability. Therefore, as detailed above, more detailed analysis using commercial port operational data (which has been checked for accuracy by a number of parties) was also completed for an individual port to triangulate results and confirm accuracy.

The third limitation of the data set used is that the port productivity data is produced only for the productive ability of a port's cranes. The data does not provide the range of information typically published by international reports, including information on berth productivity per metre, productivity of yard equipment or the productive ability of a port to handle demand from land transport operations.

The final limitation of the approach conducted is that it concentrates on the analysis of volume, capacity utilisation and productivity variables. It does not include the analysis of other factors which may impact on the performance of a container terminal, such as the financial and human elements.

## **7.6 FURTHER AVENUES OF RESEARCH**

Upon completion of this research there are three areas where I believe further study would help improve the understanding of the performance of container terminals when faced with high growth in volume demand. The first further avenue of research suggested as an extension to this research would be the calculation of further productivity measures used in large international studies – including the calculation of road, rail and yard productivity measures – to go along with the wharf productivity measures analysed here. This would allow for a greater understanding of the performance of each component of the container terminal, rather than the entirety of the container terminal.

The second further avenue of research suggested as an extension to this research would be the collection of primary, rather than secondary, data use in all ports. This would require spending time within each port understanding their collection methods, however, it would add accuracy to the analysis and a further level of understanding.

The third further avenue of research suggested as an extension to this research would be the research, collection and inclusion of wide container terminal measures typically used by container terminal managers. These would include measures across health and safety factors, commercial

costs, infrastructure/capital costs and the human or labour factors and would allow a greater level of understanding across multiple performance factors considered by container port businesses facing port rationalisation or large increases in volume and capacity requirements.

The final extension to this research would be to test the impact on productivity of an inland hub being port agnostic or dedicated to a particular port.

All the inland hub facilities studied in this research are aligned to a particular seaport. An extension to the inland hub research would be to carry out detailed research on the 'port agnostic' inland hubs to determine their impact on the capacity, throughput and productivity of surrounding ports and whether it is different to the inland hubs that are aligned to a particular seaport.



## **8 CONCLUSIONS**

### **8.1 INTRODUCTION**

New Zealand ports are expected to be rationalised when larger vessels force infrastructure upgrades which only few ports have the ability to undertake. Container volumes will be concentrated on those remaining ports. The aim of this research is to investigate the existence of a relationship between the capacity utilisation, volume and productivity of container ports. This will allow the research to provide insight to the resulting productivity impacts from the continued trend in the consolidation of container ports.

### **8.2 METHODOLOGICAL OVERVIEW**

There are three components of the research methodology which are; data collection, analysis and reporting. All three components have two different levels of investigation – national level investigation and a detailed port investigation, each focused on a different level of detail. The national level investigation aims to determine the existence of a relationship between volume, capacity and productivity at New Zealand's main container ports. The detailed port investigation aims to triangulate data and analysis and confirm the existence and significance of relationships.

The data for the national level investigation is compiled through the use of the Ministry of Transport quarterly reports titled *Freight Information Gathering System and Port Productivity Study*. This is publically available information on the productivity, volume and capacity utilisation which produces a quality data set for the six ports that handle ninety percent of New Zealand containerised trade. The use of secondary data brings with it drawbacks in relation to quality and reliability, therefore more detailed analysis using commercial port operational data was also completed for an individual port to triangulate the information and confirm the existence of the relationships and the level of significance.

The second level of focus, the detailed investigation of one port, concentrates analysis on a single port to confirm the relationships outlined in the national overview. The collection of data for the detailed port analysis concentrates on the Lyttelton Port of Christchurch. The data was produced from the port operational system and checked for consistency and accuracy by the Container Terminal Managers after the completion of each vessel. Between 2011 and 2013 the author also worked as an analyst for the Port of Lyttelton and gained an understanding of the data collection methods, accuracy and operational procedures of their container terminal and integrated inland hub facility..

### **8.3 EVALUATION OF OBJECTIVE ONE**

Objective one in this research was:

*To investigate the existence of a relationship between the capacity utilisation, volume and productivity of container ports.*

The purpose of this objective was to determine the likely productivity impacts of more container going through a fewer number of ports under a potential port rationalisation scenario.

If the ports are not operating at their capacity, growth in throughput is expected to provide economies of scale to the underutilised large scale infrastructure assets. Under this scenario a positive relationship between volume and productivity of the container terminal would be expected. However, on the other hand, if there is a capacity constraint limiting the performance of the container port a negative relationship would be expected.

Inland hub facilities provide an alternative means of quickly providing additional port capacity for the ports remaining after consolidation. This research also investigates whether the use of inland hubs by container ports impacts on the relationships throughput volume, capacity utilisation or productivity of the integrated seaport.

To investigate the first objective of this research, regression and statistical analysis were used on the national level and detailed port data sets to investigate trends in throughput volume, capacity utilisation and productivity as well as the relationship between each of these variables.

The strength of this research methodology is that it uses data and analysis techniques which are comparable with international literature and industrial publications. The statistical analysis also provides a high level of detail as to the level and significance of the relationships between variables and the impacts associated with a change in any of the variables. Another strength of the research is that it triangulates the results of the data analysis of secondary data by carrying out detailed analysis on an individual port.

The weakness of the approach is that it concentrates on the analysis of volume, capacity utilisation and productivity variables. It does not include the analysis of other factors which may impact on the performance of the container terminal, such as the financial and human elements.

The research undertaken shows that the large New Zealand ports of Tauranga, Auckland, Lyttelton and Otago, those ports likely to remain after port rationalisation, are operating at a high level of

capacity utilisation. This research suggests that further increases in volume through these ports will result in significant negative impacts on port productivity, if capacity at these ports remains the same. This result confirms the findings of previous academic literature and conceptual studies. Therefore steps are required to be undertaken to increase capacity prior to the rationalisation or large scale container growth to avoid reductions in port productivity.

However, this research shows that the results produced for Wellington is opposite to the conceptual basis and the experience of previous literature reviewed. This research suggests that CentrePort Wellington would provide productivity improvements to the New Zealand industry if the government or industrial were to undertake measures which increase volume and capacity utilisation in Wellington.

#### **8.4 EVALUATION OF OBJECTIVE TWO**

Objective two of this research was:

*To investigate whether the use of inland hubs impacts on the throughput volume, capacity utilisation or productivity of the integrated seaport*

The purpose of this objective was to determine whether New Zealand ports are using their inland hubs to generate productivity increases or to increase their competitive ability by increasing their potential hinterland.

To research the second objective, analysis focused on investigating whether there is a change in the volume, capacity utilisation and productivity trends after the introduction of an inland hub facility. The strengths and weaknesses of this approach are the same as that outlined for the analysis carried out to investigate objective one.

The productivity information and analysis suggests that there is a positive relationship between the use of inland hubs and the volume handled. The research also shows that the use of inland hubs is linked to a reduction in delays in port-side operations. Therefore, the use of inland hubs provides a fantastic opportunity for NZ ports to increase productivity of wharfside operations. Therefore, New Zealand ports could be using inland hubs to increase productivity as there is an observed positive relationship. However, the timing and location of individual inland hub facilities shows a tendency to also use the investment in hub facilities as a form of competition in the domestic or hinterland attraction of freight.

## **8.5 IMPORTANCE OF THIS RESEARCH**

This research is important given New Zealand's reliance on trade and the need to carefully plan infrastructure investments in transport and freight – where funding is scarce. New Zealand is also forecast to go through a significant rationalization process. There is no research, academic or otherwise, on the relationships between throughput volume, productivity and capacity for New Zealand ports. Greater understanding of port operations is important for New Zealand, as well as worldwide, as ports facilitate trade and are gateways to the globalised market.

The research also adds to the base of international literature on port productivity, which is typically focused on American or European seaports. However, New Zealand is different in that the domestic market is small in scale, there are a relatively high number of container ports with highly competitive and intertwined hinterlands, a lack of political direction in the port sector, an export focus and a long distance to international markets. Therefore, academically the research may also be relevant and useful in informing other contexts such as:

- Other countries or areas where there is a requirement for, or trend in, port rationalisation
- Other ports where they face the challenge of trying to cater for increasing ship sizes with a scale budget for investment in infrastructure
- Other small open economies with a reliance on trade and the performance of their port industry
- Any other country, area or port facing constrained capacity and large scale throughput growth
- Other trade areas with highly competitive hinterlands

## **8.6 FURTHER AVENUES OF RESEARCH**

Upon completion of this research there are three areas where I believe further study would help improve the understanding of the performance of container terminals when faced with high growth in volume demand. The first further avenue of research suggested as an extension to this research would be the calculation of further productivity measures used in large international studies – including the calculation of road, rail and yard productivity measures – to go along with the wharf productivity measures analysed here. This would allow for a greater understanding of the performance of each component of the container terminal, rather than the entirety of the container terminal.

The second further avenue of research suggested as an extension to this research would be the

collection of primary, rather than secondary, data use in all ports. This would require spending time within each port understanding their collection methods, however, it would add accuracy to the analysis and a further level of understanding.

- The third further avenue of research suggested as an extension to this research would be the research, collection and inclusion of wide container terminal measures typically used by container terminal managers. These would include measures across health and safety factors, commercial



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## 10 APPENDIX 1; REGRESSION ANALYSIS OUTPUTS

### 10.1 NATIONAL LEVEL OVERVIEW

#### 10.1.1 Volume and crane capacity

The equation analysed in Table 10.12 is:

$$\text{Crane utilisation} = B * \text{Volume}$$

	B-value	t-stat	P value
Auckland	2.87E-06	8.62E+15	1.8E-216
Tauranga	3.58E-06	1.75E+16	8.7E-221
Napier	1.24E-05	1.68E+16	1.6E-220
Wellington	1.13E-05	1.23E+16	1.3E-218
Lyttelton	9.07E-06	1.87E+16	3.4E-221
Otago	7.93E-06	1.7E+16	1.4E-220

**Table 10.12 Regression analysis results – volume and crane capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

In the case for Auckland if volume increases by 1,000 containers, crane utilisation would increase by 0.0287 whereas Wellington would increase by 0.113.

#### 10.1.2 Volume and yard capacity

The equation analysed in Table 10.13 is:

$$\text{Yard utilisation} = B * \text{Volume}$$

	B-value	R-squared	t-stat	P value
Auckland	3.45E-06	1	1.12E+16	4.8E-218
Tauranga	5.35E-06	1	1.51E+16	6.8E-220
Napier	1.61E-05	1	1.83E+16	4.8E-221
Wellington	1.61E-05	1	5.8E+15	4.6E-214
Lyttelton	1.15E-05	1	1.01E+16	2E-217
Otago	1.07E-05	1	1.53E+16	5.8E-220

**Table 10.13 Regression analysis results – volume and yard capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.3 Crane capacity and crane rate

The equation analysed in Table 10.14 is:

$$\text{Crane rate} = B * \text{crane utilisation}$$

	B-value	R-squared	t-stat	P value
Auckland	-21.2202	0.14	-1.51293	0.152542
Tauranga	-10.9798	0.51	-3.81	0.001913
Napier	-1.45842	0.028	-0.6314	0.537954
Wellington	24.83288	0.06	0.94559	0.360393
Lyttelton	1.082091	0.005	0.284084	0.780504
Otago	-34.4406	0.58	-4.36978	0.000641

**Table 10.14 Regression analysis results – crane productivity rate and crane capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.4 Crane capacity and ship rate

The equation analysed in Table 10.15 is:

$$\text{Ship rate} = B * \text{crane utilisation}$$

	B-value	R-squared	t-stat	P value
Auckland	-30.521	0.024	-0.58258	0.569439
Tauranga	-16.51	0.147	-1.55623	0.141966
Napier	9.328033	0.155	1.60317	0.131212
Wellington	68.49433	0.106	1.287186	0.218904
Lyttelton	23.94098	0.369	2.860664	0.012582
Otago	-34.6066	0.280	-2.33065	0.035238

**Table 10.15 Regression analysis results – ship productivity rate and crane capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.5 Crane capacity and vessel rate

The equation analysed in Table 10.16 is:

$$\text{Vessel rate} = B * \text{crane utilisation}$$

	B-value	R-squared	t-stat	P value
Auckland	-16.104	0.011	-0.40213	0.693662
Tauranga	-21.4877	0.190	-1.81045	0.091735
Napier	9.114694	0.181	1.756813	0.100788
Wellington	10.62738	0.0023	0.179168	0.860373
Lyttelton	16.64488	0.342	2.695413	0.017412
Otago	1.745612	0.0115	0.126746	0.900944

**Table 10.16 Regression analysis results – vessel productivity rate and crane capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.6 Yard capacity and crane rate

The equation analysed in Table 10.17 is:

$$\text{Crane rate} = B * \text{yard utilisation}$$

	B-value	R-squared	t-stat	P value
Auckland	-17.6587	11.6719	-1.51293	0.152542
Tauranga	-7.3527	1.929842	-3.81	0.001913
Napier	-1.12859	1.787448	-0.6314	0.537954
Wellington	17.51763	18.52562	0.94559	0.360393
Lyttelton	0.855902	3.012844	0.284084	0.780504
Otago	-25.5136	5.838633	-4.36978	0.000641

**Table 10.17 Regression analysis results – crane productivity rate and yard capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.7 Yard capacity and ship rate

The equation analysed in Table 10.18 is:

$$\text{Ship rate} = B * \text{yard utilisation}$$

	B-value	R-squared	t-stat	P value
Auckland	-25.3986	0.023669	-0.58258	0.569439
Tauranga	-11.0561	0.147477	-1.55623	0.141966
Napier	7.218475	0.155107	1.60317	0.131212
Wellington	48.31734	0.105823	1.287186	0.218904
Lyttelton	18.93661	0.368897	2.860664	0.012582
Otago	-25.6365	0.279536	-2.33065	0.035238

**Table 10.18 Regression analysis results – ship productivity rate and yard capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.8 Yard capacity and vessel rate

The equation analysed in Table 10.19 is:

$$\text{Vessel rate} = B * \text{yard utilisation}$$

	B-value	R-squared	t-stat	P value
Auckland	-13.4012	0.011419	-0.40213	0.693662
Tauranga	-14.3894	0.189708	-1.81045	0.091735
Napier	7.053383	0.180634	1.756813	0.100788
Wellington	7.496776	0.002288	0.179168	0.860373
Lyttelton	13.16561	0.341649	2.695413	0.017412
Otago	1.293146	0.001146	0.126746	0.900944

**Table 10.19 Regression analysis results – vessel productivity rate and yard capacity utilisation**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.9 Volume and crane rate

The equation analysed in Table 10.20 is:

$$\text{Crane rate} = B * \text{Volume}$$

	B-value	R-squared	t-stat	P value
Auckland	-6.1E-05	0.1405	-1.51293	0.152542
Tauranga	-3.9E-05	0.5090	-3.81	0.001913
Napier	-1.8E-05	0.02788	-0.6314	0.537954
Wellington	0.000281	0.060033	0.94559	0.360393
Lyttelton	9.82E-06	0.005732	0.284084	0.780504
Otago	-0.00027	0.57697	-4.36978	0.000641

**Table 10.20 Regression analysis results – crane productivity rate and container volume**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.10 Volume and ship rate

The equation analysed in Table 10.21 is:

$$\text{Ship rate} = B * \text{Volume}$$

	B-value	R-squared	t-stat	P value
Auckland	-8.8E-05	0.002369	-0.58258	0.569439
Tauranga	-5.9E-05	0.147477	-1.55623	0.141966
Napier	0.000116	0.155107	1.60317	0.131212
Wellington	0.000776	0.105823	1.287186	0.218904
Lyttelton	0.000217	0.368897	2.860664	0.012582
Otago	-0.00027	0.279536	-2.33065	0.035238

**Table 10.21 Regression analysis results – ship productivity rate and container volume**

Note from the table that 3.58E-06 = 0.00000358

### 10.1.11 Volume and vessel rate

The equation analysed in Table 10.22 is:

$$\text{Vessel rate} = B * \text{Volume}$$

	B-value	R-squared	t-stat	P value
Auckland	-4.6E-05	0.0011419	-0.40213	0.693662
Tauranga	-7.7E-05	0.189708	-1.81045	0.091735
Napier	0.000113	0.180634	1.756813	0.100788
Wellington	0.00012	0.00228	0.179168	0.860373
Lyttelton	0.000151	0.0341649	2.695413	0.017412
Otago	1.38E-05	0.001146	0.126746	0.900944

**Table 10.22 Regression analysis results – vessel productivity rate and container volume**

Note from the table that 3.58E-06 = 0.00000358

## 10.2 DETAILED LEVEL INVESTIGATION

### The Relationship between Volume and Capacity Utilisation

The equation analysed in Table 10.23 is:

$$\text{Crane/yard utilisation percentage} = B * \text{Volume}$$

	B-value	R-squared	t-stat	P value
Lyttelton (crane capacity)	0.000836	0.998078	1170.969	0.0000
Lyttelton (yard capacity)	0.000659	0.83439	115.2868	0.0000

**Table 10.23 Regression analysis results – Crane and yard utilisation percentage and container volume for Lyttelton Port of Christchurch Container Terminal with detailed data.**

### The Relationship between Capacity Utilisation and Productivity

The equations analysed in the investigation of these relationships are:

$$\text{Crane or ship or vessel productivity rate} = B * \text{crane or yard utilisation}$$

	B-value	R-squared	t-stat	P value
Lyttelton (crane rate/crane utilisation)	0.537	0.0015	1.990461	0.046643
Lyttelton (ship rate/crane utilisation)	9.081	0.030789	9.154257	1.07E-19
Lyttelton (vessel rate/crane utilisation)	8.870	0.03618	9.951179	6.29E-23
Lyttelton (crane rate/yard utilisation)	1.797	0.022603	7.810585	8.15E-15
Lyttelton (ship rate/yard utilisation)	17.060	0.146264	21.25911	1.05E-92
Lyttelton (vessel rate/yard utilisation)	16.132	0.1611	22.50765	9.1E-103

**Table 10.24 Regression analysis results – Productivity rate and utilisation percentage for Lyttelton Port of Christchurch Container Terminal with detailed data.**

Note from the table that 3.58E-06 = 0.00000358

### Volume and crane rate

The equations analysed in the investigation of this relationship are:

$$\text{Crane/ship/vessel rate} = B * \text{Volume}$$

	B-value	R-squared	t-stat	P value
Lyttelton (crane rate)	0.001504	0.022603	7.810585	8.15E-15
Lyttelton (ship rate)	0.014285	0.146264	21.25911	1.05E-92
Lyttelton (vessel rate)	0.013508	0.1611	22.50765	9.1E-103

**Table 10.25 Regression analysis results – Productivity rate and container volume for Lyttelton Port of Christchurch Container Terminal with detailed data.**

Note from the table that 3.58E-06 = 0.00000358

### 10.3 THE RELATIONSHIP BETWEEN PORT PRODUCTIVITY, VOLUME AND THE USE OF INLAND HUBS

The relationship between port and inland hub volume is modelled with equation being:

$$\text{Port Volume} = B * \text{Inland Hub Volume}$$

	B-value	R-squared	t-stat	P value
Lyttelton	1.173334	0.789775	17.76435	3.48E-30

**Table 10.26 Regression analysis results – Total port throughput and Inland hub throughput volume for Lyttelton Port of Christchurch Container Terminal with detailed data.**

$$\text{Port Productivity} = B * \text{Inland Hub Volume}$$

	B-value	R-squared	t-stat	P value
Lyttelton (crane rate)	0.000153	0.092819	2.931639	0.004343
Lyttelton (ship rate)	0.000932	0.271786	5.599167	2.65E-07
Lyttelton (vessel rate)	0.000987	0.343281	6.626362	3.1E-09

**Table 10.27 Regression analysis results – Crane productivity and Inland hub throughput volume for Lyttelton Port of Christchurch Container Terminal with detailed data.**

*Port Capacity Utilisation= B \* Inland Hub Volume*

	B-value	R-squared	t-stat	P value
Lyttelton (crane capacity utilisation)	1.83E-05	0.500678	9.177584	2.61E-14
Lyttelton (yard capacity utilisation)	3.23E-05	0.789775	17.76435	3.48E-30

**Table 10.28 Regression analysis results – Port Crane Capacity Utilisation and Inland hub throughput volume for Lyttelton Port of Christchurch Container Terminal with detailed data.**