Modeling New Zealand's Log's Supply Chain:

A Two-Tiered Modeling Approach of Logistical Network Resilience

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Abstract

The global characteristic of today’s market raise concerns regarding the compatibility between the different nodes within a supply chain. Political, economic, infrastructural, cultural and other risks should be considered when operating globally. Tsunamis, strikes, hurricanes, bio-security threats and wars and their impact on the logistical networks are all examples of major events that might happen in a certain place and affect other supply chain members in other parts of the world. This type of events and their disastrous consequences show the importance of being ready and having a contingency plan for such events to minimize their effect on the companies’ supply chains

The objective of this research is to provide the building bricks of a tool that functions as a decision support system to help practitioners in the log industry deciding their course of action spontaneously in response to sudden major events that might disrupt their supply chains. The resulting decision support system and recommendations of this research aim at improving the resilience of the log supply chain in New Zealand and the logistical network in general. Hopefully, the resulting DSS will be capable of producing recommendations that would increase the profitability of logs supply chain and make it more reliable and resilient under multiple disruption scenarios.

The proposed decision-making approach and the suggested improvements in this research provide an in-depth insight for policy makers and practitioners operating in the logistical network in New Zealand. This research provides a solid analytical approach for decision makers to direct their investments in the corresponding part of the supply chain that they are operating in to make the biggest possible impact of their investment on the supply chain through put. The model can be employed to generate improvement recommendations for different regions and decision makers can prioritize the presented recommendations according to their strategic goals.

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Contents

List of Figures

List of Tables

Chapter One: Introduction

A supply chain is a network of facilities in which material flows from suppliers to be processed in factories and then to be delivered to end customers, it also includes information flow from customers to suppliers and vice versa (Petrovic et al., 1998). Most academics agree that supply chain scope includes all the stages the material goes through from its ore to the final consumption point (Cooper et al., 1997). The complexity and interference of a supply chain differs with the number of nodes included within that supply chain. Businesses in modern market are being forced by the new market environment to operate on a global scale in order to improve their offerings, profitability and performance by getting lower labor costs, expanding their markets or getting closer to their suppliers. This tendency increased the complexity of the supply chains of these businesses and positioned the supply chain operations in the center of the improvement efforts as it affects the product quality, service level and profitability.

The high number of stakeholders involved in the activities taking place in different parts of the supply chain necessitated the evolution of the supply chain management concept. Supply chain management is defined by Christopher (2011) as "The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole" (p. 3). In addition, Cooper et al. (1997) mention that the main objectives of supply chain management are to allow the business to transform its supply chain into a competitive edge and to reduce the total cost by levelling material flow to accommodate customer needs. Therefore, it can be concluded that supply chain management aims at improving the overall supply chain performance to enhance customer satisfaction at lower cost. However, the wide scope of the supply chain and the corresponding risks to different stages of the supply chain make fulfilling this objective a hard task to do.

The global characteristic of today's market raise concerns regarding the compatibility between the different nodes within a supply chain. Political, economic, infrastructural, cultural and other risks should be considered when operating globally. Tsunamis, strikes, hurricanes, bio security threats and wars and their impact on the logistical networks are all examples of major events that might happen in a certain place and affect other supply chain members in other parts of the world. Labour strike in October 2002 lead to shutting down 29 ports in America's west coast, which resulted in closing the manufacturing plant of New United Motor Manufacturing (Wilson,2007). In 2011 Toyota's production capacity was dropped by 40,000 vehicles due to Japan's tsunami and the consequent nuclear crisis (Pettit, Croxton, & Fiksel, 2013). Computer manufacturers and Japanese car manufactures' supply chains were disrupted by the Thailand flooding in 2011 (Chopra & Sodhi, 2014). These events and their disastrous consequences show the importance of being ready and having a contingency plan for such events to minimize their effect on the companies' supply chains.

Even though complex supply chains' risks and vulnerabilities were widely addressed in the literature, there is not enough empirical research and findings that practitioners can use to mitigate supply chain risks (Brandon-Jones, 2014). Furthermore, transportation risks are surprisingly one of the least addressed risk types in the literature (Ho et al., 2015). The literature provides a deep insight on the types of supply chain risks, risk assessment techniques, management strategies and some conceptual frameworks for risk mitigation. The available literature provides a base for researchers to build practical tools and models that can be used in different industries to mitigate supply chain risks.

Decision Support Systems (DSS) are sought after to present solutions for problems in the supply chain from tactical to strategic level (Tako & Robinson, 2012). Researchers have used different modelling tools to simulate systems under different conditions to prepare these system for the changes that might happen in their environments and accordingly improving their responsiveness and resilience. These modelling tools include linear programing (Santoso et al., 2005), fuzzy modelling (Petrovic et al., 1998), Discrete Event Simulation (DES) (Terzi & Cavalieri, 2004) and hybrid models (Umeda & Zhang, 2006). Some researchers focused on the aggregate level analysis (e.g. Meepetchdee & Shah, 2007; Cakravastia & Diawati, 1999; Towill, 1996), while other researches addressed the micro level analysis by isolating a certain part of the supply chain to be studied in depth (e.g. Legato & Mazza, 2001; Cheng & Duran, 2004). The integration of multiple tools in one decision support system will allow that system to capture both strategic and operational considerations in the decision-making process in order to produce more reliable recommendations.

Globalization had boosted the number of international trade transactions, as customers started comparing products and services offered by suppliers from all around the world. This trend had in turn increased the total number of vessels of different types by more than 7000 vessels during the period from 2011 to 2016 (Merchant, 2016). Consequently, marine traffic during the same period has witnessed a constant growth that is expected to continue in to the future (Huang et al, 2016). This trend had increased the importance of ports in any logistical network. New Zealand is a major exporter of logs in the global market (Scoop,2014), and it relies on its ports to deliver this product to its international customers. The forestry industry is a major contributor to New Zealand's economy, it is largest export the third sector, constitute 3.2% of New Zealand's' GDP and it has provided more than

18000 jobs in 2014 (NZFOA, 2014). In 2013, New Zealand dominated more than 20% of the world's softwood log trade and became the world largest exporter of softwood log (Scoop,2014). The log industry is a large part of New Zealand's exports contributing by more 16 million m^3 of logs in exports in 2014 (NZFOA, 2014). The disruption of this supply chain by a port closure might have catastrophic consequences on New Zealand's economy, which necessitates the creation of contingency plans for such events.

This research is an industry sector study addressing the log's industry in New Zealand. More specifically, it is addressing transportation risks associated with the logs exporting under different port closure scenarios. The objective of this research is to provide the building bricks of a tool that functions as a Decision Support System (DSS) to help practitioners in the log industry deciding their course of action in response to sudden major events that might disrupt their supply chains. The resulting decision support system and recommendations of this research aim at improving the resilience of the log supply chain in New Zealand and the logistical network in general. Hopefully, the resulting DSS will be capable of producing recommendations that would increase the profitability of the log supply chain and make it more reliable and resilient under multiple disruption scenarios.

. The research is a quantitative cross-sectional study as some data was collected during the time of conducting the research in addition to historical data. The structure of the research is formal, in which certain parameters was defined and measured according to a clear procedure. Linear programing and simulation were the main analytical tools, in which there is some control over the variable in the system being studied.

The limitations in the proposed decision support system stems from the inherent nature of the analytical tools used. Even though, the use of linear programming and discrete event simulation allowed the DSS to capture more details of the logistical network, it is inevitable to make some assumptions about the real world. These assumptions limit the ability of the model to reflect the full complexity of the real world. However, it is accepted to have assumption in modeling as it is impossible to simulate the real world with its full complexity. The model also did not capture the behavioral aspects of the different companies operating in the industry and their preferences, contracts and other factors that might affect their decision during a port closure. Another limitation of this research is that some secondary data was used and that companies might not provide full information during primary data collection due to their competitiveness, which might had affected the tradeoffs that the decision support system considered.

Although it was mentioned earlier that supply chain risks were fairly addressed in the literature, it is important to briefly explain the types of supply chain risks in the literature review to understand the context and the significance of this research. The next chapter presents a thorough literature review to augment the readers' understanding of the context of the research. In the third chapter the detailed research question and the objective of the research are clarified. It includes an explanation of the different philosophical positions for tackling social science research. In addition, an appraisal of the available research methodologies are discussed to show the alignment between the research objective and the quantitative research methodologies. It also includes a section that explains the strategy of data collection and analysis. This section is followed by a short section discussing the validity and reliability of the data. After that some ethical implications are presented with the procedure followed to mitigate or minimize their effect on the research. In the fourth chapter and fifth chapter the linear program and the simulation model used to build the DSS are introduced along with the numerical results of the models. The sixth chapter discusses the theoretical and managerial implications of the findings of this research. It also provides some insights on the limitations of this research and direction for future research. The last chapter summarizes the conclusions of the research.

Chapter 2: Literature Review

This chapter is a review of the relevant literature in the supply chain risk and logistical network resilience fields. Section 2.1 present the definition of supply chain risk followed by the types of these risks and their interaction. Section 2.2 addresses the impact of these risks and provides some examples of disruption events with their resulting costs and effects. Section 2.3 discusses the factors affecting the severity of supply chain disruption and provides a general risk mitigation framework. Section 2.4 addresses the calculation methods of ports' capacities. Section 2.5 provide some insight on the concept of decision support systems, the modelling tools used to develop them and their use in the supply chain context. It also discusses some example of decision support systems used in supply chain context. . Section 2.6 sheds some light on the theory of constraints and its applications. Section 2.7 presents the research conceptual model and shows the interaction between different types of risks and how decision support systems help tackling these risks. Section 2.8 points out the gaps that were found in the literature and shows which gaps the research is addressing. Section 2.9 provides a brief summary of all the previous sections.

2.1- Supply Chain Risks

Supply chain risks are defined in a number of published papers; however, these definitions were affected by the authors' views and they were focusing on certain parts of supply chain risks. Some of them focused on supply risks (Zsidisin, 2003; Ellis, Henry, & Shockley, 2010), and information and material flow risks (Jüttner, Christopher, 2003). In this study supply chain risks are defined as the probability and the effect of any unforeseeable events and circumstances that might impair the performance of any part of the supply chain at the tactical, operational or strategic level (Ho et al., 2015). This comprehensive definition includes all types of risks regardless of it being at macro or micro level.

Supply chain risks can be categorised according to their sources to demand risks, supply risks, operational risks, security risks, macro risks, policy risks, resource risks and competitive risks (Manuj, & Mentzer, 2008). Table 1 shows some of these risks types with examples of their corresponding sources. Some of these risks are relevant only to certain parts of the supply chain and others might have a global effect on the supply chain; for example in one hand, competitive risks affect suppliers but benefit customers. On the other hand, security risks affect all the supply chain members. It is necessary to provide a brief explanation of supply chain risks to further understand their nature and their interactions. The study will focus only on the first three types because they cover the three tiers of the simple supply chain.

RISK TYPE	RISK SOURCE
SUPPLY RISK	Inventory, price volatility, product design robustness, and technological disruptions
OPERATIONAL RISK	Machines breakdown, production process capability, and operating exposure
DEMAND RISK	Demand fluctuations, introducing new products to the market, and the bullwhip effect
SECURITY RISK	Vulnerability of the supply chain to be infiltrated by unauthorized access to information , infrastructure security violation, or by physical products damage.
MACRO RISK	Major events such as natural disasters, economic shifts and significant changes in exchange rates
COMPETITIVE RISK	Lack of market intelligence

Table 1 Sources of supply chain risks,

Supply risk is the probability of a supplier or supply market failing to fulfil customer demand at the expected time, cost and quality due to a certain event(s) (Zsidisin et al., 2004). Supply risk includes the risks associated with supplier selection, make or buy decisions, national and international sourcing and all the material movements from its origins to focal nodes in the supply chain. These risks affect the early stages of the production, which mean that they have chronic ramification on all the other parts of the supply chain. The large number of papers addressing the risks associated with supplier selection and evaluation indicates its importance. Some examples of papers addressing parts of supply risks include, quality risks (Talluri, Narasimhan, & Nair, 2006), supplier time tardiness (Talluri & Narasimhan, 2003), supplier capacity risks (Viswanadham & Samvedi, 2013), transportation and geographical distance risks (Chan & Kumar 2007), breakdown risks (Ruiz-Torres, Mahmoodi, & Zeng, 2013), financial risks (Lockamy & McCormack, 2010), service level risks (Chen & Wu, 2013), suppliers' responsiveness (Ho, Dey, and Lockström 2011) and level of supplier cooperation and integration risks (Chaudhuri, Mohanty, & Singh, 2013). These risks should be considered while selecting a supplier in order to minimize the supply chain disruptions that they might cause in the future.

Operational risk is the probability of occurrence of an event that will hinder the internal capability of the company to produce its products or services (Manuj & Mentzer, 2008). It includes the risks associated with the product manufacturing process, such as machines breakdowns and production delays. Operational risk stems from internal and external factors; for example, process design and level of variation are internal factor that affect the operational risk. On the other hand, the possibility of introducing new technology for production that replaces the current one is an external factor that affects operational risk. It can be noted that this type of risk should be considered while designing the production processes of the company to maintain its competitiveness.

Demand risk is the probability of occurrence of an event that might influence the number of order, order volume or orders' assortment placed by customers. Demand risks also include the risks associated with delivering the products from a focal node in the supply chain to the final customer. Inaccurate information received from the downstream supply chain is one of the sources of demand risks (Johnson, 2001). Other sources of demand risk include improper introduction of new products, degree of innovation in the introduced product (the higher the innovation the higher the risk as the company might over/under stock the product, which will cause significant losses), new products introduced by competitors and seasonality of the product.

As mentioned earlier supply chain risks can affect a part or the whole supply chain. Figure 1 shows the main risks associated with each part of the supply chain. It shows a logical spread of the risks across the supply chain, in which in the upstream risks are mainly supply risks and at the middle part of the supply chain, where the production takes place, it is mainly operational risks and as we move closer to the distributors and final customer it becomes more focused on demand risks. It also shows that security risks are being considered at all the stages of the supply chain. Although the Figure shows that each risk is concentrated in certain parts of the supply chain, it can be argued that there

[redacted]

Figure 1 : Risks spread across the supply chain (Mentzer, 2001)

supply chain risks are affected by each other and one risk in one part of the supply chain might amplify another risk in another part of the supply chain. For example, if the demand risks increased significantly due to a certain reason, this increase in demand will amplify the capacity risks at the suppliers' side. Figure 2 shows the interference between supply chain risks. It put forward some of the factors that contribute to different supply chain risks. It can be noted from the Figure that capacity and quality risks are being considered as components of both supply risks and operational risks. While transportation risk is a component of supply risks, operational risk and demand risks. It also shows that security is an overarching risk in which this risk must be considered carefully during all the stages the products goes through from its ore to the final customer. Regardless of the risk type and place in the supply chain, it can cause disruptions and serious problems to the material and/or information flow, which will lower the profitability of the supply chain. It is important in this context to know more about the impact of these disruptions to understand the effect of supply chain risks on its performance.

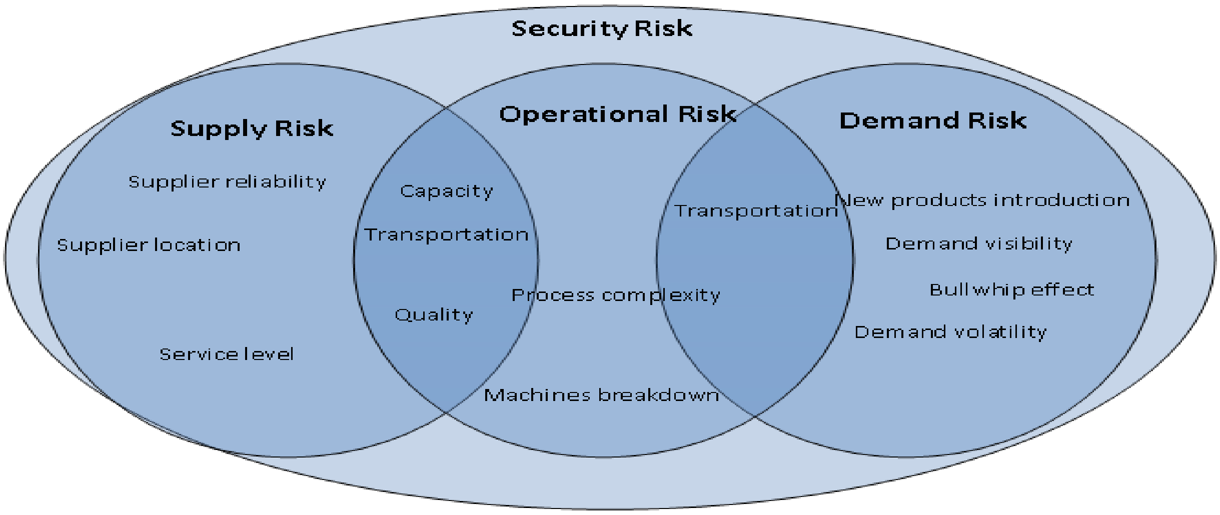

Figure 2 Risks overlap in the supply chain (source:author)

2.2-Supply Chain Disruptions

Supply chains disruption happens when an event prevents the flow of material from following its normal track and arriving at its planned time (Sevensson, 2000). In other words, disruptions are the undesired results associated with the supply chain risks. It might be at small scale due to minor reasons such as machine breakdown or it might happen at a large scale due to major events such as wars, unforeseen disasters , earthquakes, economy crises, strikes and biosecurity threats (Blackhurst *et al.*, 2005). These events in turn might lead to shutting down airports, ports and make the use of certain roads prohibitive. Furthermore, it might affect the communication infrastructure, which may slow down the material and information flow in the supply chain.

The costs associated with these disruptions are high and might have a long-lasting effect on the business performance. For example, in 2000 Ericson announced that it has lost 400 million Euros due to a disruption in its upstream supply chain, in which the material flow was disrupted by a fire in one of Philips semiconductor plants that was supplying Ericson with electronic chips (Chopra & Sodhi, 2004). Land Rover had to let go 1,400 employees because one of its suppliers announced bankruptcy

(Blackhurst et al., 2005). Furthermore, labour strikes in October 2002 led to shutting down 29 ports in America's west coast, which resulted in closing the manufacturing plant of New United Motor Manufacturing (Wilson, 2007). In 2011 Toyota's production capacity was dropped by 40,000 vehicles due to Japan's tsunami and the consequent nuclear crisis (Pettit, Croxton, & Fiksel, 2013). Computer manufacturers and Japanese car manufactures supply chains were disrupted by Thailand flooding in 2011 (Chopra & Sodhi, 2014).

The aforementioned examples shed some light on the severe impacts that a disruption event can cause to the supply chain members. However, not all disruption events lead to catastrophic losses so determining the severity of the disruption event is important to consider in the contingency plan. The impact of supply chain disruptions vary depending on the disruption scale, design of the affected supply chain and the supply chain ability to mitigate the risk and recover after it passes (Craighead et al., 2007). In the context of this research the addressed disruption event is port closure, the severity of the closure is dependent on the importance of the port, the infrastructure readiness, and the closing time. The closure of a major port with big capacity for a long period is more severe than closing a small port for a short time. Port capacity is an indicator of its importance to the logistical network so it is important to understand how port capacities are calculated as it is the main factor that will determine the severity of the disruption in our model.

2.3- Calculating Ports' Capacities

Globalization had boosted the number of international trade transactions, as customers started comparing products and services offered by suppliers from all around the world. This trend had in turn increased the total number of vessels of different types by more than 7000 vessels during the period from 2011 to 2016 (Merchant, 2016). Consequently, marine traffic during the same period has witnessed a constant growth that is expected to continue in to the future (Huang et al, 2016). This growth can cause congestion in ports, which will increase ship waiting times, costs of shipping and navigational risks. Therefore, it is necessary for ports officials to know the current capacities of their ports in order to develop plans to accommodate future growth.

Even though port capacity was defined in multiple published papers (e.g. Fan and Cao, 2000; De Weille & Ray, 1974), there is no globally accepted definition for this term. The definitions mentioned in the literature are influenced by the problem addressed by the particular authors, in which some authors focused on terminal capacity (Ligteringen and Velsink, 2012), bottlenecks of the port network (Fan and Cao, 2000), berth occupancy rate (De Weille & Ray, 1974) or other capacity dimensions. The relation between the elements of ports activities and their dependency on the rest of the infrastructure explains the invalidity of using only one of these dimensions as a port capacity indicator (Bellsolà Olba et al, 2015). For example, evaluating the port network capacity depending on bottlenecks can be misleading as the bottlenecks might be shifting from one point to another in the network when handling different kind of ships. Accordingly, it is important to study the factors that need to be considered during the process of evaluating port capacity.

The dimensions of port capacity can be categorized into two main groups, physical factors and institutional factors (Bassan, 2007). Physical factors include, the size of container yard, availability of inland waterways, number of gates and berths, cranes and all the other infrastructural facilities in the port (Islama & Olsena, 2011). Institutional factors include regulations and labour related issues such as skill levels, working hours and safety rules. Even though it is hard to quantify institutional dimension of port capacity, it is important to consider its impact on the port throughput. Taking the previously mentioned points in mind, port capacity can be defined as the maximum number of ships of a given fleet that a port can handle using its current infrastructure and resources, under a certain demand rate and traffic composition during a certain period of time, while fulfilling its service time promise and satisfying safety requirements (Fan and Cao, 2000).

Measuring port capacity can be done by analyzing historical data or by developing a model that simulates the ports operations. Bellsolà Olba et al. (2015) developed a model to quantify port capacity using simulation. In their model they embedded the different ports operations and run the model under different operational conditions to evaluate its outflow, service time, waiting time and other performance and capacity indicators. They conclude that by plotting outflow as a function of the ratio of waiting time to service time under different demand rates the ratio starts to increase with a certain slope until it reaches an inflection point. After this point, the outflow starts stabilize and the ratio continue to increase. This inflection point represents the transition point in the port status from normal to congested, the authors emphasized that this point is representative of the Port Traffic Network Capacity (PNTC). Including waiting time to service time ratio makes this way of measuring port capacity representative of both institutional and physical factors of port capacity, that is because of the dependency of service time on infrastructure, policies and labor. However, it can be argued that this indicator does represent accurately the amount of cargo handled. Therefore, this indicator must be triangulated with other indicators in' order to quantify the port capacity in general units (such as Twenty Equivalent Units TEUs) rather than the number of vessels handled.

Using historical data of the annually handled volume provide some insight on the port capacity but it will not provide a fully reliable measure as it is not guaranteed that the port was operating at its full capacity. After determining the disruption severity (represented by port capacity in this research), the decision makers should determine their course of action to mitigate the effect of this event. In the next section a risk mitigation framework will be discussed to understand the mechanism of responding to supply chain risks.

2.4-Supply Chain Risk Mitigation

Academics had developed some conceptual frameworks for risk mitigation. Figure (4) is a framework suggested by Ho et al. (2015). In this framework risks are divided into macro and micro risks. Macro risks are the ones with significant impact on the supply chain and they are grouped into two groups; (a) manmade events such as wars and (b) natural events such as earthquakes, biosecurity threats and tsunamis. Micro risks also have significant impact on supply chain performance but it is relatively lower than macro risks impact. Micro risks include supply risks, demand risks, infrastructural risks and manufacturing risks. The Figure also shows that appropriate information, financial, and transportation systems must be in place for the supply chain to function properly. The mitigation process starts by identifying a risk and categorising it on one of the previously mentioned categories then assessing the impact of that risk , after that developing or selecting a mitigation strategy and the process is closed by continuing to monitor the supply chain to detect other risks.

[redacted]

Figure 3 General supply chain risk mitigation framework, adopted from Ho et al. (2015).

Mitigation strategies include avoidance, postponement, transferring /sharing risk, hedging and control. For further details of these strategies readers are referred to Manuj and Mentzer (2008). Regardless of the mitigation strategy, responding to risks requires making important decisions in a short period of time. However, it is hard to make the right decision at a short notice to respond to a sudden undesired event. Accordingly, there is a need for a tool that function as a decision support system to allow the decision makers to make their decisions rapidly. Thus, it is important to understand the concept of decision support systems that serve to fulfil that objective.

2.5- Decision Support Systems (DSS)

Improving supply chain performance means being able to make better decisions in shorter time periods to be more responsive to supply chain risks and market changes. DSS is sought after to present solutions for problems in the supply chain from tactical to strategic level (Tako & Robinson, 2012). Researchers have used different modelling tools to simulate systems under different conditions to prepare these system for the changes that might happen in their environments and accordingly improving their responsiveness and resilience. These modelling tools include linear programing

(Santoso et al., 2005), fuzzy modelling (Petrovic et al., 1998), System Dynamics (SD) (Angerhofer & Angelides, 2000), Discrete Event Simulation (DES) (Terzi & Cavalieri, 2004) and hybrid models (Umeda & Zhang, 2006) among other tools (Tomlin, 2006; Kim et.al, 2011). Some researchers focused on the aggregate level analysis (e.g. Meepetchdee & Shah, 2007; Cakravastia & Diawati, 1999; Towill, 1996), while other researches addressed the micro level analysis by isolating a certain part of the supply chain to be studied in depth (e.g. Legato & Mazza, 2001; Cheng & Duran, 2004). The use of linear programing in the aggregate level analysis (e.g. Meepetchdee & Shah 2007; Santoso et al., 2005) and the use of discrete event simulation in the operational level analysis (e.g. Terzi & Cavalieri, 2004; Legato & Mazza, 2001) indicated their effectiveness in the corresponding level of analysis. The integration of these tools in one decision support system will allow that system to capture both strategic and operational considerations in the decision-making process in order to produce more reliable recommendations.

DES emerged in the 1950s and in that time, according to Robinson (2005), it was developed in machine codes. He adds that the introduction of programming languages and high speed PCs in the 1960s founded a base for breakthroughs in the simulation field and allowed for the development of specialist simulation software such as GPSS, SIMSCRIPT and SIMULA. Hurrion (1976) addressed the potentials of the new simulation programming languages in regards to their ability to use animation and be both more visual and interactive after the introduction of microcomputers in the 1970s. These revolutionary improvements were the foundation of more complicated simulation software packages in the next three decades. The first Visual Interactive Simulation (VIS) program is SEEWHY, introduced in 1979. The continuous development of computers in the 1990s continued to support the commonality of VIS and led to the introduction of low cost VIS packages such as EXTEND (Robinson, 2005). After these VIS packages were introduced users demanded simulation optimisation solutions, which were later created by the VIS vendor such as SimRunner for ProModel (Harrel & Price, 2003). From the previous discussion, it can be noted that a lot of work had been done on VIS packages to make them more reliable as a DSS, which explains their extensive use now.

Linear programing and DES will be used in this research as they have been proven to be effective modelling tools in many fields. Linear programing is extensively used in the supply chain field (Kumar et al., 2006). It is generally used for optimising certain processes or functions in the supply chain such as storage cost minimization (Anthony & Buffa , 1977) and vendor selection (Moore, & Fearon.1989). DES was employed in healthcare field (Jacobson et al., 2006), manufacturing systems costing (Spedding & Sun, 1999) and supply chain (Schmitt & Singh, 2009). In the supply chain field, DES is more commonly used at the tactical and operational level such as distribution, sequencing production activities, supply chain optimisation and transportation planning. Furthermore, sometimes it is used in conjunction with SD at the strategic level (Tako & Robinson, 2012). Articles published in this field accordingly validate its success in tackling the uncertain environment of the supply chain (Schmitt & Singh, 2009; Petrovic et. al, 1998; Spedding & Sun, 1999).

Meepetchdee and Shah (2007) tried to define the concept of logistical network resilience and suggested that resilience should be considered by decision makers during the logistical network design stage. In their work, they developed a mathematical model using MILP with an objective function minimizing the cost while maintaining a minimum level of resilience to obtain a logistical network configuration that satisfy the prescribed requirements. The model is designed to help decision makers to determine the number of distribution centres to be established in order to maintain a certain level of resilience. It was also an effective tool for assigning customers to warehouses and establishing contingency links between the customers and the other warehouses to determine which warehouse will be assigned to serve each customer should a disruption occur. However, the work of Meepetchdee and Shah (2007) is simplified and does not address the details of the constraints that might be faced in the logistical network. It only provides a bird eye configuration of the logistical network by locating the facilities in certain locations relative to the customers' locations. Furthermore, the proposed model is supposed to be used during the design stage and assumes that the decision maker is in control of all the supply chain facilities, which is only true in limited cases. Supply chains usually involve multiple independent organizations that already have established facilities. The proposed model cannot be used to improve their logistical network resilience without building new facilities. However, with some modification the model might be used to help decision makers to establish contingency links between customers and the available warehouses.

Legato and Mazza (2001) used discrete event simulation to model the container terminal activities (i.e. arrival, berthing and departure processes) at Gioia Tauro container terminal in Italy. They used the model to spot the congestion points along the processes that vessels go through from arrival to departure. The simulation model was proposed to function as a berth planning system to help the berth planner in the decision-making process at a marine container terminal. The berth planning system objective is to allocate the constrained berth space to the incoming ships. The system takes into consideration while allocating the slots on the berths to the vessels, the location of the containers in the yard and the penalty of delaying the berthing time of a ship.

Adding the penalty and the location of the vessel's container in the yard relative to the allocated berth slot to the formula of decision-making makes the process harder to the berth planner, as the planner will have to compromise between efficiency and cost that might be incurred due to any delays in berthing. The approach that they have used allowed them to study the process activities in depth and identify the potential bottlenecks. Accordingly, the model was an effective tool to identify the improvement opportunities in the process flow and for providing some insights on whether activities capacities should be increased or reallocating resources in a more efficient way will resolve the bottleneck. However, the proposed system is only limited to the operations taking place at the terminal. The model does not encompass the bigger picture that includes the interaction between the terminal activities and other activities taking place at the port and the extended supply chain.

Cheng and Duran (2004) developed a decision support system using discrete event simulation in conjunction with stochastic optimal control to optimize an inventory and transportation system in the oil transportation field. In the conclusion of their research they propose a new system that offers better control over the inventory and distribution process compared to the current one. However, they were unable to find the global optimal system due to computational difficulties. DSSs were also used for supply chain re-engineering (Cakravastia & Diawati, 1999; Towill, 1996), inventory management (Sterman, 1989) and international supply chain management (Akkermans et al., 1999).

The results produced using these models are analyzed using different approaches depending on the objective of the decision support system; for example, Lean thinking and value stream mapping can be used if the objective was to eliminate waste (Wee & Wu, 2009) (Seth & Gupta, 2005). On the other hand, the theory of constraints process can be used if the objective was to maximize the throughput by identifying and exploiting the bottlenecks in the system being studied (Goldratt, 1990). The extensive use of DSS for different reasons using various modelling and analyzing tools demonstrates the positive impact of having such systems as a part of the decision-making process in a business.

2.6- Theory of Constraints

Eliyahu Goldratt introduced the Theory Of Constraints TOC in his book The Goal, which was published in 1984. The basic principle that TOC was built on is the limitation concept, regardless of the limitation type whether it was in the resources, policies, key performance indicators, or in the market itself. Goldratt (1990) defines a constraint as anything that restricts the company from accomplishing its goal. TOC proposes that, in order to get an improvement that affects the whole system, improvement efforts must be focused on the constraint within the system.

Over the years TOC was integrated in different managerial areas; such as Project Management (Goldratt, 1997); Integrated Management Systems (Goldratt et al., 2000); Supply Chain Management (Goldratt, 2009). In addition, Watson et al (2007) state that TOC was used in various governmental agencies and mass production facilities such as NASA and Ford. This, according to Goldratt (2009), has provided a proof of the ability of TOC to perform as an alternative approach for production systems management. The thinking process (TP) of TOC is a method that uses a set of tools used individually or collectively to spot , investigate and solve problems (Kim et al. 2008). Cox and Schleier (2010) add that TP-TOC enable the company to identify the main problems and to create a win-win outcome of these problems, in addition to smoothing the way for the implementation of the improvements.

Musa et al. (2005) state that TP fundamentally uses effect-cause-effect relationships and identify the rationale behind the detected problem, which means that it answers why the problem is there rather than how it happens. Pereira Librelato et al. (2014) add that during the consideration of the relationships between the parts of the process an assumption must be kept in mind, that is all the undesired effects are a result of a lower number of causes. Cox and Schleier (2010) summarize applying the methodology of TP-TOC by answering the following three questions using a suggested tool or set of tools:

- What to change? to answer this question a technique called current realty tree (CRT) is used. The CRT aims at identifying the main problem(s) in the system by using a visual representation of the undesired effects and their causes, which are usually lower in number.
- What to change into? evaporating the cloud EC is used to answer this question. EC aims at expressing the assumptions of the main problem to find solutions.
- How to make the change? three tools are used in this question, namely future realty tree (FRT), prerequisites tree (PRT), and transition tree (TT). FRT aims at identifying the advantages, disadvantages, and underlying effects of the proposed solutions on other parts of the process in order to ensure its effectiveness. PRT aims at dividing the solution into phases and set intermediate objectives to be achieved to ensure proper application of the solutions. TT aims at setting the action plan objective that finds a solution that eliminates the main problem that was identified in the previous steps.

In summery TP-TOC deduce the reasons of the undesired effects and then helps in figuring out how to fix it. Goldratt (2008) mention that the basic assumption of CRT is that complex systems have inherent simplicity, which means that the number of real causes is fewer than the number of all the undesired effects they cause. Even though, the objective of TOC implementation might be more relevant to the system throughput, having a balanced flow of materials in the supply chain reduce its vulnerability to disruptions. This makes its use as a part of a decision support system more desirable, as it helps in increasing throughput and improving resilience at the same time. The use of TOC will allow the decision support system to identify the bottlenecks and the improvement opportunities in the process, which will allow it to present impactful recommendations. Consequently, this integration would also increase the moderating effect of the DSS on the impact of supply chain risks.

2.7- DSS Moderating Effect on the Impact of Supply Chain Risks.

Based on the literature review, this research proposes a tool that functions as a decision support system to help policy makers and practitioners to moderate the effect of supply chain risk. Knowing that this research is directed towards an audience in governmental and commercial sectors, the different perspectives of the target audiences must be considered. Figure 4 shows the interaction between exogenous risks, capacity risks and transportation risks. In this context capacity risks should be thought of from a governmental point of view, accordingly, it is related to the facilities and services that governments offer. On the other hand, transportation risks are approached from a commercial perspective, in which it includes the inbound and outbound movement of the products and materials across the supply chain. Exogenous risks are the risks that are hard or impossible to control, such as tsunamis, earthquakes, bio security threats, and other natural and manmade disasters.

The Figure shows that exogenous risks directly increase the severity of capacity and transportation risks. The increase in capacity risk is then reflected on the infrastructure capabilities of the affected country, which in turns amplify the transportation risks of the companies using that country’s infrastructure. Having a decision support system, which is continuously updated by information about the status of the infrastructure, will help both policy makers and practitioners to respond to such events in a short time to mitigate or lower the impact of these events.

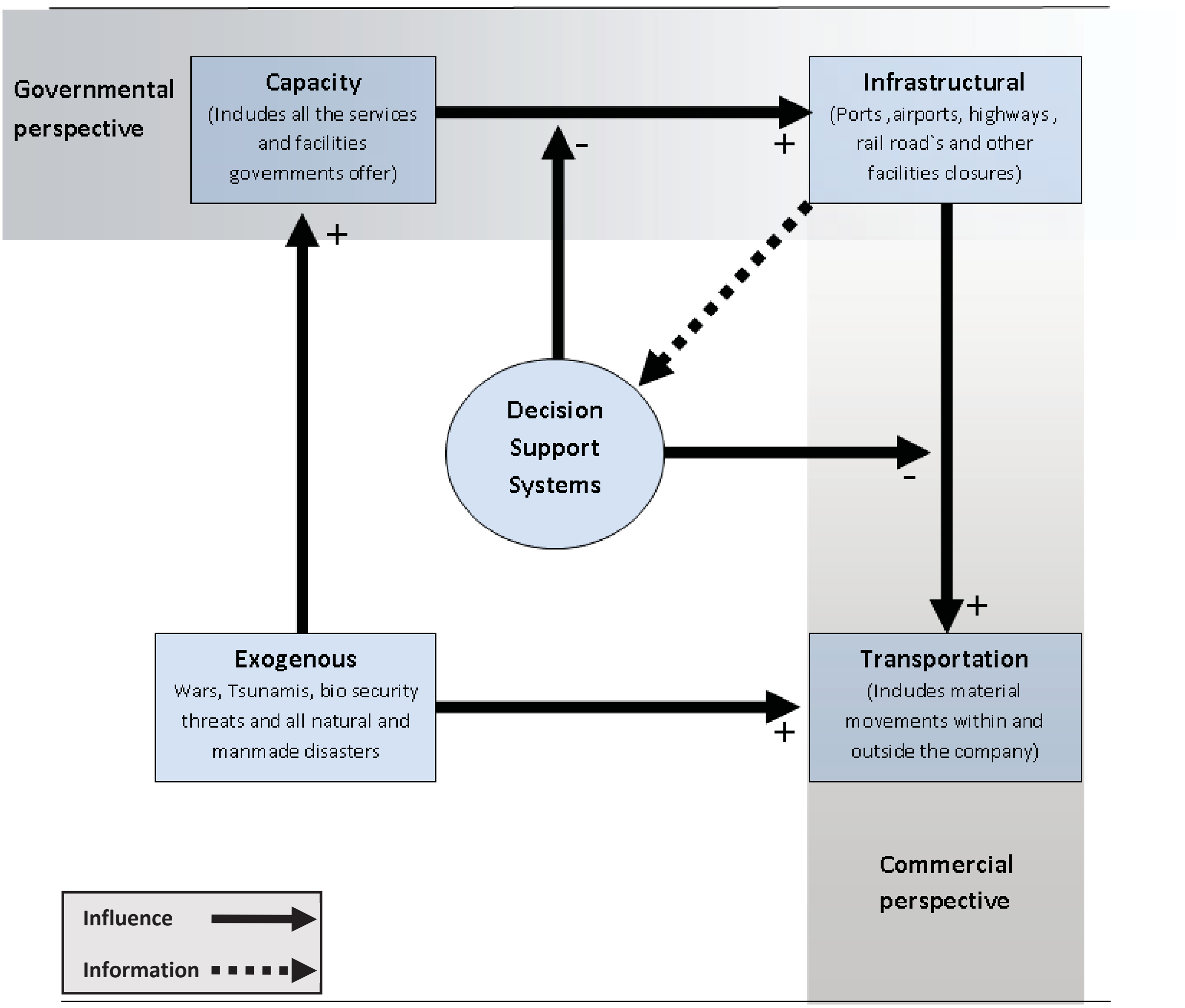

Figure 4 DSS moderating effect on the impact of exogenous risks on transportation and capacity risks (source: author)

2.8- Research Gap

As mentioned earlier, supply chain risk is a well-established field of study with abundant publications addressing different topics in this discipline. Supply chain risks identification, mitigation frameworks, quantitative and qualitative studies for risk mitigation are among the topics that captured the attention of academics and practitioners in the past three decades. However, some risks including transportation risks have not been addressed sufficiently in the literature (Manuj & Mentzer, 2008). Furthermore, according to Brandon-Jones, et al. (2014) there is alack in empirical research addressing supply chain risks. Ho et al. (2015) reviewed 226 articles in the supply chain risk, of which only 1 paper was addressing transportation risks and 6 addressing macro risks. It can be concluded that there is consensus in the literature that transportation and macro risks still need to be researched more. This research will help bridging two of these research gaps as it is going to address the transportation risks due to bio security threats, which is considered a macro risk. It will investigate the impact of a macro risk and its ramification on the logistical network and try to present a tool for mitigating the effect of this risk type.

2.9- Literature Review Summary

Supply chain risk is the probability and the effect of any unforeseeable events and circumstances that might impair the performance of any part of the supply chain at the tactical, operational or strategic level (Tako & Robinson, 2012; Schmitt & Singh, 2009; Spedding & Sun, 1999). Supply chain risk types include supply, operational, demand, information, security, policy, competitive and macro risks, it is also possible to categorize these risks in a number of different way using different criteria (Manuj & Mentzer, 2008). These risks are broad and other risks are considered inherent to them such as transportation and capacity risks. These risks could disrupt the material flow across the supply chain causing the supply chain members to incur significant losses. The impact of supply chain disruptions vary depending on the disruption scale, design of the affected supply chain and the supply chain ability to mitigate the risk and recover after it passes (Craighead et al., 2007). It is also worth mentioning that although supply chain risk identification, assessment, mitigation and monitoring are all addressed in the literature, as mentioned earlier there are still some gaps that need to be studied. Researchers developed a number of risk mitigation frameworks, however, the empirical studies on these frameworks are still not enough to prove their validity (Brandon-Jones, et. al., 2014).

Regardless of the risk mitigation framework being employed, companies and/or governments need to respond to the events that disrupt their supply chains shortly after they happen. Decision support systems are being used to generate the best course of action to be followed during the situation in hand. These systems, which are continuously updated with the current status of the problem in hand, help companies and/or governments to make the decisions that is in the best interest for their organizations. In order to achieve this, decision support systems use different modelling tools to study the system of interest and to develop the best possible solution. These tools include fuzzy modelling (Petrovic et al., 1998), discrete event simulation (Terzi & Cavalieri, 2004), system dynamics (Angerhofer & Angelides, 2000) and some other tools. The results produced using these models are analyzed using different approaches depending on the objective of the decision support system; for example, lean thinking and value stream mapping can be used if the objective was to eliminate waste (Wee & Wu, 2009) (Seth & Gupta, 2005). On the other hand, theory of constraints thinking process can be used if the objective was to maximize the throughput by identifying and exploiting the bottlenecks in the system being studied (Goldratt, 1990). The extensive use of DSS for different reasons using various modelling and analyzing tools demonstrates the positive impact of having such systems as a part of the decision-making process in a business.

Chapter 3: Research Objective and Methodology

3.1- Research Objective

Forestry industry is a major contributor to New Zealand's economy, it is the third largest export sector, constitute 3.2% of New Zealand’s GDP and it has provided more than 18000 jobs in 2014 (NZFOA, 2014). Forest ownership in New Zealand is divided between international Timber Investment Management Organization (TIMO’s) and locals. In 2013, New Zealand dominated more than 20% of the world’s softwood log trade and became the world largest exporter of softwood log (Scoop, 2014). The log industry is a large part of New Zealand’s exports comprising more than 16 million m^3 of logs in exports in 2014 (see Figure 5). New Zealand continued to be the world largest exporter of softwood logs in 2016 followed by Russia and the US, the exports of these three countries combined make up almost 50% of the total traded logs in the world (Scoop, 2016).

Logs are exported from New Zealand via multiple ports. Figure 5 shows the amounts of exported logs and sawn timber in cubic meters from all New Zealand’s different ports. It is noted that Tauranga port has the largest share of exports followed by Whangarei port and then Auckland port. China is the main customer of New Zealand’s logs and New Zealand is competing with other global competitors in the field for a larger share of this market. Figure 6 shows the largest round wood trade channels in the world in 2014 and confirms that New Zealand’s export log trade channel with china is the largest of its kind in the world, accounting for 13.3 million m^3 of exports in 2014. Furthermore, New Zealand had exported 12 million m^3 of logs to China in 2013 and around 10 million m^3 in 2015 (Scoop, 2016). This confirms the importance of New Zealand as a major player in the global log trade and the importance of the log industry to New Zealand’s economy.

It is important to mention that log prices are volatile, during the period 2012-2016 the price of one cubic meter of log fluctuated between 82 USD and 130 USD (Scoop, 2016). This volatility increases the risk in this supply chain, which necessitates the development of contingency plans to protect this strategic sector in New Zealand.

Port of Loading	Sawn Timber	Logs	Total
			Quantity m³
Whangarei	3,501	2,588,534	2,592,035
Auckland	210,529	158,894	369,423
Tauranga	769,189	5,844,015	6,613,204
Gisborne	1,274	2,259,367	2,260,641
New Plymouth	-	231,615	231,615
Napier	340,827	1,118,670	1,459,497
Wellington	4,250	818,518	822,768
Nelson	88,712	585,030	673,742
Picton	1,624	642,921	644,545
Christchurch	110,136	676,730	786,866
Timaru	878	457,279	458,157
Dunedin	62,197	808,559	870,756
Invercargill	110,050	395,503	505,553
Total	**1,703,168**	**16,585,635**	**18,288,803**

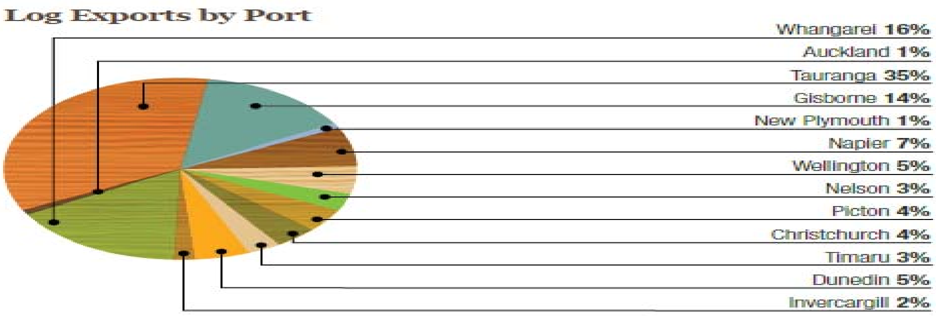

Figure 5 Logs exports per port in New Zealand, adopted from (NZFOA, 2014).

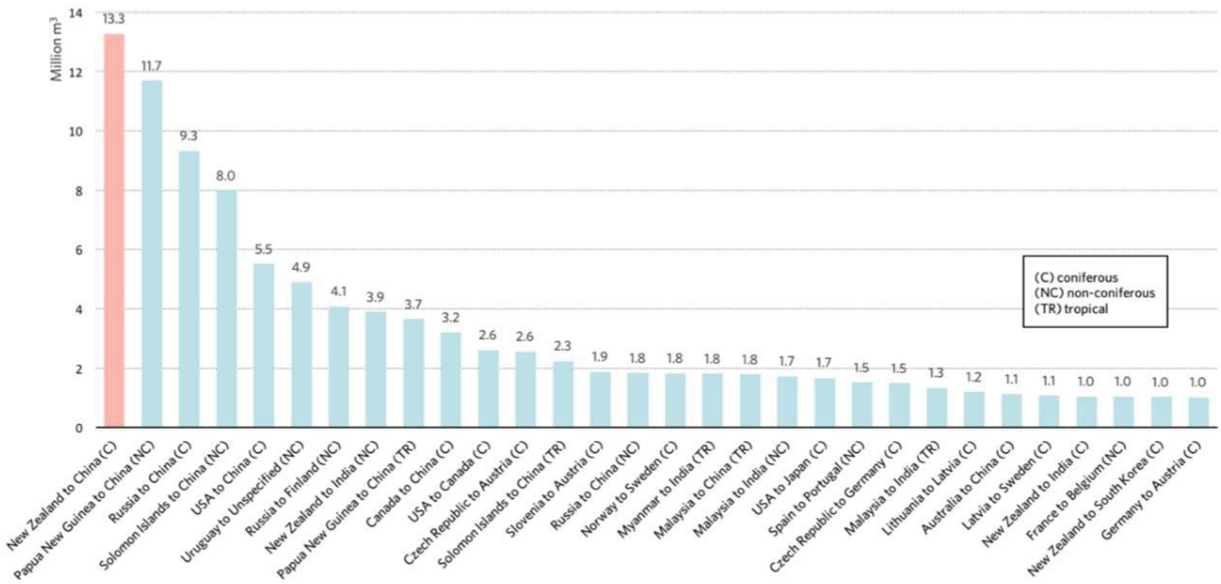

Figure 6 World largest round wood trade channels in 2014 Adopted from Bezuidenhout., Pusztai, Christians,& Wilson, (2016).

This research is an industry sector study addressing the export log industry in New Zealand. More specifically, it is addressing transportation risks associated with the logs exporting under different port closure scenarios. The objective of this research is to provide the building bricks of a tool that functions as a decision support system to help practitioners in the log industry deciding their course of action in response to sudden major events that might disrupt their supply chains. The resulting decision support system and recommendations of this research aim at improving the resilience of the log supply chains in New Zealand and the logistical network in general. Hopefully, the resulting DSS will be capable of producing recommendations that would increase the profitability of logs supply chain and make it more reliable and resilient under multiple disruption scenarios. However, it should be emphasized that this study aimed at demonstrating the capability of a combined modelling approach, as opposed to capturing the detailed industry attributes. The systems simulated in this study are not necessarily representative of the real world.

The need for decision support systems to improve the resilience of New Zealand's log supply chain against disruptions resulting from biosecurity threats had prompted this research. A linear program was created to simulate New Zealand's logistical network under different port closure scenarios. The objective function of the linear program aimed at optimizing the allocation of logs harvested in different forests across the country to available ports in order to increase the supply chain profitability. This model provides an aggregate view on the country's logistical network and identify some focal ports that are interesting to be studied in depth. The model findings were used as the starting point of the second part of the research, in which a certain region was selected and simulated using Deseret Event Simulation (DES) to capture the fine details of that region's logistical network. The primary questions that this research attempts to answer are:

1. What is the impact of a port closure on New Zealand's logistical network?

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2. What is the best course of actions to be followed when any of the ports is closed due to bio security threats in New Zealand?

The first question will investigate and clarify the ramifications of a port closure on the logistical network and its impact on the companies' supply chains. The second question aims at producing a response action plan framework to mitigate the impact of the disruption. The objective of this research is to provide a tool for practitioners that allow them to decide their course of action in response to sudden events that might disrupt their supply chains. The resulting DSS and recommendations of this research will improve the resilience of the log supply chain to the different risks that might be encountered in the future. The aim of answering the above-mentioned questions is to reduce the delays in the log supply chain and to make it more reliable and resilient, which would hopefully improve the supply chain profitability.

3.2- Epistemological and Ontological Standing

Philosophical Epistemological and ontological positions should be clearly defined at the early stages of starting a research as it is a major contributor in selecting the type of questions to be asked and the methods to be followed in the research project.

3.2.1- Ontological Positions

Ontology deals with the question of whether social entities should be studied as and considered to have an objective reality that is not affected by the actors (objectivists' perspective), or their reality is being constructed by the actors' actions, experiences and perspectives in that social entity (constructionists' perspective) (Bryman & Bell, 2011)..

Objectivism is ontological position proposes that there is an external fact associated with any social phenomena that cannot be affected by the actions and experiences of the people participating in that phenomena (Bryman & Bell, 2011). For example, objectivism implies that if we study a culture of certain country or an organization, we will assume that the culture or the organization possess predetermined and accepted sets of rules and procedures that the participants follow. Furthermore, it assumes that whoever fail to confirm to these rules will be undermined or eliminated from that social entity. It can be concluded that ,from an objectivist perspective, participants are not contributing to the set of beliefs or procedures within the social entity rather they are only doing what they are expected to do because that social entity and accepted procedures are restraining them from adding to that culture or organization

Constructionisim is an ontological position that opposes objectivism. It assumes that accepted beliefs, procedures within a culture or an organization are continuously being changed by either terminating old agreements or creating new ones according to the actors' convenience within the social entity (Bryman & Bell, 2011). From this perspective actors are the main contributor to build the social phenomena and accordingly non-confirming actors will not be eliminated as they are expected to be adding to the set of beliefs and procedures of their social entity. It also worth mentioning that authors who support this position such as Strauss and Becker, as cited by Bryman and Bell (2011), say that this approach should not be pushed to the extreme and they accept the pre-existence of the social entity being studied. Table 2 provides a summary of the main differences between constructionism and objectivism.

[redacted]

Table 2 Comparison between objectivism and Constructionism, adopted from Bryman and Bell (2011)

3.2.2- Epistemological Positions

Epistemological position deals with the question of what is deemed to be an accepTable or true knowledge in a certain field of study (Bryman & Bell, 2011). It defines the researcher's perspective towards the research topic, it particularly addresses the way that social science should be tackled. In this context, there are two epistemological position positivism and interpretivism. These positions contradict each other on their approach of understanding social science, in which positivism suggest studying it in a similar way to natural science and interpretivism suggests that the principles of studying natural science cannot be copied to studying social science .

Positivism is an epistemological position in which it assumes that knowledge is accepted only if it is observable and measurable (Bryman & Bell, 2011).It proposes studying social sciences the same way natural sciences are being studied, in which reality is not being affected by the perspective, behaviour or culture of the researcher or the participant (Mertens, 2005). In other words, reality is objective by itself regardless of who is studying it, which complement objectivists' ontological positions. Positivist position is usually associated with deductive type of relation between research and theory, in which a hypothesis is developed according to a theory and a research is conducted to test the validity of that theory by rejecting or failing to reject the hypothesis.

Interpretivism is a contradicting epistemological position to positivism. It suggests that the study of social science should be totally different from natural science, in which reality is subjective to the researcher's and participants' perspective and past experiences as they are continuously affecting and being affected by the events in their surroundings, which is compatible with interpretivist ontology. This means that studying such a field can only be done by understanding reality from the perspective of the people within that environment being studied (Bryman & Bell, 2011). The results of researches with such type of epistemological position are mostly new theories rather than validating existing ones, which is the usual case in positivists' researches. This type of research is called inductive research in which the major goal of the research is to introduce a new theory.

From the previous discussion, it can be noted that positivism and interpretivism differs in their approach to social science, effect of the actors, and research outcomes among other differences. Table 3 provides a brief summary of the comparison between the two positions. It can be concluded that each position possesses some uniqueness and have its own contribution to the body of knowledge. However, it can be argued that the results coming from a research with a positivist position are more solid and reliable because they are measurable and repeatable. It also worth mentioning that the difference between positivism and interptivisim is not as straight forward as it is being presented here and it has further complications to be studied (Bryman & Bell, 2011). For example, researches with interpretivist epistemological position might be conducted to test a theory rather than creating new one. However, the below comparison is just a topical one to clarify the uniqueness of each position.

[redacted]

Table 3 Comparison between positivism and interpertivisim, adopted from Bryman and Bell (2011)

3.2.3- Researcher's Ontological and Epistemological Positions

I believe that an objectivist ontological position and a positivist perspective provide an excellent way for studying social sciences. As these positions can provide the body of knowledge of the field being studied with tangible, repeatable and measurable results that can be generalized and employed in different areas using reliable statistical tools. This research is investigating supply chain risk mitigation in order to improve performance and reduce costs through collecting some data about the parameters being considered such as costs and time delays. So it can be noted that the objects being studied possess a reality that transcend the participants of the system. As such the completion of this research will support the objectivist and positivist positions' approach of studying social science by providing outcomes that can be measured and repeated in a part of the social science field.

3.3- Appraisal of Different Research Methodologies

Research methodology is the strategy that defines the general orientation that will govern the research project. Mainly there are two research methodologies quantitative and qualitative, a mixed methodology from both quantitative and qualitative methodologies might be suggested as a third type. It is necessary to differentiate between quantitative and qualitative methodologies as it helps in categorizing the various research methods employed in the business research field (Bryman & Bell, 2011).

Quantitative research methodologies are the methodologies that rely heavily on quantification in data gathering and analysis (Bryman & Bell,2011). Researches that use such methodology usually possess a positivist epistemological position, which in turns mostly related to deductive type of research and objectivist ontological perspective. The deductive nature of quantitative research necessitates the need for data collection for a predetermined set of variables according to a well-defined procedure in order to test the hypothesis. Statistical tools are used after that to analyze and generalize the research results. It worth mentioning that it is also accepTable in a quantitative research to collect some narrative data, however, during the analysis it will be transformed into numbers to be quantified. The main drawback of this type of methodologies is that it is almost impossible to articulate all the variables in the real word within the experiment being conducted to test the hypothesis (Wienclaw, 2015). Consequently, researchers are usually forced to ignore some of the factors and focus on a limited number of them during their experiments.

Qualitative research methodologies are the methodologies that rely mainly on words and perspectives of actors and usually uses interactive techniques that involves the researcher and the actors in data gathering and analysis (Bryman & Bell, 2011). Researches that use such methodology usually possess a interpretivist epistemological position, which in turns mostly related to inductive type of research and constructionist ontological perspective. The inductive nature of qualitative research makes having a defined procedure prohibitive, as the aim of the research is to explore, so it is hard to predict where the researcher will end up with his/her research. Accordingly, data collection is done on an ad hoc basis to cope up with the development of the research as it progresses. The techniques used for data gathering in this type of researches enable the participants to share their feelings, experiences and perspectives an example of such techniques is interviews. Some of the limitation of this type of methodologies is that it is hard to include all the questions that the researcher need in an interview or a survey and the reliability of the participants' answers might be questioned as they might lie or not be motivated to participate sincerely in the research (Wienclaw, 2015). Table 4 summarises the previous discussion of the difference between qualitative and quantitative methodologies.

[redacted]

Table 4 Comparison between quantitative and qualitative methodologies, adopted from Bryman and Bell (2011) and Neuman (2006)

This research is an industry sector study addressing the log industry's supply chain in New Zealand. The research is a cross-sectional study as the data used will be collected at the time of conducting the research and before. In the context of this research the structure will be formal, as certain parameters will be defined and they will be measured according to a clear procedure. Linear programing and simulation will be used as the main analytical tools, in which there is some control over the variables in the system being studied. Thus, a quantitative research methodology will be perfectly aligned with the procedure and the objective of this research. Table 5 summarises the researcher's ontological and epistemological positions, methodology employed and other research design considerations.

CRITERIA	RESEARCH POSITION
PURPOSE	Causal
THEORY AND RESEARCH	Deductive
EPISTEMOLOGY	Positivist
ONTOLOGY	Objectivist
METHODOLOGY	Quantitative
DATA COLLECTION METHOD	Monitoring
PARTICIPANT PERCEPTIONS	Actual Routine
TIME FRAME	Cross-sectional
VARIABLE CONTROL	Experimental
SCOPE	Industry Sector Study
STRUCTURE	Formal
RESEARCH ENVIRONMENT	Simulation

Table 5 Research design consideration

3.4- Data Collection and Analysis

In the context of this research, the concept operationalization is shown in Table 6 (Ghauri & Grønhaug, 2005). The research adopts the idea that Decision Support Systems (DSS) have a positive impact on the logs' supply chain resilience. This impact can be measured by the profit increase and cost reduction after employing the DSS. The visualization of this improvement will be apparent in the field by the improved port utilization and the lowered level of inventory at the companies' side (in the form of logs in the forests).

OPERATIONALIZATION	RESEARCH CONCEPT
CONCEPT	DSS improve the responsiveness of logs' supply chain to ports closure due to bio security threats
MEASURES	Cost and net profit
INDICATORS	Quantity of logs until the closed port open again, and ports utilization.

Table 6 Research Concept Operationalization

3.4.1- Data Collection

Scion was used as the main data source for this research in conjunction with other government data as well as export and forest description data. Scion is a specialized research institution in the forestry, wood product and other related industries. Scion is a New Zealand crown research institute that has a long history dating back to the 1800s ("About Scion", 2009). Its current headquarter was a forest nursery for a huge governmental afforestation program in the 1800s. Scion started research on its current site in 1947 under a different name as a government forest experimental station. Now the research institute is the leading crown research institute in several areas including forestry bio security, risk management and mitigation ("About Scion", 2009) and is one of the largest forestry research institute in the world. Accordingly, Scion is experienced in the field and is a credible source of information for the forestry industry. The data collected from the institute will be referred to as (Scion, 2016) or (Scion, 2017) from hereafter.

Data collection was done in two phases, the first phase relied on historical data concerning the average volumes handled by all the ports included in the study to get some insight on their capacities. This data was collected for the same period for all the ports. Logistical network capacities and distances travelled by trucks or trains to transport logs from the different districts in the country to each port along with the expected costs were gathered in the during the first phase of data collection. Interviews and road network data-bases were used as a collection method for this phase. In the second phase, the collected data was focused on the details of the activities taking place in different parts in the logistical network. The data was collected by interviewing experts from Scion, the national rail line Kiwi Rail, and other experts in the industry. Interviews covered: current status clarification; available options companies have during these events including routes followed; the costs and time delays associated with these options; details about the activities taking place on different parts of the logistical network and logistical network facilities' capacities. Table 7 summarizes the collected data with its corresponding source and the phase in which it was collected. Data collected in phase1 is the data that were used to build the linear program, while data collected in phase 2 is the data that was used to build the simulation model.

DATA TYPE	DATA SOURCE	PHASE 1	PHASE 2
ROAD DISTANCES	Google Maps	✓	✓
RAIL DISTANCES	Scion and Google Maps	✓	✓

FORESTS DESCRIPTION	Ministry of Primary Industries (MPI) and New Zealand Forest Owners Association (NZFOA)	✓	
LOG TRANSPORT, PORT, AND MISCELLANEOUS COSTS	Scion	✓	
LOG EXPORTS HISTORY BY PORT	Ministry of Primary Industries (MPI)	✓	
TIME NEEDED FOR EXECUTING HANDLING ACTIVITIES	C3 (a product handling company operating in multiple ports in New Zealand), Kiwi Rail and Scion		✓
LOGISTICAL NETWORK FACILITIES AND THEIR CAPACITIES	Council of Log Transport Safety, Scion, C3 and Kiwi Rail	✓	✓

Table 7 Data Collection Phases

3.4.2- Sampling

Two sampling techniques will be used in the two data collection phases: cluster sampling and purposive sampling (David &Sutton, 2011). The first phase data sampling was carried out using cluster sampling in which each of the ports included will be considered as an independent region. In the second phase, purposive sampling was employed. Researcher’s judgment was used for the selection of participants, with the objective of selecting the participants who are the most knowledgeable with the process and its associated costs.

3.4.3- Analysis

linear programing in conjunction with Discrete Event Simulation (DES) and the theory of constraints were used as analytical tools in this research. Linear programing is an optimization tool used to find the minimum or maximum of an objective function that is in the form of a linear equation in the presence of a set of linear constraints in the form of equations and/or inequalities (Bazaraa et al., 2011). DES is a tool used to create models that simulate the changes that occur to a system over time, in which the system’s status changes instantaneously at discrete and countable points of time (Law, 2006). These models are created in order to allow decision makers to compare the system’s performance under different conditions to improve their businesses profitability (Sweetser, 1999).

The two-tiered methodology used in this research allowed in the first part to maximise the profitability of the supply chain in general while considering only the main constraints of the logistical network. The use of linear programming as stage one analytical tool allowed this stage to provide aggregate insights that help policy makers in strategic decision making. The linear program had an overarching high-level objective function that is to maximise the profitability of the supply chain.

Through this tool, it was easy to consider only the strategic level constraints, while neglecting the operational level constraints. This had allowed the linear program to provide configurations that are more profitable than the ones that might be presented if the operational constraints were included in the model.

The second step was focused more on analysing the details of the logistical network by taking into consideration more constraints than the first step to identify the weaknesses of the logistical network and present solutions accordingly. The aim of this step was to consider the operational level constraints, that were not included in the first step, in order to provide a more holistic risk mitigation plan that includes both strategic and operational level insights. In this part of the analysis the thinking process (TP) of TOC was employed to spot, investigate, and release bottlenecks. The simulation model allowed the DSS to present recommendations that would ensure the feasibility of the optimal forest distribution that was recommended by the linear program

Figure 7 shows the steps the DSS proposes to produce a prioritized list of recommendations to improve the resilience of a certain logistical network. The process starts by modeling a certain scenario at the country level in pursuance of the optimal solution, i.e. modeling the distribution of forests after a port closure. Further, the analysis is taken to a more detailed level to predominantly consider the affected region rather than the country's whole logistical network by means of endorsing a recommendation list which mitigates the effect of possible closure scenario in that region. In this research, the macro level analysis included all the ports in the logistical network. However, only one closure scenario was taken to the micro level analysis and simulated using DES to produce a recommendation list.

Repeating the proposed approach for different scenarios in different regions would produce multiple sets of recommendations for different regions. The proposed recommendations impact on the resilience of the logistical network are then compared to create a prioritized recommendation list. The impact of the recommendations can be quantified by comparing the amount of logs exported before and after introducing the model's recommended improvements, the validity of the recommendation under different scenarios, and other factors that was included in the model such as expected increase in profit. It is also important to include the cost of implementing the proposed recommendation in the prioritization process. The final list would include a set of improvement opportunities to be presented to decision makers to help them direct their investments to achieve their strategic goals.

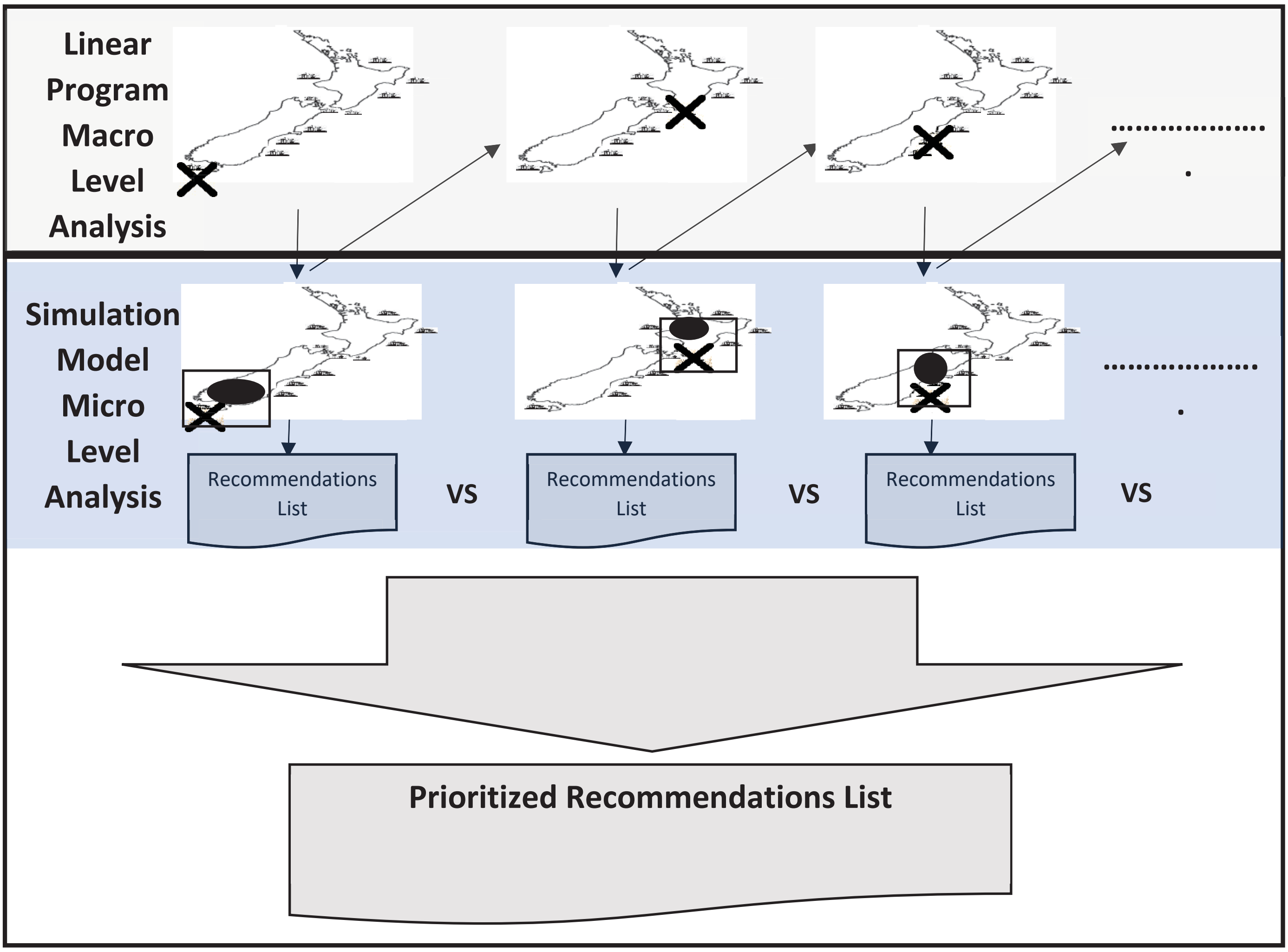

Figure 7 The Integration of Macro and Micro Level Analysis in The Proposed DSS

3.5- Validity and Reliability

The reliability and validity of data are central issues for any research. Reliability means that the results are repeatable under similar conditions, which indicates that the measurements are dependable and consistent (Neuman, 2006). Validity means that the variables or indicators considered in the research realistically and meaningfully characterize the case or the phenomena being studied (Neuman, 2006). For this research, the research methodology, data collection and analysis tools were carefully selected to ensure that the research results are valid and reliable. The collected data cover a long period of time and it also covers all New Zealand ports. Experts' opinions were taken into consideration while developing the DSS, which excluded the possibility of having unrealistic solutions. Moreover, the collected data also included practices followed by different companies operating in the industry, while their input was used to test the validity of the DSS. Accordingly, this proves the reliability and validity of the collected data and research results.

Given that the first set of data is historical data collected over a long period of time, it provides stability for this set. In addition, because this data was collected for all New Zealand ports it can be considered to be representative. Equivalence reliability is realized in this set as it includes more than one variable that is used to triangulate the main variable to improve its equivalence reliability.

The second set of data is collected by interviews (excluding road network data, which relied on archival data). Accordingly, the responses will be affected by the experience and knowledge of each participant, which might affect the stability of the data. However, since the participants will include several experts from different fields in the industry, the data will be representative. Moreover, having more than one measure included in the interviews provided an indication of the equivalence reliability of the data. The validity and full representation of the different variables, that should be considered, was ensured during the interviews because the participants are experts in the field.

3.6- Ethical Consideration

Ethical considerations must be well thought-out in the research project because it is necessary not to cause the participants any physical or emotional harm, which includes stress, embarrassment, privacy loss, discomfort, and pain (Cooper& Schindler, 2008).

The objective of the research and its scope were clearly explained to the participants, institutions and companies participating in this research. Knowing that this research included more than one company operating in the same field, a conditionality agreement was created to assure the companies that the information that will be provided about their processes will be protected. No hazardous threats were identified that might affect the researcher or the participants. Knowing that the researcher is not working with any of the companies or institutions included in the research and does not have any aspiration to be an employee at these institutions, eliminates the possibility of any conflict of interest. Moreover, after reviewing Massey University's ethical consideration form there were no identified ethical implications in this research.

The Forestry industry is a major contributor to New Zealand economy; it is the third largest export sector, comprises 3.2% of New Zealand's GDP and it provided 18,000 jobs in 2014 (NZFOA, 2014). Improving the growth of this sector will be beneficial to the country's economy. The outcome of the research helped in providing building bricks for a decision support system that would allow organizations working in the industry to be more responsive to disruptions in their supply chains. Accordingly, this will improve their competitiveness and market share in the global market, which will increase the profitability of this industry. Furthermore, the DSS will also be helpful for port officials to improve the efficiency of their risk mitigation processes, which will be positively reflected in the supply chains performance of the companies using these ports.

One of the limitations of this research is that some companies might not provide full information about the rerouting costs and their decision-making process, which might affect the tradeoffs that the DSS makes. The assumptions made during building the linear program to simplify the reality would have some effect on the suggested optimal solutions. However, it is accepted to have assumption in modeling real world as it is impossible to simulate the real world with its full complexity.

Chapter 4: Macro Analysis and Results

4.1- New Zealand's Ports' Capacities

New Zealand is located in the southern hemisphere 1,600 Km south east of Australia. It consists of several islands the main populated islands are the North Island and the South Island, which are the main interest in the context of this research. The logistical infrastructure in New Zealand in general is developed and at a first world class. New Zealand's two main islands have different geography and different infrastructure so each island will be discussed separately. In this research, the main interest is the ports capacity to handle logs, which are usually exported in bulk form.

The amount of logs exported annually from New Zealand create pressure on the country's ports. The allocation of logs harvested from certain forests to certain ports using an optimisation model might help in releasing this pressure and improve the profitability of the supply chain in general. If a certain disruption happens and it leads to a port closure, then it is definite that the pressure on the available ports will increase. This makes the forest allocation process and the rerouting process in case of closure very hard and risky. The port capacities are an important factor in the forest allocation process and in the decision-making process during a port closure event. The evaluation of these capacities will allow the decision support system to know how much logs can be exported through a certain port to allocate forests to that port accordingly. It also helps in evaluating the extra capacity that each port has, which will help in creating more realistic contingency plans during a port closure. These plans will help decision-makers in directing their investments in a more efficient way that would improve the resilience of their supply chains.

The capacity of each port was evaluated using historical data of the log export volume handled by each port per quarter during the period Jan-2010 to Jun-2016 obtained from the Ministry of Primary Industry (MPI). The maximum volume handled per quarter during any time of this period was multiplied by four and assumed to be 70% of the port maximum annual capacity (Scion, 2017). Equation 1 represents the method of calculating port annual capacity:

$$C= 4*q_m*1.3 \tag{1}$$
$$C= 5.2q_m$$

where:

C: is the port's annual capacity, and

q_m: is the maximum actual quantity handled in one quarter during the period Jan 2010 to Jun 2016."

This is a simplistic approach to calculate port capacity and more research is needed to evaluate the true capacity of the ports. However, the value provided by this approach is representative and can be used to develop a relatively realistic model.

The North Island has seven seaports, a rail link with eight public train sidings that can handle logs and a well-connected road network. All the ports in the North Island except Auckland Port have the facilities to handle bulk cargo. Hence, Auckland port was not included as an alternative port where logs could be exported in case of port closure. On the other hand, the South Island has a bigger geographical area than the North Island, but it has a lower population and generally a sparser infrastructure. It has six seaports, a rail link with only one public train siding that can handle logs and a well-connected road network. All the ports in the South Island have the facilities to handle bulk cargo.

The capacity indicators that were used to describe each port include (a) the number of ship calls, (b) the number of berths, (c) the storage area, (d) availability of rail links and (e) the amount of logs handled per quarter. Capacity indicators were gathered for each port from the Ministry of Primary Industry reports and the ports themselves, the following example is the description of Tauranga port:

Tauranga Port

Tauranga city is situated on the western bay of Plenty, the city's port is the largest seaport in the country with a total of 1,555 ship calls in 2014 including logs' ships. The number of log ships calls in 2014 was 287 calls, which compromises 18.5% of the total. The port has 4 berths that can be used by log ships, a link to rail and 294,000 m^3 JAS of storage area. The storage area is divided into two categories, leased to exporter (264,000 m^3 JAS) and common storage area (30,000 m^3 JAS). Figure 8 shows the amount of log handled by the port of Tauranga per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the third quarter of 2013, during which the port exported 1,678,174 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 8,726,503 m^3 JAS. Then this amount is converted to tons/ year using the north island average density factor (see Appendix A.1).

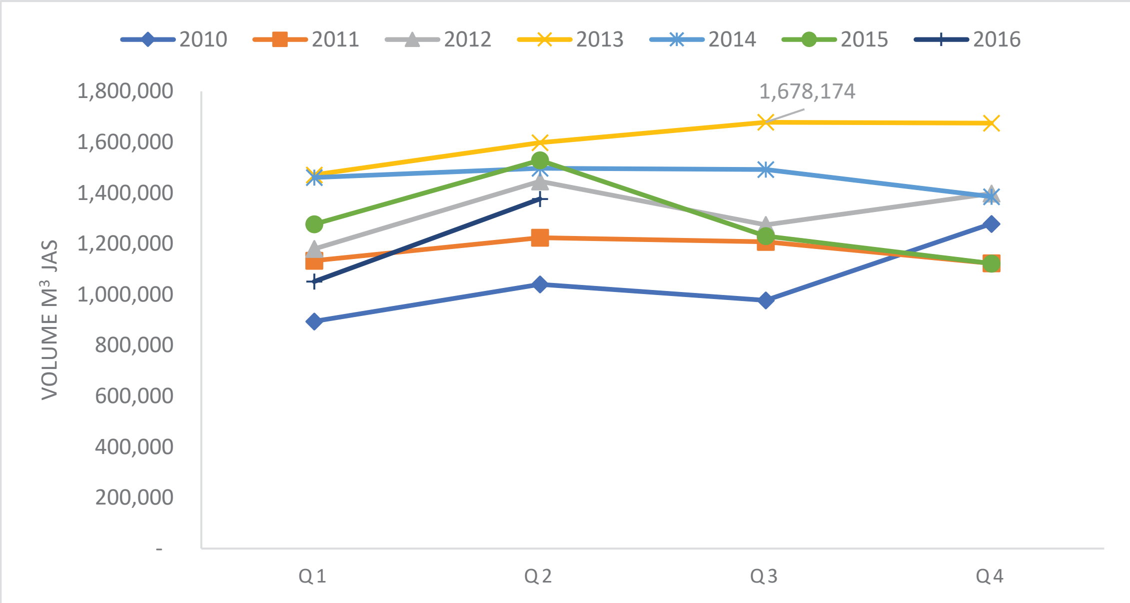

Figure 8 Total quarterly log volume exported from the port of Tauranga during the period from Jan 2010-Jun 2016.

Each port has a replicated description of the one mentioned above with its corresponding information (see Appendix A). However, only the ports' capacities and locations are important in building the linear program not the detailed description. Figure 9 shows the port locations with their corresponding estimated capacities using the previously discussed method. Auckland port was not included in the Figure because it only handles containerized shipments and logs are usually shipped in bulk form. It is worth mentioning that Otago ports consist of two ports, Dunedin port and Chalmers port. Dunedin port is the main port for exporting logs, while Chalmers port handles a small proportion of log volume. The ports were grouped under one port because of their close geographical location and the small quantity handled by Chalmers port makes it negligible if it was to be considered as an independent port. Furthermore, in the case of a biosecurity threat affecting any of these two ports, it will lead to the closure of both. It is noticed that Tauranga is the biggest port on the North Island, while Otago ports have the highest capacity on the South Island.

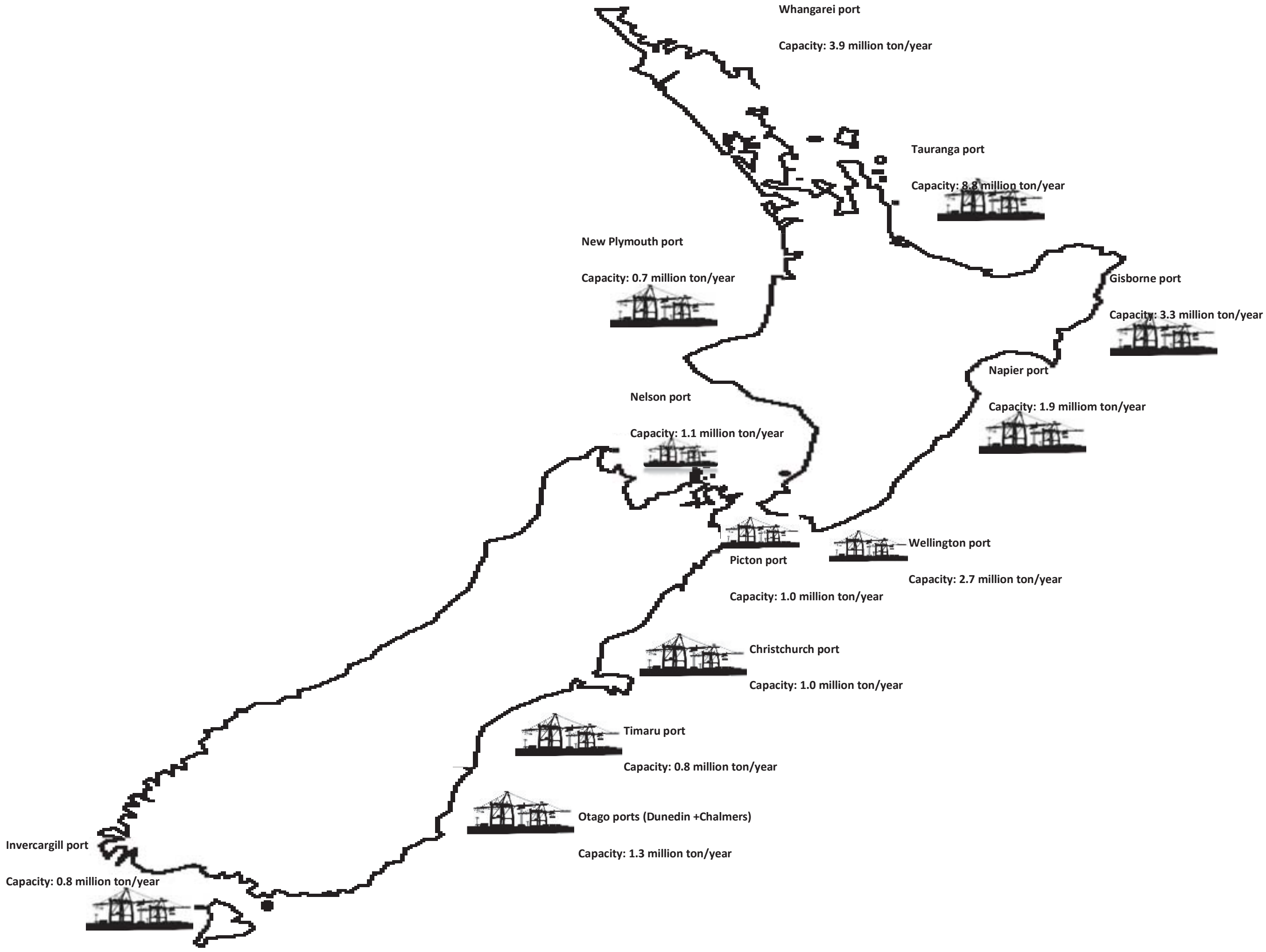

Figure 9 New Zealand ports with their corresponding estimated annual log export capacities.

4.2- New Zealand's Forests Distribution

Forests ownership in New Zealand is divided between Timber Investment Management Organisations (TIMO's) and privately owned forests (Ministry of Primary Industry [MPI], 2017). The log industry is a large part of the forestry industry, comprising more 16 million cubic meters of log in exports (New Zealand Forest Owners Association [NZFOA],2017) . the total planted area stocked for forests production is estimated at 1.72 million hectares as at 1 April 2015.

Figure 10 shows the contribution of different species to New Zealand's forests. It is clear that Radiata pine is the dominant specie and makes up 90% of the planted area. Accordingly, Radiata pine harvesting age will be considered as the harvesting age for the New Zealand's forests in general.

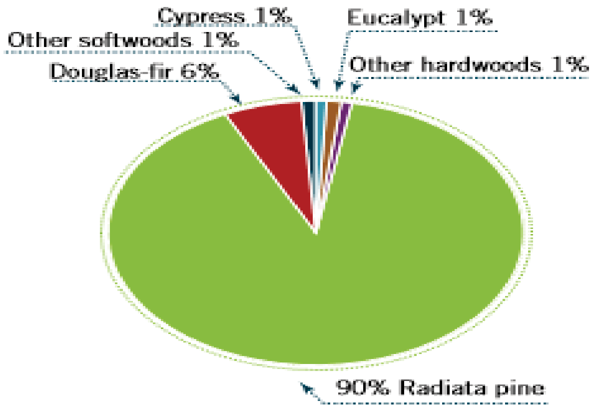

Figure 10 contribution of different species to New Zealand's forests, Adopted from (MPI (B), 2017)

The standard age for harvesting Radiata pine is between 26 and 32 years. Figure 11 shows new forest plantings (since 1988) and deforestation (since 2005). The areas planted between 1992 and1998

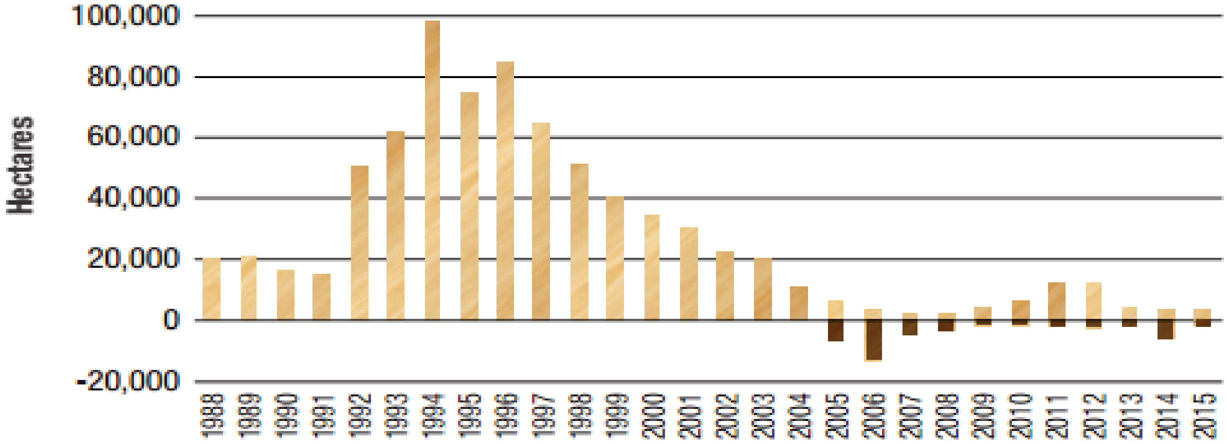

Figure 11 New forest planting (since 1988) and deforestation (since 2005), (Adopted from NZFOA, 2017)

and are expected to reach their harvesting age between 2018 and 2025. Figure 12 and 13 show the forest age distribution in 2011 and 2015, respectively. The two Figures show the progression of the planted areas during the period 1992 and 1998 towards their maturity age between 2018 and 2024. This implies that there will be an abundance of logs during this period, which in turn is likely to increase the volume of logs allocated for exporting. An increase in exports will put the sea ports under pressure and will amplify the impact of a port closure. For this reason, the period between 2018 and 2025 was selected and is investigated in this research.

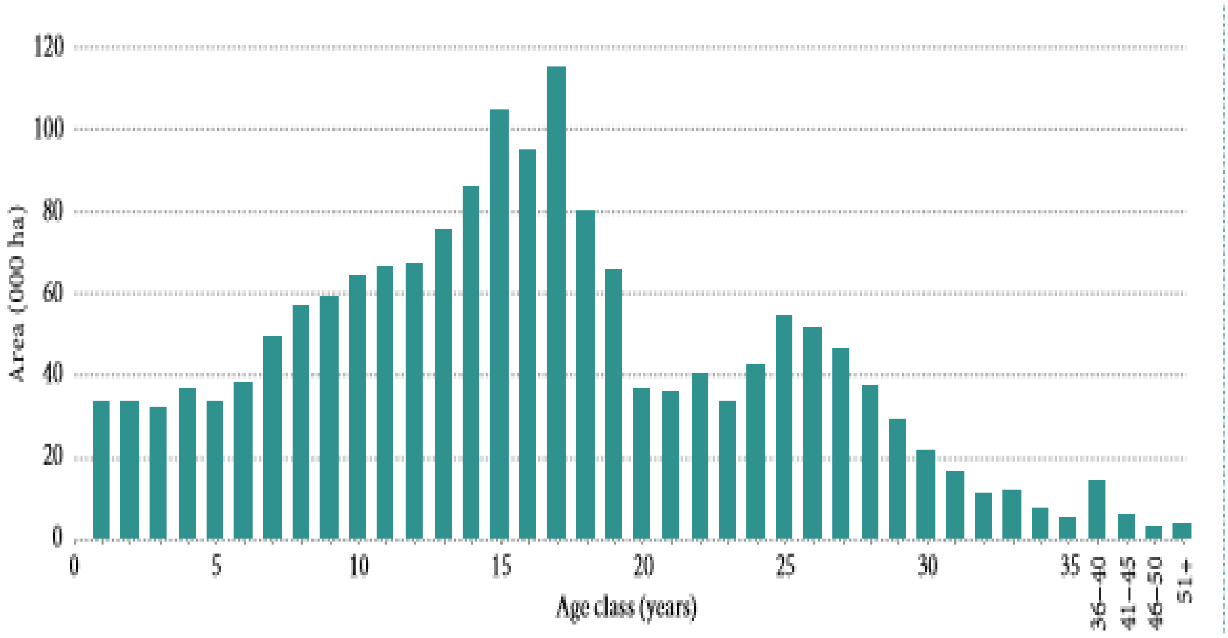

Figure 12 Forest age distribution as at April 2011, adopted from (MPI, 2017 a)

Figure 13 : Forest age distribution as at April 2015, adopted from (MPI, 2017 b)

4.2.1- North Island Forests

The North Island is divided into five wood supply regions: Northland, Central North Island, East Coast, Hawke's Bay, and Southern North Island (MPI ,2017 b). These regions are further divided into 43 territorial districts and city councils; the location and name of each district is shown in Figure 14. The planted area of some regions is shown in Table 8, the yield of these areas in m^3JAS is calculated using the yield factor of each region in which each forest area is multiplied by the corresponding yield factor (see Appendix A.2 for all the regions). Table 8 also shows the volume used by local processing mills, the processing volumes were calculated using historical data and it was assumed for simplification that the volumes will remain constant. It was also assumed that all the abundant quantity will be exported to other countries and that the international market demand can absorb these quantities. It is noticed that some regions' production is not enough to satisfy the demand of the processing mills, which means that these mills will need to procure the deficit from neighbouring regions. For these regions, the export volumes are negative, which means that mills will absorb some of the volume allocated for exportation by other regions. For example, Rotorua district is expected to produce around 1.17 million m^3JAS of logs annually during the period 2020-2025. However, the processing mills in the district are expected to consume 1.52 million m^3JAS per year, so it is shown in the Table that the export volume from Rotorua district is -0.35 million m^3JAS per year.

Figure 14 North island's regions and territorial districts. adopted from (MPI (B), 2017)

Territorial authority	***Gisborne District***	***Wairoa District***	***Rotorua District***	***Napier City District***	***Central Hawkes Bay District***
Harvesting area Total 2020-2025 (Hec)	36 156	11 572	8 657	12	4 100
Annual harvesting area 2020-2025 (Hec)	7 231	2 314	1 731	2	820
Total Recoverable Volume TRV (annual)(m3)	4,266,408	1,286,806	1,174,662	1,334	455,920
Export Volume (M3)	3,993,408	1,286,806	-352,838	-1,404,666	413,920
Processing volume (m3)	273,000	-	1,527,500	1,406,000	42,000
Conversion Factor Hec to m3	590	556	678	556	556

Table 8 A Sample of North island's yield, processing and exporting volumes by district (Scion, 2017).

4.2.2- South Island Forests

The South Island is divided into four wood supply regions: Nelson/ Marlborough, West Coast, Otago/ South Island, and Canterbury (MPI ,2017 b). These regions are further divided into 23 territorial districts and city councils; the location and name of each district is shown in Figure 15. The planted area of some regions is shown in Table 9, the yield of these areas in m^3JAS is calculated using the conversion factor of each region, in which each area is multiplied by the corresponding conversion factor. The Table also shows exporting and processing volumes of each region(see Appendix A.2 for all the regions).

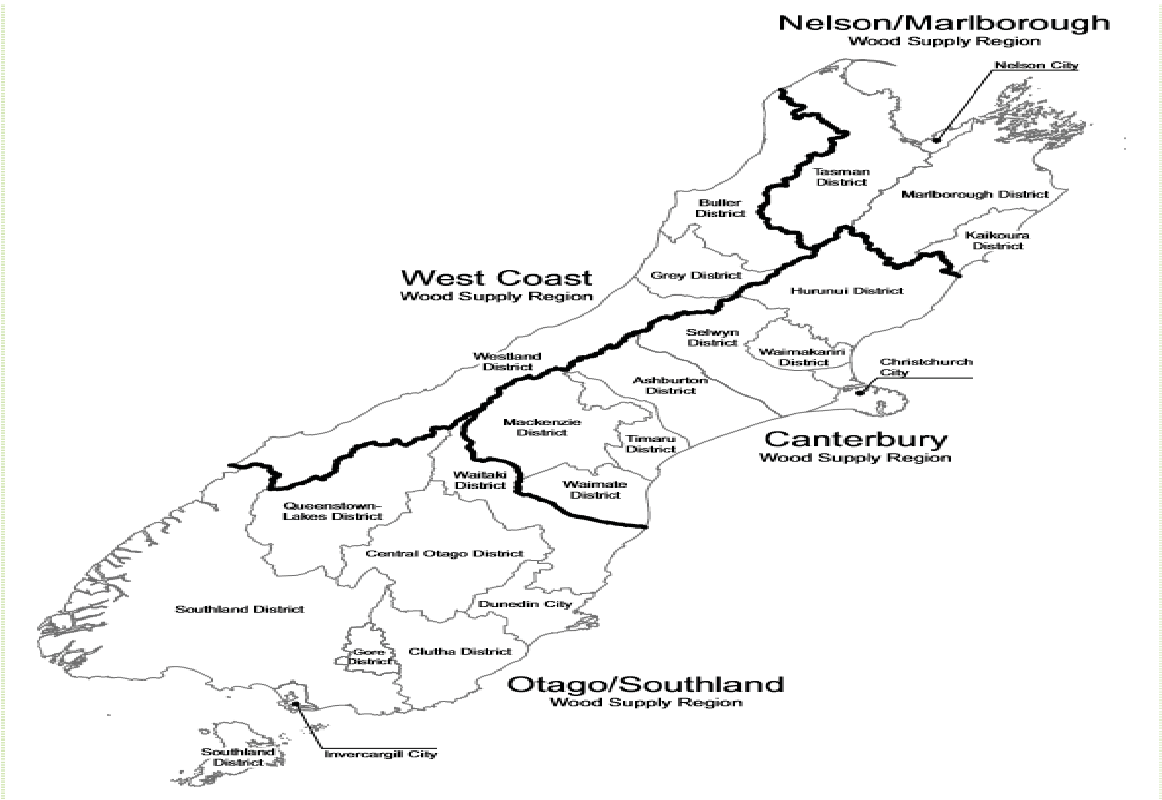

Figure 15 South Island's regions and territorial districts. adopted from (MPI (B), 2017)

Territorial authority	*Nelson City District*	*Tasman District*	*Marlborough District*	*Kaikoura District*	*Buller District*
Harvesting area Total 2020-2025 (Hec)	1 653	17 029	15 550	338	621
Annual harvesting area 2020-2025 (Hec)	331	3 406	3 110	68	124
Total Recoverable Volume TRV (annual)(m3)	162,785	1,676,988	1,531,338	33,286	26,951
Export Volume (M3)	-1,730,215	1,635,988	1,361,338	33,286	18,951
Processing volume (m3)	1,893,000	41,000	170,000	-	8,000
Conversion Factor Hec to m3	492	492	492	492	217

Table 9 A Sample of South Island's yield, processing and exporting volumes by district (Scion, 2017).

4.3- Linear program

The objective of the linear program is to maximize the profit of the supply chain by redistributing the logs on the available ports in response to a port closure. The closure period due to a biosecurity threat was estimated to be one year (Scion, 2016). The model reallocates the quantities of logs to be exported through the available ports (Q_{ij}) during the closure period, while considering the port capacities, the shock in log price due to the port closure, harvesting cost, transport costs, and port costs. The model also considers the option of delaying the harvesting until the closed port reopens after one year. This option has an additional maintenance cost and an additional revenue (due to the forest growth during the closure period) that the model takes into account. The optimal solution presented by the model ensures earning the highest possible profit under the given constraints and assumptions.

In this section, the equations and inequalities used to build the model are discussed along with the variables used in the equations or inequalities. The section starts with the description of the constraints that reflects the constrained capacity of the logistical network followed by the cost calculation equations and the objective function. The model was based on the work of Meepetchdee and Shah (2007), however, it includes major changes from their model to accommodate the uniqueness of the research topic.

Constraints

Number of ports

Assuming that there is n number of districts (forests) and the number of ports that can be used is limited to E then:

$$\sum_{i=0}^{n} P_i \leq E, \tag{1}$$

where P_i is a binary variable such that:

$$P_i = \begin{Bmatrix} 1, & If\ a\ port\ is\ established\ in\ district\ i \\ 0, Otherwise & \end{Bmatrix}$$

Each forest is served by one primary port to which the forest is assigned. To account for this relation the following constraint is included:

$$X_{ij} \leq P_{i,}\ \forall\ i \tag{2}$$

Where X_{ij} is a binary variable such that:

$$X_{ij} = \begin{Bmatrix} 1, If\ Forest\ j\ is\ a\ assigned\ to\ a\ Port\ i \\ 0, Otherwise \end{Bmatrix}$$

Knowing that each forest is assigned to only one primary port (the nearest port that has the infrastructure and capacity to handle the logs) then:

$$\sum_{i=0}^{n} X_{ij} = 1, \ \forall j \tag{3}$$

Capacity Constraints

The quantity of logs from Forest j to be handled in Port i (Q_{ij}) is less than or equal to the total amount of log allocated for exporting by Forest j (M_j):

$$Q_{ij} \leq M_j \,.X_{ij}\ \forall\ j, i \tag{4}$$

Q_{ij} is limited by the port capacity C_i. This relation is embedded in the following:

$$\sum_{j=0}^{n} Q_{ij} \leq C_i, \ \forall\ i \tag{5}$$

The total quantity handled by all the ports including for a certain Forest j should be equal to the total allocated for exporting from that forest.

$$\sum_{i=0}^{E+1} Q_{ij} = M_j, \ \forall j \tag{6}$$

A demo port is added to represent a waiting option (in which the forest is not harvested until the port that is closed opened again). Accordingly, The summation was set to (E+1) to include the quantity that is allocated to the demo waiting port.
Contingency and alternate ports constraints:

A number of secondary ports can be assigned to each forest, however, the set of secondary ports should not include the primary port.

$$XS_{ij} + \ X_{ij} \leq 1\ \forall\ j, i \tag{7}$$

Where XS_{ij} is a binary variable such that:

$$XS_{ij} = \begin{cases} 1, & \text{I}f\ \ Forest\ \ j\ is\ allowed\ to\ use\ Port\ i\ as\ a\ secondery\ port \\ 0, Otherwise & \end{cases}$$

A Forest j can use port i only if the port exists. It should be noted that an independent model was developed for each island. Accordingly, the secondary ports for any given forests should be within the island that it belongs to.:

$$XS_{ij} \le P_i\ \forall\ j, i \tag{8}$$

The total number of secondary ports that can be assigned for a certain forest must be less than or equal to the total number of ports minus one (which is the primary port). However, a demo port is added to represent the waiting option (in which the forest is not harvested until the port is open again) so the total number of secondary ports for Forest j is:

$$\sum_{i=0}^{n} XS_{ij} \le \mathrm{E} - 1 + 1\ ,\ \ \forall\ j$$

$$\sum\nolimits_{i=0}^{n} XS_{ij} \le \mathrm{E}\ ,\ \ \forall\ j \tag{9}$$

The ability of Port i to handle more quantity of logs is limited to its abundant capacity (AC_i), which the excess capacity that a port possess after exporting the primary allocated forests

$$AC_i \le C_i - \sum\nolimits_{j=0}^{n} Q_{ij}\ ,\ \ \forall\ i \tag{10}$$

In the context of this research, the resilience of the logistical network is represented by the ability of the logistical network to cope with the closure event by rerouting the logs shipments through other ports. while remaining more profitable than delaying forest harvesting until the closed port opens again. Accordingly, the exported quantity during a closure event as a percentage of the total quantity allocated for exporting is the resilience index (β), which can be calculated by the following equation:

$$\beta\ = \frac{\sum_{j=0}^{n} M_j - \sum_{j=0}^{n} X_{ij}.M_j}{\sum_{j=0}^{n} M_j}\ \ \forall\ i = waiting \tag{11}$$

Non-Negativity Constraints

$$AC_i\ , C_i, Q_{ij}, M_j, P_i \geq 0 \tag{12}$$

Costs

Attempts were made for costs to be as comprehensive as possible by including all stages through which logs go through from harvesting until loaded on ships. Figure 16 shows these costs, it shows that the total cost is comprised of port costs, transportation cost and miscellaneous costs. The bar on top of each stage roughly represent its contribution to the total cost. Port costs are incurred to handle the ship when it arrives at the port. Wharf, berth, and tugs boats costs vary between ports and they are calculated per ship consignment. Transport costs are the costs incurred to move the logs from the forests to the ports using trucks or trains. Harvesting, fumigation and scaling costs are constant regardless of the origin forest or the destination port. It is noticed from the Figure that the highest contributor to the total cost is transportation cost. It is worth mentioning that even though some costs are constant and have a minimal effect on the optimal solution. These costs were included to have a better reflection on real costs in the model. The waiting costs are not shown in Figure 16 because they are only incurred by the forests that will be waiting for their primary port to reopen. However, it is discussed in detail late in this section.

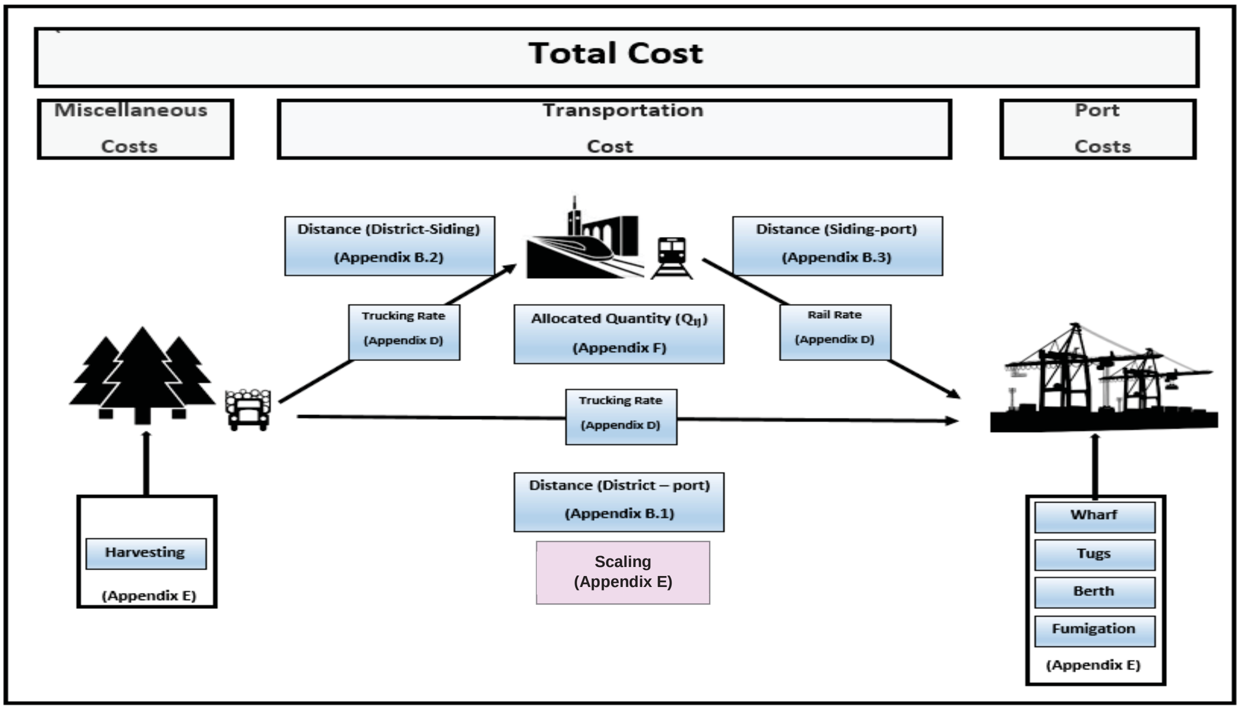

Figure 16 Costs Included in the Model

Transportation Costs

The costs that can be minimized are mainly the transportation costs of the logs from the forests to the ports. There are two main modes of transportation available, trucks and trains. Coastal shipping is not an option because new Zealand does not have a network of inland water ways that can be used to transport logs from forests to ports.

Train Costs,

Transporting logs using train implies that the destination port must have rail facilities R_i , where R_i is a binary variable such that:

$$R_i = \begin{Bmatrix} 1, & \text{I}f \;\; Port\ i\ has\ rail\ facilities \\ 0, & Otherwise \end{Bmatrix}$$

Each forest is allocated to its nearest Train Siding S_{sj}, where S_{sj} is a binary variable such that:

$$s_{sj} = \begin{Bmatrix} 1, & \text{I}f \;\; \text{Train Siding } s \text{ is the nearest siding to Forest j} \\ 0, & Otherwise \end{Bmatrix}$$

The train cost is mainly a function of the quantity to be transported from Forest j to Port i (Q_{ij}) , the distance between the forest and the Train Siding F_{js} and the rail distance between the train siding and the port RL_{si} .The cost of transporting the logs from Forest j to Port i include the cost of trucking the logs from Forest j to Train Siding s and the train cost from train siding s to the Port i. The total is divided by S_{sj} to limit the forest access to the rails only to be through the nearest train siding. The second cost component is divided by R_i to make using the rails for a port that does not have the rail facilities prohibitive.

$$\sum_{s=1}^{K} \sum_{i=1}^{E} \sum_{j=1}^{n} (\text{Ct}_{F_{js}}.Q_{ij} /S_{sj}) + \sum_{s=1}^{K} \sum_{i=1}^{E} \sum_{j=1}^{n} (Cr.RL_{si}.Q_{ij} /S_{sj}.R_i) \qquad (13)$$

such that:

$Ct_{F_{js}}$: the trucking unit cost per ton for the distance category to which F_{js} belongs

Cr : the train unit cost per ton per Km

For example the cost of trucking a ton of logs for distance between 0-59 Km is 25 NZD so if F_{js} is 49 Km then $Ct_{F_{js}} = 25\ NZD$)

Trucking cost

The trucking cost is a function of the quantity to be transported from Forest j to Port i (Q_{ij}) and the distance between Forest j and Port i (D_{ij})

$$\sum_{i=1}^{E} \sum_{j=1}^{n} Ct_{D_{ij}}.Q_{ij} \qquad (14)$$

such that:

$Ct_{D_{ij}}$: the trucking unit cost per ton for the distance category to which D_{ij} belongs.

Accordingly, the transportation cost for Forest j to Port i is the minimum between the trucking and train cost.

$$Tranportation\ cost = Min[\,Ct_{D_{ij}}.Q_{ij} \ \ ,\sum_{S=1}^{k}(\,Ct_{F_{js}}.Q_{ij}/S_{sj} \ \ ) + \sum_{s=1}^{k}(Cr.RL_{si}/S_{sj}.R_i\,)Q_{ij}]\ ,\forall\ i,j \ (15)$$

The total transportation costs for all the forests is:

$$\sum_{i=1}^{E} \sum_{j=1}^{n} (Min[\,(\,Ct_{D_{ij}} \ .Q_{ij}\,,\sum_{S=1}^{k}(\,Ct_{F_{js}}.Q_{ij}/S_{sj} \ ) + \sum_{s=1}^{k} (Cr.RL_{si}/S_{sj}.R_i\,)Q_{ij}]\,) \ (16)$$

Note that the cost of the quantity allocated to the demo waiting port (E+1) is not included in the above formula as it is going to be considered as a part of the waiting costs as shown in the following section.

Waiting Cost

The waiting option will incur the forests owners' additional costs for keeping the logs until the primary port is open again, which is the inventory holding cost. The total waiting cost will include the transportation cost to the primary port (after the port open again) plus the inventory holding cost because of delaying the log harvesting of Forest j (Ch_j). Inventory holding cost include the maintenance (Cm_j) and the lost opportunity cost (Co_j). These costs are a function of the quantity that will be allocated to the demo port that represents waiting(Q_{ij} for i =waiting). Accordingly, the holding cost is calculated as per equation (17):

$$\mathrm{Ch_j} = (\mathrm{Cm_j} + \mathrm{Co_j}).\mathrm{Q_{ij}} \qquad \forall\, i = \text{waiting} \tag{17}$$

such that:

Ch_j: inventory holding cost of Forest j

$\mathrm{Cm_j}$: the cost of maintaining a ton of logs from Forest j for another year

$\mathrm{Co_j}$: the lost opportunity cost resulting from delaying the selling of a ton of logs from Forest j

Then the total waiting cost for Forest j is:

$$\mathrm{Cw_j} = \mathrm{Ch_j} + \mathrm{Min}[\,\mathrm{Ct_{D_{ij}}}.\mathrm{Q_{ij}}, \sum_{s=1}^{k}(\mathrm{Ct_{F_{js}}}.\mathrm{Q_{ij}}/\mathrm{S_{sj}}) + \sum_{s=1}^{k}(\mathrm{Cr}.\mathrm{RL_{si}}/\mathrm{S_{sj}}.\mathrm{R_i})\mathrm{Q_{ij}}]\,\forall\, \mathrm{j, i\ primary\ port} \tag{18}$$

Port and Harvesting Costs

The port costs are divided into two categories, (a) specific port costs that varies from one port to another and (b) general port costs that is constant for all ports. Specific port costs include berthage, wharfage and tugs costs. General port costs include fumigation (if available at the port) and scaling. Harvesting costs are the costs incurred for felling the trees. General port costs and harvesting costs are constant regardless of the forest or the port. Accordingly, the total port and harvesting cost is:

$$\sum_{i=1}^{E} \sum_{j=1}^{n} (\mathrm{Cp}_i + Cv).\mathrm{Q_{ij}} \tag{19}$$

such that:

Cp_i: the specific port cost per ton of logs.

Cv: the sum of general port cost and harvesting costs per ton of logs.

The total cost is:

$$Total\ cost = \text{Transportation cost} + \text{Port and Harvesting costs} + \text{Waiting Cost}$$

$$Cst = \sum_{i=1}^{E} \sum_{j=1}^{n} (\mathrm{Min}[\,\mathrm{Ct_{D_{ij}}}.\mathrm{Q_{ij}}, \sum_{S=1}^{k}(\mathrm{Ct_{F_{js}}}.\mathrm{Q_{ij}}/\mathrm{S_{sj}}) + \sum_{s=1}^{k}(\mathrm{Cr}.\mathrm{RL_{si}}/\mathrm{S_{sj}}.\mathrm{R_i})\mathrm{Q_{ij}}]) + \sum_{i=1}^{E} \sum_{j=1}^{n}(\mathrm{Cp}_i + Cv).\mathrm{Q_{ij}} + \sum_{j=1}^{n} \mathrm{Cw}_j \tag{20}$$

Equation (20) represents the total cost incurred for harvesting, transporting and the maintenance costs (if all or part of the forest was going to wait until the port opens again).

Objective Function

The total profit is a function of the log selling price, sold quantity minus total cost. The log price is highly volatile and New Zealand is the world's largest exporter of softwood's log, so an anticipated drop in supply from the largest exporter in the world would influence the selling price of logs. Accordingly, the price was assumed to increase in the case of port closure. This increase was proportional to the volume that was supposed to be exported through the port. This assumption was checked against some the large exporters and while no evidence exists, anecdotally they agreed with this approach. Similarly, the price will not only restore, but may be lower after the affected port has reopened because excess logs (in waiting) may flood the market. The price drop after the port closure finishes was calculated proportionally to the waiting quantity that caused an excess in the supply. Consequently, three log prices were used; average price when all the ports are operational, price during port closure (higher than the average) and after port closure price (lower than average). These prices are calculated as follows

$$Ip_i = Pa.(1 + I_i) \tag{21}$$

where:

Pa: the average price of log per ton for the last 20 years

Ip_i: the increased log price per ton after Port i is closed.

I_i: the price increase percentage when Port i is closed

During Port i closure all the logs exported through the other ports (except for the waiting demo port) will be sold at Ip_i. The logs at the demo waiting port will be sold at Rp_i, in which:

$$Rp_i = Pa.(1 - L_i) \tag{22}$$

where:

Pa: the average price of log per ton for the last 20 years

Rp_i: the reduced log price per ton after Port i closure finishes.

L_i: the price reduction percentage after Port i closure finishes.

However, it should be mentioned that during the waiting period the forest will grow and produce more wood. This implies that the waiting quantities will generate an additional revenue that may contribute to offsetting the costs incurred because of waiting and the reduced selling price. The increase in the revenue is calculated using the following equation:

$$IR_j = \ N_j . Q_{ij} \qquad \forall\ i = waiting \tag{23}$$

Such that:

IR_j: is the total increase in revenue for the quantities waiting from Forest *j*

N_j: is the increased revenue per ton of logs from Forest j after one year of waiting

Q_{ij}:is the quantity of logs from Forest j (in tons) handled by Port i (in this case i =waiting)

Knowing that each scenario will have a certain Rp_i and Ip_i and that the objective function is to maximise the total profit then:

$$Profit = Total\ Revenue - \ Total\ cost,$$

thus

$$\text{Maximise [Pofit} = \left\{ \begin{array}{ll} \sum_{j=1}^{n} \left(\text{Rp}\ \ .\text{Q}_{\text{ij}}\right) + \text{IR}_{\text{j}} - Cst\ , \forall\ \text{i} = \text{waiting} \\ \sum_{i=1}^{E} \ \sum_{j=1}^{n} \ \ (\text{Ip}\ \ .\text{Q}_{\text{ij}}) - Cst, \qquad \forall\ \text{i} \neq \text{waiting} \end{array} \right\} \forall\ \ \text{Rp}_i, \text{Ip}_{\text{i}}] \ (24)$$

4.4- Linear Program Application

In this study, New Zealand was divided into two main islands and an independent model for each island was developed. However, log price fluctuation due to port closures were calculated using the drop/increase in supply as a percentage of the country’s total. Each island was divided into smaller districts and a point at the centre of each district was identified, using google maps, to calculate the distances to the ports and sidings. Rail distances between each train siding and each port that have train facilities were calculated using google maps. Districts were initially allocated to their nearest port and only one access point to the rails was allowed for each district, which was the nearest train siding (see Appendix C for allocation matrices).

The cost of handling a standard log ship was used in the model to calculate the port costs. The characteristics of *Glorious Plumeria* 2007, a typical standard ship is shown in Table 10. This ship load was used to calculate the costs per ton of logs throughout the model.

Ship	Glorious Plumeria
Year	2007
Breadth (M)	32.2
Dead Weight Tonnage DWT	49,636
Gross Tonnage GT	39,904
Average Speed (knotts)	12.8
Max Speed (knotts)	14.4
Max Draught (m)	11.55
Volume (t)	47,651
km/hr av	23.7

Table 10 Glorious Plumeria ship characteristics (Scion, 2017).

Transportation cost is for moving the logs using rails or road from each district to each port, the mode with the lowest cost was selected by the model on a case by case basis. The scaling cost is constant regardless of the transportation mode. Scaling can take place either at the train siding while loading the train or at the port during unloading the truck or the train. Three factors affect the transportation cost, rail/trucking rates, distance, and quantity. For details of distances, allocated quantities, costs and rates their corresponding Appendices are shown in Figure 16. To calculate the trucking costs, the trucking rates were categorized into 12 groups of distances and each group had a certain rate for trucking a ton of logs (see Appendix D). On the other hand, rail rates are charged on a per ton per kilometre basis and is constant. Accordingly, there is only one category in the rail rate. From Figure 16, it is also noticed that moving logs via rails have two components, trucking the logs to the nearest train siding and then moving it by train to the destination port. The first component was calculated using the previously mentioned trucking rates and the distances between the districts and train sidings (see Appendix B.2). Some districts, such as the Far North district, were excluded from these analysis as no feasible train sidings exist in the area. Each district can access the rail only through the nearest train siding to minimize the trucking cost as much as possible. The following examples shows the mechanism of transportation cost calculation in the model.

Cost Calculation Example 1: calculating the cost of transporting logs from the Far North district to Whangarei port using trucks.

1- Refer to Appendix B.1 to find the distance between Far North district and Whangarei port (159 Kilometres).
2- Use Appendix F to find the quantity handled by Whangarei port from Far North district (339,223 tons, in the initial state (scenario 1))

3- From Appendix D, it is noticed that the cost of trucking one ton of logs for 159 Kilometres is 39 NZD. Accordingly, the trucking cost of all the quantity is :

339,223 (Ton) X 39 (NZD / Ton) =13,229,667 NZD

Cost Calculation Example 2 : calculating the cost of transporting logs from Taupo district to Napier port using Train.

1- Refer to Appendix B.2 to find the distance between Taupo district and the nearest train siding (OJS Kinleith siding, 70 Kilometres).

2- Use Appendix F to find the quantity handled by Taupo port from Napier district is (401,833 tons in the initial state scenario)

3- From Appendix D, it is noticed that the cost of trucking one ton of logs for 70 Kilometres is 25 NZD. Accordingly, the cost of trucking all the quantity to the nearest train siding is:

401,833 (Ton) X 25 (NZD / Ton) =10,045,825 NZD

4- Refer to Appendix B.3 to find the rail distance between OJS Kinleith siding and Napier port (695 Kilometres).

5- From Appendix D, it is noticed that the cost of moving one ton of logs for one Kilometre is 0.1 NZD. Accordingly, the total cost of moving all the quantity to Napier port is calculated by multiplying the 401,833 ton by 695 Km by 0.1 NZD.

401,833 (Ton) X 695 (km) X0.1 (NZD / Ton.km) = 29,323,763 NZD

And the total transportation cost from the forest to the port for all the quantity is:

10,045,825 NZD+ 29,323,763 NZD= 39,369,588 NZD

In the case of a port closure, there is an additional cost that is incurred only if some of the forests harvesting is delayed until the port opens again. As mentioned earlier, the waiting cost is comprised of two components lost opportunity cost and maintenance cost. Lost opportunity cost was calculated by discounting the value of the forest at the average price at 8% discount rate. Maintenance costs includes animal control cost, insurance, and other miscellaneous costs. The discount rate and maintenance costs were advised by economists and financial specialists from Scion. On the other hand, leaving the forest unharvested until the port opens again will cause the forest to grow during this period. Assuming a closure time of one year, on average one hectare of forest grow an additional 20 cubic meters of logs annually (Scion, 2017). This volume was converted to Tons using a unique conversion factor for each district (see Appendix E).

Total revenue and profit were evaluated for the starting or base scenario, in which all the ports are operational, selling price for all the logs in this scenario was the average price of 95 NZD/ m3 JAS. In the following scenarios, in which one of the ports is closed, the selling price of the logs sold during the port closure was higher than the average price and the selling price of the logs sold after the port closure finished was lower than the average price. The fluctuation in the price is dependent on the anticipated supply shortage during the port closure and the anticipated supply increase after the port closure finishes (caused by delayed forest harvesting).

Figure 17 shows the mechanism of calculating the percentage of increase/decrease in log price for each scenario. The percentages in the Figure are dependent on two factors, (a) the initial allocated quantity to the port and (b) the quantity of logs that will wait until the port open again. Given the volatility of log prices in the international market and since New Zealand is a major player in the global log trade and the Chinese Market is heavily reliant on the logs exported from New Zealand as illustrated in Figure 7, it was assumed that the relation between the increase/decrease in price and the decrease/increase in supply, respectively, is linear. This assumption was also considered realistic by practitioners operating in New Zealand's log industry. Accordingly, the price increase when a certain port closes is equal to the percentage of the allocated quantity to that port to the country's annual total exporting volume. To evaluate the decrease in the price, the model was ran using only the average price and the price increase percentages to find the quantity of logs that will wait until the port is open again and the percentage of that quantity to country's annual total exporting volume represents the percentage of price decrease when the port opens again.

For example, if Tauranga port shuts down and 3.8 million tons of logs (18% of the country's total annual exporting quantity) were supposed to be exported through that port, then the price will increase by 18% from the average price during the closure period. However, after running the model according to the above percentage 1.5 million tons of logs (7% of the country's total) will wait until the port is open again , which will increase the available supply by 7% in the following year and accordingly it will cause the price to decrease by 7%.

In the following sections the details of both North Island model and South Island model will be discussed, followed by the findings of each model.

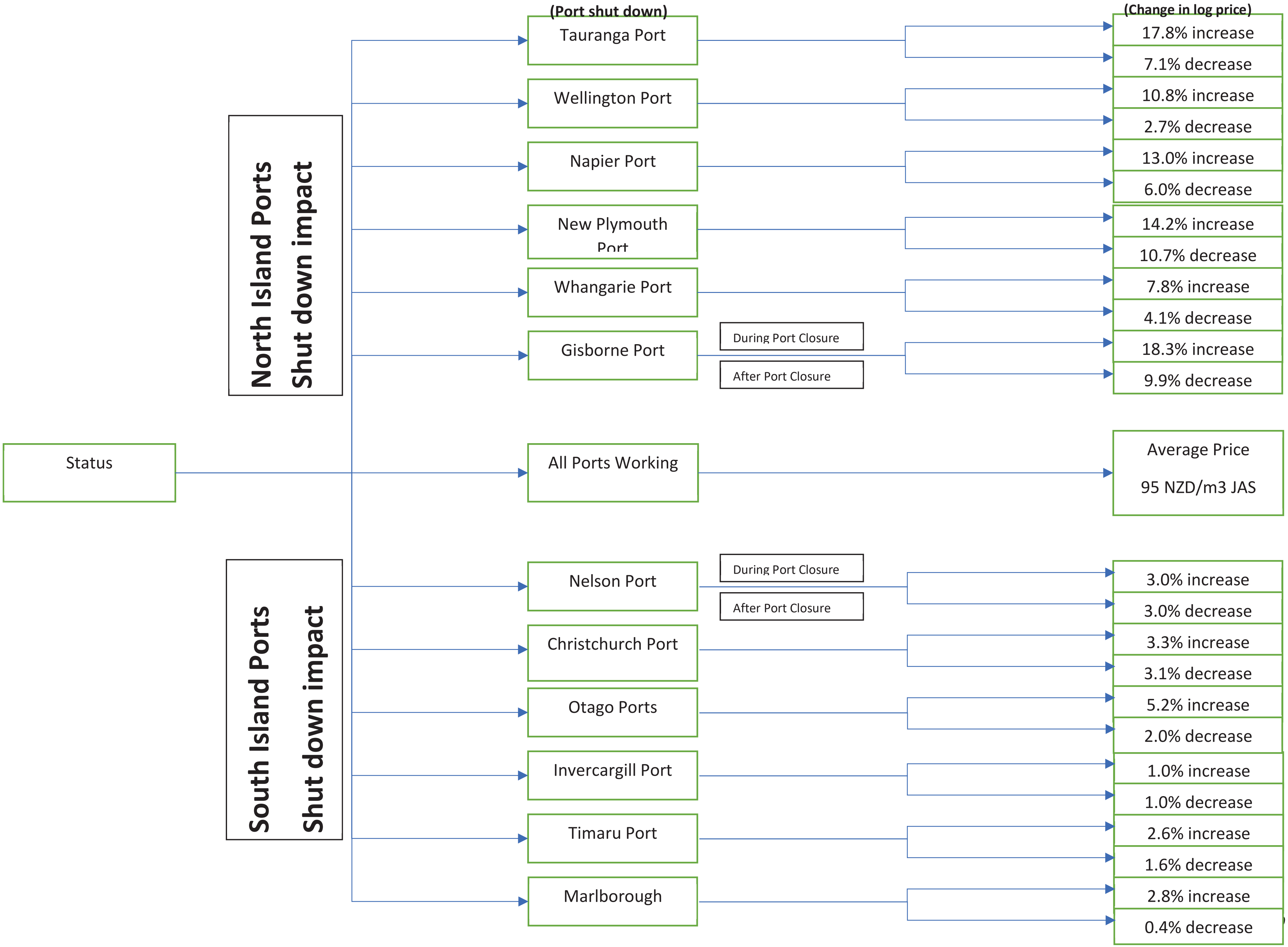

Figure 17 Price Calculation Decision Tree

4.4- North Island Model Results

For the model, the districts that do not have any exporting volume were removed and the volume that will be consumed by the processing mills (in the regions that have a negative number in their exporting volumes in Appendix A.2) were subtracted from their neighbouring regions. The deficit was initially taken from the nearest region and if that was not enough the rest of the quantity was taken from the second nearest region. In case there were two regions nearly equally distant from the region with the deficit, the deficit was divided on both. The rest of the territories were divided into 28 district, the amount in tons of logs (M_j) to be exported from each district annually is shown in Appendix A.3. All the ports in the island can be used by any district, so any port other than the primary port of the district is a secondary port for that district. Furthermore, the waiting option is added as a secondary port for all the districts (primary port (X_{ij}) and secondary port (XS_{ij}) allocation matrix is shown in Appendices C.1 and C.2 Respectively).

The ports capacities as calculated in the previous section are shown in Table 11. However, when the calculated capacities were compared to the allocated weights (Table 12), it was noticed that some of the ports, such as New Plymouth and Napier port, are already operating at or near their full capacities. This caused the problem with the ports already full then, the model was not able to assess alternative situations other than delaying harvesting. Even though it is favourable to have high port utilization from a lean supply chain perspective, from a national export resilience perspective this leaves New Zealand vulnerable in the case of a port closure. To test and demonstrate the capabilities of the model, it was assumed that the ports capacity will grow in the future to satisfy the increased demand plus 30% allowance, which will allow to see how the ports are affected when one of them is shut down. The industry is aware of the significant increase in logs export forecasts during the years 2020 to 2025, which makes the assumption more valid as the industry needs to prepare for that period. The assumed future capacities (C_i), which were used in the model, are shown in Table 13.

North Island ports	***Capacity (Ton/Year)***
Tauranga	8,726,503
Wellington	2,699,778
Napier	1,877,476
New Plymouth	689,282
Whangarei	3,810,516
Gisborne	3,281,768

Table 11 Calculated Capacities.

North Island ports	Allocated Quantity (Ton/Year)
Tauranga	3,747,675
Wellington	2,280,367
Napier	2,735,629
New Plymouth	2,988,126
Whangarei	1,638,909
Gisborne	3,850,311

Table 12 Allocated Quantities for Each Port.

North Island ports	Adjusted Capacity (Ton/Year)
Tauranga	4,871,976
Wellington	2,964,476
Napier	3,556,318
New Plymouth	3,884,563
Whangarei	2,130,582
Gisborne	5,005,404

Table 13 Future Adjusted Capacities.

The results report is designed to show five main aspects of each scenario, port utilization, the quantity of log that will be waiting until the port opens again, cost, net profit and the resilience index. These aspects will provide some kind of quantification for the severity of each port closure and its effect on the other ports. The analysis in this chapter will help in identifying interesting regions that need to be analysed in further details.

Port utilization is the ratio of the logs quantity handled per year by a certain port to the annual capacity of that port. Table (14) shows the ports utilizations under different scenarios. It is noticed that in the initial state (where all the ports are working) the utilization of all the ports is the same (77%) this is a result of the assumption that was previously made regarding the capacities of the North Island ports. This state is the reference for quantifying the impact of port closure on the other port, in which if the utilization of a certain port is 77% after a port closure event this means that the closure did not affect this port otherwise it means that it was affected. For example, when Tauranga port is shut down Wellington and Whangarei ports utilizations stay the same at 77% which means that they were not affected and they are handling the same amount of logs that they were supposed to handle before the closure. On the other hand, Napier, New Plymouth, and Gisborne ports utilizations have increased, which means that they have handled more logs than they were supposed to before the closure.

Port Utilization

	All Ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
Tauranga	77%	Closed	83%	83%	90%	93%	83%
Wellington	77%	77%	Closed	100%	81%	77%	99%
Napier	77%	99%	100%	Closed	77%	77%	100%
New Plymouth	77%	87%	85%	85%	Closed	77%	77%
Whangarei	77%	77%	77%	77%	77%	Closed	77%
Gisborn	77%	100%	77%	88%	77%	77%	Closed

Table 14 Port Utilization During Each Closure Scenario

Tauranga port supports all the other ports during their closure. In addition, Napier port is operating at full capacity in three out of five closure events. This indicates the importance of these two ports as contingency infrastructure to mitigate the effect of port closures on the North Island.

The quantity of logs that will wait until their primary port reopens represents lost sales for the forest owners. Figure (18) shows these quantities at each closure scenario. At the reference state the quantity of logs waiting when all the ports are working is zero, the bars on the right-hand side of each pair in the Figure represent the allocated quantity to each port at that state. The amount of logs waiting is an indicator of the logistical network robustness, in which if the network is able to export a good portion of the allocated quantity of logs via another port while continuing to be more profitable than waiting until the primary port is open again then the network is considered to be robust. It is noticed that New Plymouth port is the most sensitive port in the network because if it closes 2.2 million tons of logs (around 75% of the allocated quantity to that port) must wait until the port is open again.

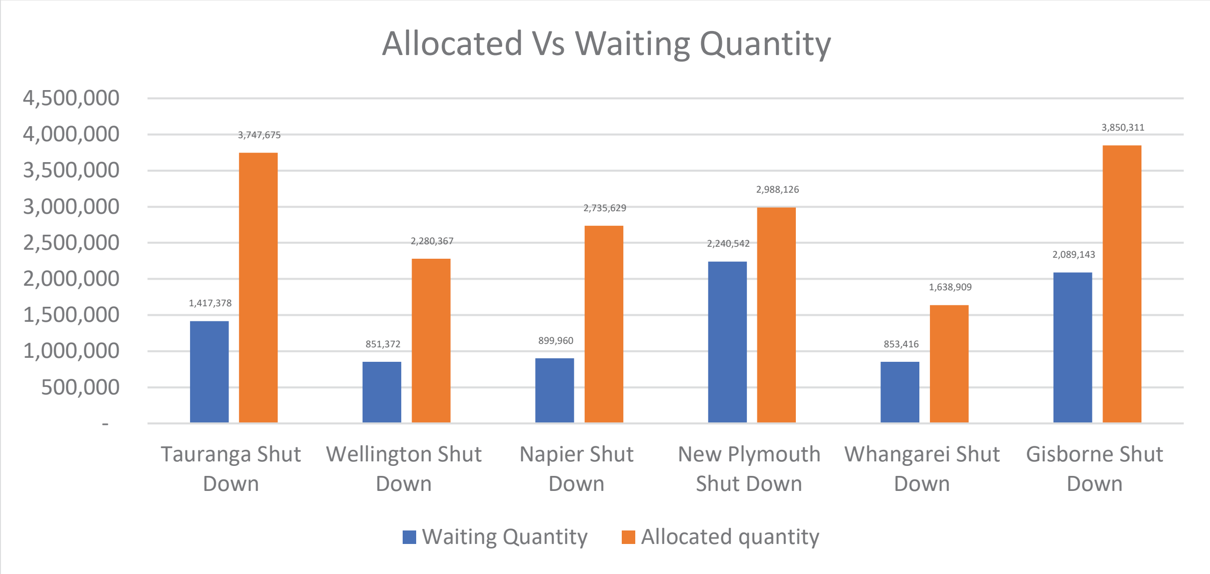

Figure 18 Waiting Vs Allocated Quantity During Each Closure Scenario

Table 15 shows the Resilience Index (β)value during each scenario. It is noticed that Wellington port closure will minimally affect the network performance, as the waiting quantity is relatively small (see Figure 18) indicating that the port is well supported by other ports. Even though the waiting quantity is very close to the waiting quantity during Whangarei port closure, it should be compared to the allocated quantity to the port. Another example, when Tauranga port shut down around 1.5 million tons of logs must wait until the port reopened, comprising 39% percent of the total allocated quantity. This percentage is calculated by dividing the waiting quantity on the total allocated quantity as the quantities are shown in Figure 18. On the other hand, when Whangarei port shutdown 0.9 million tons of logs must wait until the port is open again. However, this quantity represents 55% percent of the total allocated quantity. If the same amount of logs that was allocated to Tauranga port was allocated to Whangerie port, then it is expected that the impact of closing Whangarei port will be much more severe than closing Tauranga port and will cause the resilience index to drop significantly. Accordingly, it is important to look at the waiting quantity as a percentage of the total allocated quantity during the analysis of the resilience indexes (in Table 15) in the different scenarios in order to pin point the true weaknesses in the network and respond properly.

Scenario	Resilience Index (β)
All Ports Working	100%
Tauranga Shut Down	91.78%
Wellington Shut Down	95.06%
Napier Shut Down	94.78%
New Plymouth Shut Down	87.00%
Whangarei Shut Down	95.05%

Gisborne Shut Down	87.88%

Table 15 Resilience Index During Each Scenario

In the case of port closure, it is expected that total cost will increase when compared to the reference state (all ports are working). This increase is a result of exporting a proportion of the allocated logs quantity through farther ports and the costs incurred to wait until the port is open again, which includes maintenance, insurance, and other costs. Figure (19) shows the total cost and net profit in each scenario. It is noticed that the highest increase in cost is in the case of Gisborne and Tauranga ports closure, this increase is because of the high quantities that were allocated to these ports that need to be redistributed on the other more distant ports.

Profit acts differently during a port closure event because of the previously mentioned price sensitivity assumption. From the Figure, it is noted that whenever a port is closed the net profit increases, this is because when the port is closed the log prices spike and all the logs will be sold at a higher price and a much smaller proportion of them will incur additional transportation costs. Even though that the waiting quantity is sold at a lower price, the increased price during the port closure offset this loss. It noticed that the higher the allocated quantity to the port the higher the profit when that port is closed, which is due to the proportional relation between the anticipated supply shortage and the increase in the price. For example, the profit during Gisborne port closure and Tauranga port Closure is the highest.

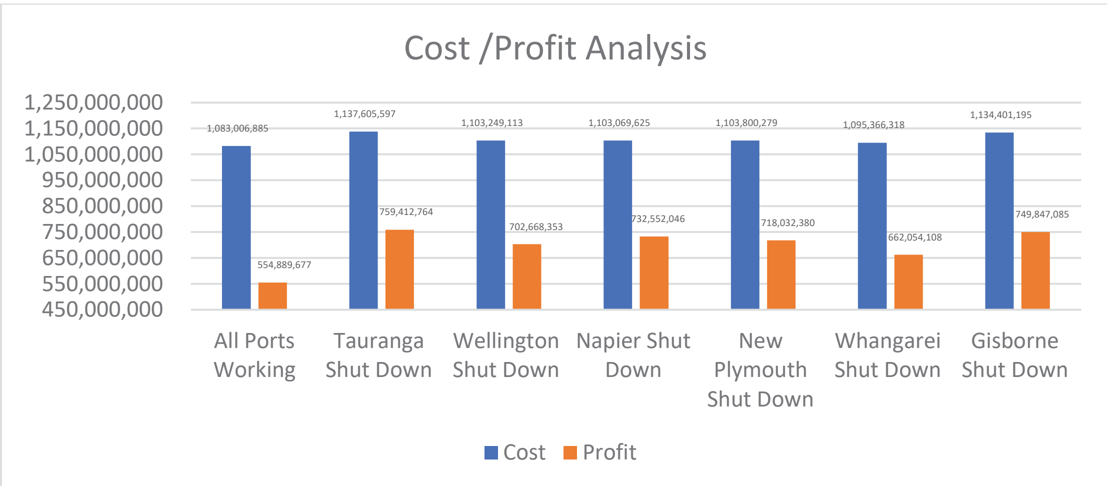

Figure 19 Cost/ Profit During Each Closure Scenario

4.5- South Island Model Results

The South Island was divided into 23 district and the amount in tons of logs (M_j) to be exported from each district annually is shown in Appendix A.3. All the ports in the island can be used by any district, so any port other than the primary port of the district is a secondary port for that district. Similar to the North Island model, the waiting option is added as a secondary port for all the districts (primary port (X_{ij}) and secondary port (XS_{ij}) allocation matrix is shown in Appendix C.1 and C.2, respectively.).

The ports capacities as calculated in the previous section (C_i) is shown Table (16). Unlike the North Island model, the calculated ports capacity are enough to satisfy the future demand with a good allowance of extra capacity, which will enable us to see how the ports are effected when one of them is shut down.

Port	Capacity Tons/Year	Allocated Quantity Tons/Year
Nelson	1,110,639	633,991
Christchurch	962,764	697,755
Otago	1,288,243	1,073,582
Invercargill	762,085	219,918
Timaru	815,629	570,245
Picton	1,018,608	593,949

Table 16 Calculated Ports Capacities Vs Allocated Quantities

Table 17 shows the ports utilizations under different scenarios. It is noticed that in the initial state (where all the ports are working), the utilization varies from one port to another depending on the allocated quantity and the port capacity. Unlike the case in the North Island where the utilization at the initial state was 77% for all the ports because of the assumption made about their capacities. This state is the reference for quantifying the impact of port closure on the other port. If the utilization of a certain port stay the same as it is at this state during a port closure event, then this means that the closure did not affect this port otherwise it means that it was affected. For example, when any port shut down Nelson port utilization stays the same at 58% which means that it was not affected by any of the closures. On the other hand, Invercargill port utilization rise form 29% at the initial state to 100% when Otago ports are closed, which means that it handled more logs than it was supposed to before the closure. It is noticed that there is a minimal interaction between the ports during a closure event, except in the case of Otago ports closure in which we can see a significant increase in the quantities handled by Invercargill port and Timaru port.

Port Utilization

	All Ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
Nelson	57%	0%	57%	57%	57%	57%	57%
Christchurch	72%	72%	0%	72%	72%	72%	76%
Otago	83%	83%	83%	0%	83%	83%	83%
Invercargill	29%	29%	29%	100%	0%	31%	29%
Timaru	70%	70%	75%	83%	70%	0%	70%
Picton	58%	58%	58%	58%	58%	58%	0%

Table 17 Port Utilization during Each Scenario

Figure (20) shows the waiting quantities verses the initially allocated quantities to each port at each closure scenario. Similar to the North Island model, the quantity of logs waiting when all the ports are working is zero. From the Figure, it is noticed that waiting quantity is almost equal to the allocated quantity to the closed port , except in the case of Otago ports shut down. This finding reinforces the previous conclusion about the minimal interaction between the ports,which is mainly because of the dispersed geographical nature of the South Island,

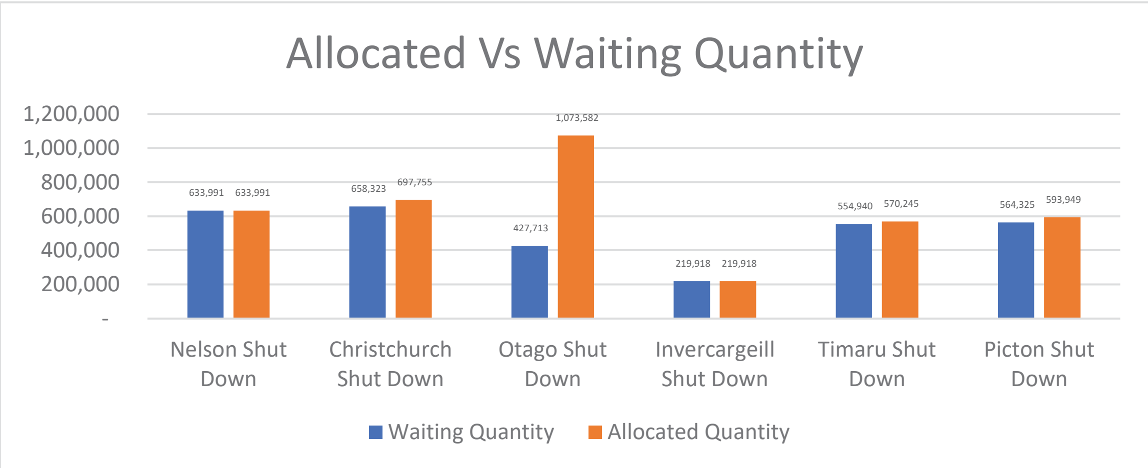

Figure 20 Waiting Vs Allocated Quantity During Each Closure Scenario

Table 18 shows the Resilience Index (β)value during each scenario. From the Table, it is noticed that Otago ports closure have the minimum effect on the network performance, as the waiting quantity is relatively small indicating that the port is well supported by other ports. On the other hand, it is noticed that any other closure will significantly impair the logistical network performance in the South Island. This weakness in the South Island network is mainly because of the big geographical area of the island, which increases the cost of rerouting the logs through other ports making the option of waiting until the closed port opens again a more profitable option.

Scenario	Resilience Index (β)
All Ports Working	100%
Nelson Shut Down	83%
Christchurch Shut Down	83%
Otago Shut Down	89%
Invercargeill Shut Down	94%
Timaru Shut Down	85%
Picton Shut Down	85%

Table 18 Resilience Index During Each Scenario

As mentioned earlier, total cost will increase during a port closure when compared to the reference state (all ports are working). This increase is a result of exporting a proportion of the allocated logs quantity through farther ports and the costs incurred to wait until the port is open again, which includes maintenance, insurance, and other costs. Figure 21 shows the total cost and net profit in each scenario. It is noticed that the highest increase in cost is during Otago ports closure, this is because the relatively huge amount being rerouted through other ports. However, in the other closure scenarios the cost increase is minimal, that is because the increased cost is only coming from the waiting cost as most of the logs allocated to the closed port are waiting until the closed port opens again. The profit acts similarly in both North Island and South Island models, in which the net profit increases when a port a closure happens for the reason was discussed earlier.

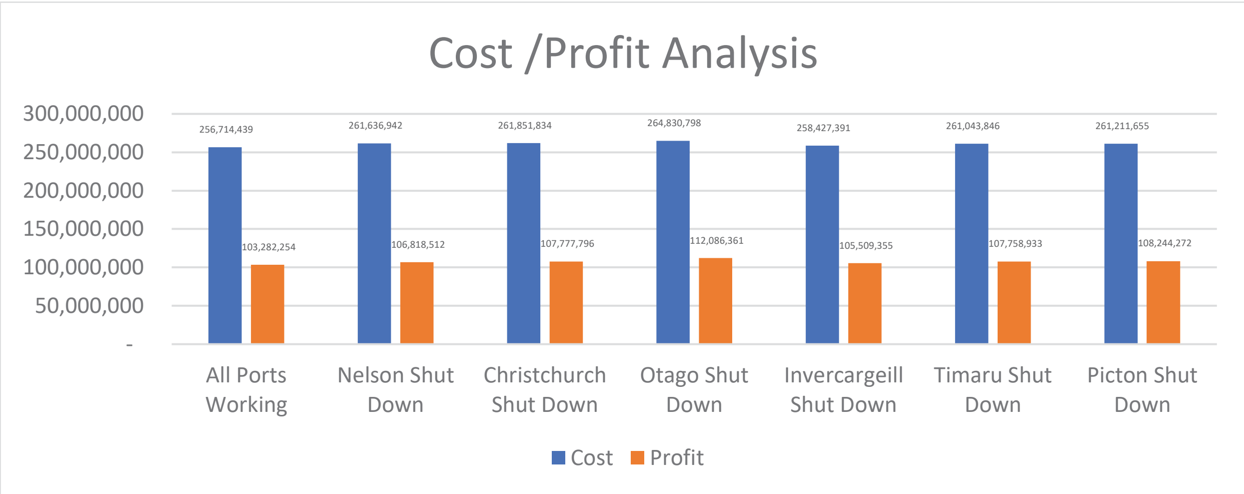

Figure 21 Cost/ Profit During Each Closure Scenario

4.6- Sensitivity analysis

The model objective function is constrained by the ports capacities and affected by two variables log prices and total cost. The changes in price and cost alter the optimal solution, in this section the interaction dynamics of these two factors will be discussed.

4.6.1- Log Prices.

Log price variations affect the optimal solution and change the rerouting decisions of the model. Table 19 and 20 show the impact of decreasing/increasing the average price by 20% on the waiting quantity, cost and net profit for the North Island and the South Island, respectively. It is noticed that the price change is inversely proportional to waiting quantity. This is a logical conclusion because increasing the average price will amplify the price increase during the port closure and will offset the cost of transporting the logs to farther ports, which will make the rerouting option more profitable than waiting until the port opens again. This also means that the ports utilization will increase because of the increased exporting volume. However, it is noticed that the waiting quantity in some cases in the North Island and in most cases of the South Island was not affected by the price increase. The reason of this constant behavior is that the 20% increase in the price was not enough to make rerouting option more profitable than the waiting option. The 20% increase in the price was not enough because of the additional long distances the logs will have travel to get to the alternate port, especially in the South Island which is geographically diverse.

It is common sense that the net profit is directly proportional to the price change as increased revenue at a constant cost will increase net profit, which is the noticed trend from the tables. However, it is noted that the total cost also increases when the price is increased, this additional cost is justified by the increased exporting quantity that was induced by the increased price.

Waiting Quantity (Thousand Tons) Sensitivity

Factor	All ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
20% Price Increase	0	693	311	843	2,241	853	1,221
20% Price Decrease	0	1,503	1,442	1,252	2,241	853	2,089

Total Cost (Millions NZD) Sensitivity

Factor	All ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
20% Price Increase	1,083	1,156	1,110	1,105	1,107	1,097	1,162
20% Price Decrease	1,083	1,134	1,096	1,096	1,100	1,094	1,131

Net Profit (Millions NZD) Sensitivity

Factor	All ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
20% Price Increase	882	1,139	1,064	1,098	1,077	1,011	1,125
20% Price Decrease	227	384	345	369	359	313	378

Table 19 North Island Model Sensitivity Analysis for Price

Waiting Quantity (Thousand Tons) Sensitivity

Factor	All ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
20% Price Increase	0	634	658	428	220	351	88
20% Price Decrease	0	634	658	531	220	555	564

Total Cost (Millions NZD) Sensitivity

Factor	All ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
20% Price Increase	257	263	263	265	259	262	263
20% Price Decrease	257	261	261	264	258	260	260

Net Profit (Millions NZD) Sensitivity

Factor	All ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
20% Price Increase	175	179	180	186	178	180	181
20% Price Decrease	31	35	35	38	33	35	36

Table 20 South Island Model Sensitivity Analysis for Price

4.6.2- Costs

Cost variation also affects the optimal solution and changes the rerouting decisions of the model. Table 21 and 22 show the impact of decreasing/increasing the total cost by 20% on the waiting quantity, cost and net profit for the North Island and the South Island, respectively. It is noticed that in most cases in the North Island model the cost change is directly proportional to waiting quantity, this is a logical result because increasing the cost will make the waiting option more profitable than transporting the logs to farther ports. However, in the South Island model the quantities stays constant because they are already around their maximum, which is the allocated quantity for the closed port. Surprisingly, in the Otago ports closure scenario the total waiting quantity decreases when the cost was increased. After investigating the reason of this anomalous behavior, it was noted that increasing the costs by 20% makes rerouting the logs to Timaru or Invercargill port cost around the same as waiting until Otago ports open again. This explains the decrease in the waiting quantity because the objective function is maximizing the profit and the logs will be sold at a higher price during the port closure than if sold after the port is open again. The fact that the model reveals solutions that may appear counter intuitive confirms the value of this technology.

It can be concluded that the relation between the increase/decrease in cost and the waiting quantity is dependent on the cost differences between the available options for each region. After deciding the impact of the cost increase, the ramification of this increase on the ports utilization is anticipated depending on the waiting quantity. The increased waiting quantity means that the ports utilization will decrease because of the decreased exporting and vice versa. The Tables also shows a logical inverse relation between net profit, total cost and cost change, in which increased cost at the same original price assumptions will decrease the net profit and increase the total cost, and vice versa.

Waiting Quantity (Thousand Tons) Sensitivity

Factor	All ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
20% cost Increase	-	1,503	1,139	1,221	2,241	853	2,089
20% cost Decrease	-	693	311	843	2,241	853	1,221

Total Cost (Millions NZD) Sensitivity

Factor	All ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
20% cost Increase	1,300	1,363	1,321	1,318	1,325	1,314	1,361
20% cost Decrease	866	924	887	883	883	876	928

Factor	Net Profit (Millions NZD) Sensitivity						
	All ports Working	Tauranga Shut Down	Wellington Shut Down	Napier Shut Down	New Plymouth Shut Down	Marsden Shut Down	Gisborne Shut Down
20% cost Increase	338	533	483	514	499	444	525
20% cost Decrease	771	989	924	952	937	880	978

Table 21 North Island Model Sensitivity Analysis for Cost

Factor	Waiting Quantity (Thousand Tons) Sensitivity						
	All ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
20% cost Increase	-	634	658	428	220	555	564
20% cost Decrease	-	634	658	531	220	555	564
	Total Cost (Millions NZD) Sensitivity						
Factor	All ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
20% cost Increase	287	293	293	296	289	292	293
20% cost Decrease	226	230	230	234	228	230	230
	Net Profit (Millions NZD) Sensitivity						
Factor	All ports Working	Nelson Shut Down	Christchurch Shut Down	Otago Shut Down	Invercargill Shut Down	Timaru Shut Down	Picton Shut Down
20% cost Increase	73	76	77	82	75	77	77
20% cost Decrease	134	138	139	143	136	139	139

Table 22 North Island Model Sensitivity Analysis for Price

4.7- Findings

The model was developed to maximize the net profit during port closure events. Port capacities were constraining the model and the tradeoffs between the incurred costs when using the waiting option and the rerouting options along with their corresponding generated profit according to the previously mentioned price assumptions forms the optimal solution. The allocation of forests to the ports varies under different closure scenarios, prices and cost levels (See appendices G&F) . For example, Gisborne district’s forests are originally allocated to Gisborne port and when the port shut down some of the quantity is exported through Napier and Tauranga ports and the rest waits until the port is open again. However, under the same closure scenario and if the cost is increased or the price is decreased, it is noticed that the allocated quantities to the supporting ports after the closure decreases and the waiting quantity increases. The analysis of the behavior of each district will help forest owners in selecting their forest locations to make their supply chains more resilient and capable to cope with sudden port closures.

The profit acts similarly in both North Island and South Island models. However, it is noted that the increase in profit during a port closure in the South Island model is less than the North Island model. The reason behind that is the relatively small quantity exported through the South Island in genera. The annual exporting volume from the North Island is estimated at 17.2 million ton/year during the period 2020-2025, while the South Island annual exporting volume is estimated at 3.8 million ton/year during the same period. This affects the impact of the port closure on the log prices, for example shutting Tauranga port alone will cause the price to increase more than shutting down all the South Island ports together. Accordingly, the change in the exporting volume will reform the optimal solution each time it changes, which makes the numerical findings of this research exclusive for the studied period. However, the conceptual findings and the methodology used in this research can be applied to other periods.

The mitigation of the port closure impact is dependent on the closure scenario. For example, in the Gisborne port closure scenario it can be concluded that the port is well supported and the waiting quantity can be reduced by expanding the supporting ports that became fully utilized after the closer (such as expanding Napier port, see Table 14). In other cases, such as the New Plymouth or Nelson scenarios, expanding the capacities of other ports will not help reducing the impact. All the ports are underutilized during the closure, see Table 14 and 17, because the ports are far from the allocated districts to New Plymouth and Nelson ports.

Even though each scenario has its own uniqueness, it is possible to find focal ports that can be used to improve the resilience of the whole network. Napier port is a good example because this port is almost fully utilized in three out of five port closure scenarios. Expanding this port will improve the resilience of the network against three closure scenarios. Otago and Wellington ports are also good examples of well-located ports, which makes studying the dynamics at these ports more interesting.

New Plymouth port is clearly isolated in the North Island's logistical network for two reasons: first, the current capacity (real capacity not the one used in the model) of the port is small and will not be enough to satisfy the forecasted future demand; Second, this is the only port on New Zealand's west coast, making rerouting the allocated forest of New Plymouth to other ports costly. The South Island's ports are almost entirely isolated from each other because of the big geographical area, which makes finding cost effective transportation modes necessary to solve the problem. In conclusion, more analysis is needed for each of these points to derive recommendations and action plans that could help in improving the resilience of New Zealand's logistical network.

The key insights that can be drawn from this chapter are the relations between the different factors that affect the resilience of the logistical network. Each closure event had forced the linear program to redistribute the forests on the available ports differently. The different ways that network responds to different closure scenarios provided some insight on the strategic importance of some ports. The effect of transportation costs and price changes on the viability of exporting had shed some light on the significance of these factors on the resilience and profitability of the supply chain. These insights allow the decision makers to see the most imminent needs that their logistical network requires. In the next chapter, discrete event simulation is used to simulate the regional logistical flow under a certain closure scenario. The objective of this step is to take the previous insights to a more detailed level that would enhance the logistical network resilience of the affected region against that closure scenario.

Chapter 5: Micro Analysis and Results

The results of the linear program are dependent on the assumptions made during building the model, so more analysis is needed to validate the recommended configurations by the liner program. In this chapter, the resilience of a regional logistical network is analysed in depth. This will be done by building a discrete event simulation model to simulate one of the closure scenarios. One closure scenario is selected to be simulated to produce recommendations to improve the logistical network resilience. It was mentioned earlier the primary data was gathered from Scion, however, in this chapter additional data was also gathered from the national rail in New Zealand Kiwi Rails, and other organizations and companies such as the log transport safety council and C3 (a product handling company operating at a number of ports in New Zealand).

The simulation of regional logistical flows aims at analysing the details of the logistical network by taking into consideration more constraints than what the previous section did to pin point the weaknesses of the logistical network and to present more realistic solutions accordingly. The aim of this step is to (a) consider the operational level constraints, that were not included in the linear program, and (b) to provide a more holistic risk mitigation plan that includes both strategic and operational level insights. In this part of the analysis the iterative thinking process (TP) of TOC is employed to spot, investigate, and release bottlenecks. The proposed distribution of forests under certain closure scenario by the linear program provides a high-level solution that needs to be validated by considering the lower level constraints existing in the logistical network. The integration of macro level analysis and micro level analysis in the proposed decision support system provides an iterative validating process for the proposed recommendation by the DSS.

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5.1- Model Description and Region Selection

In 2016 during the time of this research a significant series of earthquakes struck Kaikoura and caused Wellington port to briefly suspend its operations (NZ Herald. 2016). According to a survey conducted by Scion (2016), logs were rerouted to Napier port, which is consistent with the results of the linear program. However, because the closure was for a short period of time the rerouted quantities was not enough to fill Napier port and to spill over to New Plymouth port as the model predicted. The disruption caused by the earthquake revealed some of the dynamics of responding to Wellington port closure, but it was not severe enough to push the logistical network to its limits. As mentioned in the previous chapter, Wellington port is well supported by other ports, so closing this port will put more pressure on the logistical network in the lower North Island region. If the disruption was caused by a biosecurity threat or an earthquake with a higher magnitude, in which the port closure will be prolonged, then this will reveal the bottlenecks in the supply chain. In this chapter, the closure of Wellington port for a period of one year is analysed using the discrete even simulation software ExtendSim to identify the bottlenecks in the region's logistical network and to present recommendations accordingly.

To build a simulation model, the steps that a log goes through from harvesting until it is loaded on the ships must be studied. This will help in identifying and including the right sequence of activities, the available capacities and the time needed to execute each activity. Figure 22 is a flow chart of the processing steps that the logs undergo from harvesting to ship loading. At the beginning of the supply chain there is only a single flow of operations, in which harvesting and trucking the logs are done for all the logs. However, it is noted that there are two transportation modes that can be used to transport the logs, and the mode with the minimum cost is selected for each forest, which in turn affects the sequence of the activities.

The scaling activity will occur at different points depending on the transportation mode. For logs transported by train, scaling can be done at the train siding during loading or at the port during unloading and for the logs moved directly to the port by trucks, the scaling is done before unloading. Furthermore, if fumigation was available at the port, it is done on the wharf for some logs or alternatively in the ship's hold. This implies that logs coming from different forests might go through different processing steps until they are loaded on the ship, and each of these activities is a potential bottleneck that might need to be exploited to improve the supply chain performance. Accordingly, all these activities will be included in the simulation model.

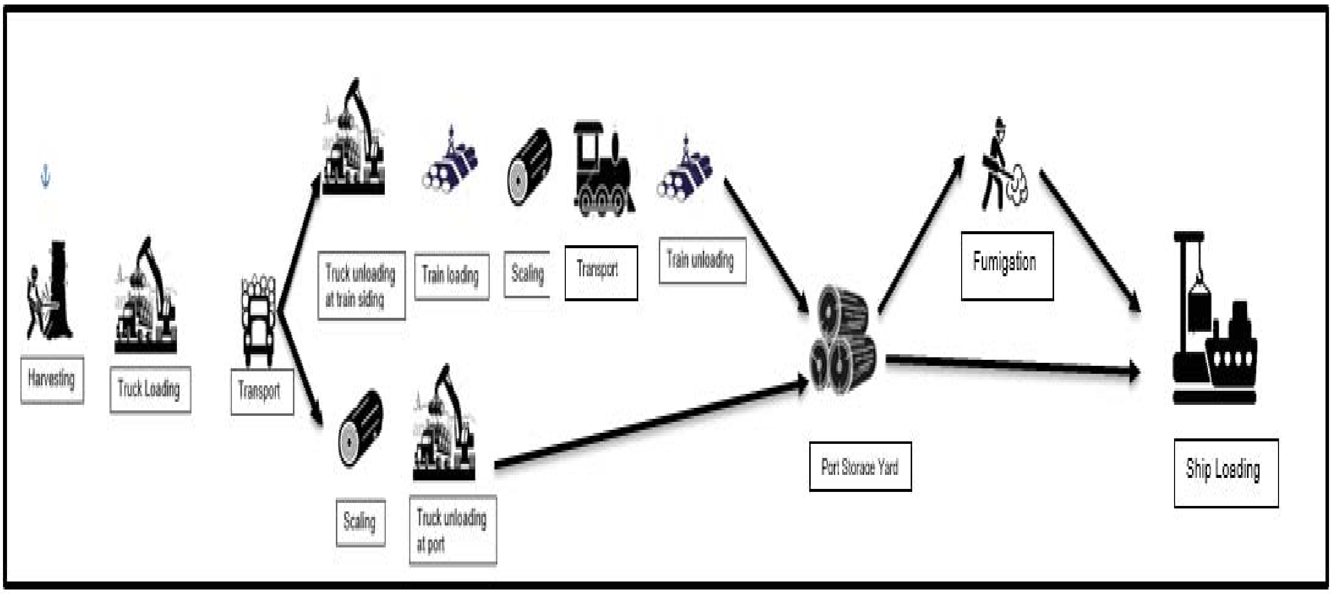


Figure 22 Logs Supply Chain Activities

Wellington port is shown in Figure 23 (a), where it is noticed that seven districts are allocated to this port. After the port is closed these districts are either waiting until the port reopens or rerouted to Napier and New Plymouth ports. Figure 23 (b) shows how the linear program redistributed the forests to the other available ports, while considering every possible distribution to maximise profit. It is important to notice that some of the forests that were originally allocated to Napier port (which was not closed) were now reallocated to other ports in order to make capacity available that will maximise the overall profit. These forests will put pressure on other parts of the logistical network outside the region of interest and were not included in the simulation model. The forests that are included in the simulation are the ones that were originally allocated to Wellington port and will be rerouted to other ports because of the closure. In addition to the forests that will be sharing the same facilities with the rerouted forests such as train sidings, trucks, port storage yard and other facilities and resources in the logistical network.

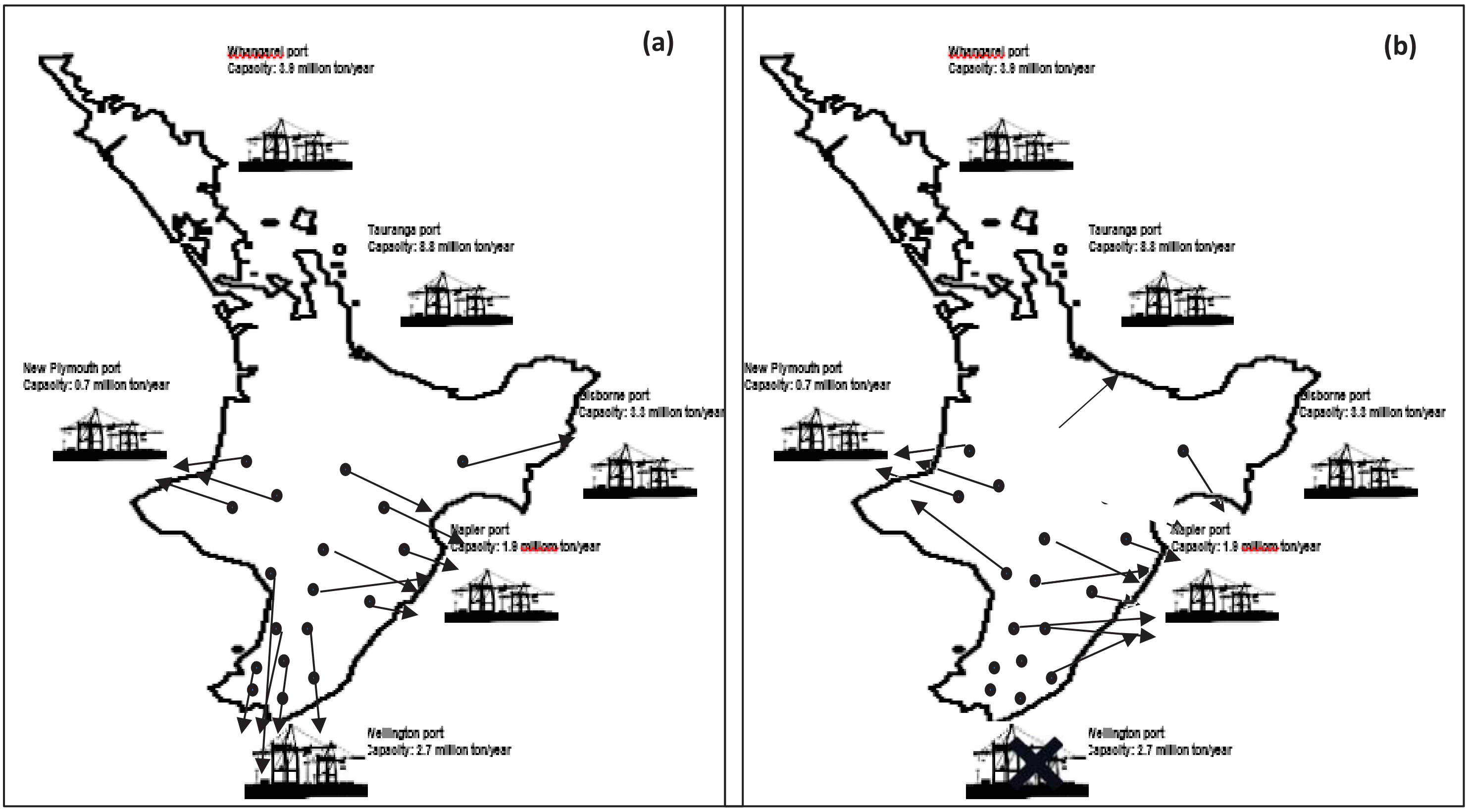


Figure 23 Forest Allocation Before and After Wellington Port Closure

The second type of forests will be introduced in the model at different points depending on the first point that they start to put pressure on the facilities used by the rerouted forests. Using this approach allow the decision support system to focus on the region of interest and present recommendations that are relevant to that region. For example, logs coming from Wairoa forests to Napier port uses different train sidings, trucks, and road network to transport the logs so they enter the model at the start of the port activities, which is where these logs start to put pressure on the shared facilities. On the other hand, logs coming from Rangitikei to Napier port will use the same trucks pool and road network used by the rerouted forests so they enter the model from the beginning of the supply chain.

The simulation model included all the processing steps that the logs undergo from harvesting to ship loading for the first type of forests. The harvesting activity triggers the model, in which once a truck load of logs is harvested the model assigns a truck to that load. The truck travels to its destination port or train siding where the unloading activity takes place. Once the truck is unloaded it will travel back to the forest to pick up another load. If the port or train siding yard is full then the truck will have to wait until the yard discharge some of the logs to be unloaded and only then the truck starts to travel back to the forest. If the log was unloaded at a train siding, then it will wait until a whole train load accumulate at the yard and for the train to arrives at the sidings. Trains have a predetermined schedule, if the train arrives at the siding and the yard at the train siding does not contain a whole train load then the train will wait until the full load accumulates at the yard. Once the train or the truck arrives to the destination port, it is unloaded there if there is space in the yard otherwise it will have to wait. Scaling activity takes place before unloading the logs from the truck or during unloading the logs from the train. If the port has fumigation facilities, then 50% of the unloaded logs will be fumigated at the port yard while the rest are fumigated on the ship. The logs then accumulate at the port yard until a ship arrives, once a ship arrives a certain load is assigned to the ship. The ship goes through some stages such as berthage and wharfage before the loading activity starts. When the ship arrives at the wharf, the loading activity starts after which the ship exists the model. In the following sections these stages are discussed in detail.

5.1.1- Harvesting

Forest harvesting rate is dependent on the amount of machinery and personnel deployed in the forest. In the case of a port closure, the harvesting activity is released because some of the forests that were supposed to be harvested during the year will be delayed until the port reopens. In the model, it was assumed that the harvesting of each forest was distributed over the full year in order to level the demand on the machinery and personnel. Accordingly, the harvesting rate varies from one forest to another depending on the forest volume. One harvesting crew can harvest 428 hectares/year and one crew can only load 2-3 trucks at a time. The number of trucks that can be loaded at the same time for a certain forest is proportional to the number of crews deployed in the forest. This number was calculated by dividing the total area of the forest allocated for harvesting by 428 hectares/year/crew and the resulted number is then rounded up to estimate the loading capacity at the forest. Furthermore, working hours and shifts were also taken into consideration during the calculation of the harvesting rate. In New Zealand harvesting companies work 8 hours/day and 5 days/week, so the total number of working hours is 40 hours/week. Public holidays and annual leave were also accounted for and were assumed to be 4 weeks/year so the year was assumed to be 48 weeks instead of 52 weeks. To calculate the harvesting rate for a certain region, the annual production volume was divided by 48 weeks/year and then by 40hours/week.

5.1.2- Primary Transport

The simulation model considers two primary transport modes to move logs from the forests in order to preserve consistency with the linear program assumptions. The process starts with loading the trucks at the forests and then transporting them to the train sidings or to the port yards directly. Depending on the truck destination, the truck load might or might not be scaled before unloading. If the truck destination was the train siding, then the load will not be scaled and if the destination was a port yard then it will be scaled before unloading. Scaling the logs on the truck before unloading means that the resource (the truck) will be held for a longer period of time, which will constrain the use of that resource. The logs arriving by train will be scaled either at the train siding during train loading or at the port during train unloading. However, according to the scaling companies, it is preferred to perform scaling at the port because it will be more accurate so it was assumed in the model that the scaling for logs coming by train is done during offloading at the port.

After the truck arrives at its destination port or train siding it is offloaded and then it travels back empty to the forest. The average speed of the loaded truck is 60 km/hour and the speed of the empty truck is 70 km/hour. The train speed is 80 km/hour, regardless if it was loaded or not. The travelling time is dependent on the truck/train origin and destination points (see Appendix B for distances). The time needed to perform loading, unloading and scaling varies depending on the logs sizes. Triangular statistical distributions were used to describe the time needed to perform each activity, in which there is a maximum, minimum and most likely values (see Table 23). The values in Table 23 were gathered from C3, a product handling company operating at Napier port, New Plymouth port and other ports in New Zealand.

ACTIVITY	MAXIMUM (MIN)	MINIMUM (MIN)	MOST LIKELY (MIN)
TRUCK LOADING	60.0	10.0	40.0
TRUCK UNLOADING	10.0	5.0	7.5
TRUCK SCALING	20.0	5.0	12.5
TRAIN LOADING	180.0	120.0	150.0
TRAIN UNLOADING AND SCALING	321.6	254.4	288.0

Table 23 General Transport Activities time

5.1.3- Rail Way

The logistical network of the region of interest has three log train sidings, Palmerston North , Waingawa and Woodville. As shown in Figure 24, the trains coming from Palmerston North and

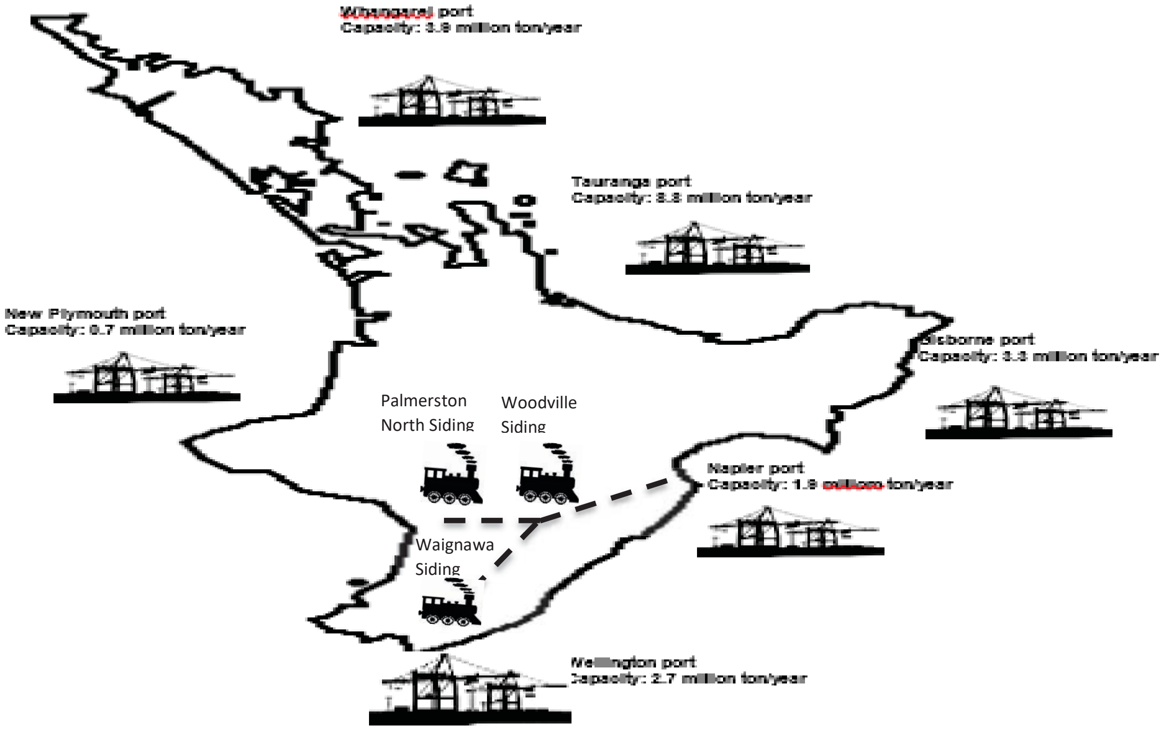


Figure 24 Train Sidings and Rail Line locations.

Waingawa sidings intersect at Woodville, which makes it a congestion point. Consequently, the total number of trains that can be operated in the rail way is constrained to 8 trains distributed over 24 hours. The capacity of the storage yard of each siding, the number of trucks that can be unloaded at the same time and the number of trains that can be loaded at the same time are shown in Table 24 and the number of trains that can use a certain rail line at the same time is shown in Table 25. The numbers shown in these tables were advised by Kiwi Rail and Scion.

TRAIN SIDING	YARD CAPACITY (TONS)	UNLOADING CAPACITY (TRUCKS)	LOADING CAPACITY (TRAINS)
PALMERSTON NORTH	3120	4	1
WAINAGAWA	7470	4	1
WOODVILLE	5070	4	1

Table 24 Train Sidings Capacities

RAIL LINE	CAPACITY (TRAINS)
PALMERSTON NORTH - WOODVILLE	1
WAINAGAWA - WOODVILLE	1

WOODVILLE - NAPIER	2

Table 25 Rail Line Capacities

5.1.4- Road Network

Trucking the logs directly to the port will not make the road network congested so it was not considered to be a constraint. However, the number of trucks operating in the network might become a constraint and slow down the flow of logs to the ports. Accordingly, a resource unit (truck) was assigned to each log parcel in the model from the moment the logs are loaded on the truck after harvesting until they are unloaded, either at the port or at the train siding. Furthermore, the truck trip back to the forest was accounted for in the model, so the truck only becomes available when it arrives at the forest. This was done to capture the possible impact of the number of available trucks on the regions logistical network performance.

The log transport safety council advised that there are 1750 log trucks in all New Zealand. The council also advised that 450 plus/minus 50 are operating in the region of interest. Since Wellington port closure will be considered an emergency, it was assumed that the total number of trucks that will be operating in the region is the maximum (500 trucks). In order to test whether 500 trucks are enough to move the logs from the forests to the train sidings and the port yards, it was assumed that the train sidings and port storage yards capacities were temporarily increased in a pre-run scenario to infinity to prevent the trucking activities (loading, transportation, unloading, and scaling) from being constrained at the yards. It was concluded that 500 trucks are enough to move the logs to their different destinations, further investigation revealed that 250 trucks was the minimum number of trucks required to do the same task, given that the previously mentioned trucking activities will not be blocked by the full yards. However, 250 trucks are enough only to move the logs allocated for exporting as the model does not take into consideration the other parts of the tree that are used locally by the processing mills. The number of available trucks in the region were assumed to be enough if the trucks were utilized efficiently. The real capacities of the yards were restored in the model after this test, which means that all the analysis of the model was done while the yards were constrained.

5.1.5- Ports

Napier and New Plymouth ports are used to export containerised cargo as well as bulk cargo. This means that the wharfs at the ports are used by both log ships and other types of ships. It was assumed (under an emergency) that log ships cannot use the wharfs for more than 35% of the time in

Napier port and 40% of the time for New Plymouth. This will constrain the available time to load logs ships. The allocated time in New Plymouth was slightly higher than Napier Port because it was concluded earlier in Chapter 4 that the allocated quantity New Plymouth port will be exporting during the period 2020-2025 is bigger than any quantity historically exported through that port and because the port only has two berths. These assumptions were discussed with specialists at Scion and were found to be reasonable during an emergency. The details of the capacities and available facilities in each port are shown in Table 26. These numbers were retrieved from Scion's data-base and C3. Although the loading of the log ships is done using the ship's cranes, the loading rate varies depending on how many cranes can be used at the same time. Each crane requires a crew and machinery from the port to be operated. This explains the difference in the loading rate between Napier Port and New Plymouth Port.

FACILITY	NAPIER PORT	NEW PLYMOUTH PORT
NUMBER OF WHARFS	3	2
RAIL LINK	Available	Available
FUMIGATION	Available	Not Available
STORAGE YARD CAPACITY	108,000 (m^3 JAS)	45,000 (m^3 JAS)
LOADING CAPACITY	390 m^3 JAS/ Wharf	240 m^3 JAS/ Wharf

Table 26 Ports Facilities and Capacities

It should be noted that the average load quantity per ship at New Plymouth port is lower than Napier port because New Plymouth port is shallow and ships cannot leave the port safely if they were fully loaded. Table 27 shows the distribution of the actual ship loading tasks that occurred at New Plymouth and Napier ports from 2013 to 2015 (Scion, 2017). These numbers were used to derive triangular probability functions for loading quantities.

PORT	MAXIMUM (M^3 JAS)	MINIMUM (M^3 JAS)	MOST LIKELY (M^3 JAS)
NAPIER	54,990	6000	20,010
NEW PLYMOUTH	21,000	2490	15,000

Table 27 Ships Loads Distributions

The activities that take place at the port are scaling, unloading, fumigation (if applicable), tugging the ship, berthing the ship and loading. Table 28 shows the time needed to perform these activities. The ship loading time is dependent on the amount of logs to be loaded and on the port's loading rate, so it is necessary to have unique loading time for each ship that enters the model. The model assigns a certain quantity to be loaded to each ship that enters the ports and then calculates the time needed to load the ship according to the load quantity and the port loading rate. If the allocated load to the ship exceeds the available quantity on the port yard, then the model will check if the available quantity is bigger than or equal to the minimum load quantity at that port (Table 27), in which case the available quantity will be loaded on the ship. Alternatively, the ship will not enter the port and more time will be given for the stock to accumulate on the yard.

Logs at the ports yards are owned by different exporters who charter different ships to export their logs. The allocation of a certain amount of logs to the ship that enters the port partially reflect this aspect in the model. For example, if a ship enters the port with an allocated load quantity of 10,000 m^3 JAS and the available quantity in the yard is 20,000 m^3 JAS then only 10,000 m^3 JAS will be loaded on the ship. This is assumed to represent the quantity that is owned by a certain exporter which has to go on a certain ship. However, when the available quantity in the port's yard is lower than the allocated load quantity to the ship and higher than the minimum load, all the available quantity is loaded on the ship as if it was owned by one exporter. This limitation in the assumption is not important because in real life, if the exporter realises that the ship will arrive at the port before the allocated quantity of logs is available, the exporter will often try to buy logs from other suppliers to load it on the ship on time. The model behaves in a similar way, but instead of generating more logs to arrive to the port at a certain time, it uses the available quantity in the storage yard.

ACTIVITY	MAXIMUM (MIN)	MINIMUM (MIN)	MOST LIKELY (MIN)
TUGGING	25	15	20
BERTHING	30	20	25
SHIP LOADING	Varies depending on load quantity and loading rate		

Table 28 Port Activities Times

The model simulates two supply chains, as the logs going to Napier port use different facilities than the ones used by the logs exported through New Plymouth port. However, both supply chains share the same pool of trucks to move the logs to their destinations. The trucks that were used in Wellington area are going for further distances to move the logs to New Plymouth and Napier ports, which increase the impact of any delay in truck unloading at the ports or the train sidings. This relationship makes the effect of a bottleneck in one supply chain affect the throughput of the other one. The results reported in this section focus on four aspects, (a) throughput, (b) work in process inventory (WIP), (c) activities and (d) resources utilization, and activities block time. Throughput is the amount of logs that leave the system, in the model this is represented by the total amount of logs leaving the ports storage yards. The objective was to maximise the throughput of the logistical network by identifying and exploiting the bottlenecks in the system. WIP is calculated by adding up all the quantities of logs accumulated at different parts of the logistical network, which is equal to the total harvested logs minus the system throughput. Stock levels in the train sidings and ports' yards during the simulation was plotted to visualise the amount of time during which a certain yard is full.

ExtendSim software calculates the cumulative utilization of each activity at the end of a simulation run. The utilization is calculated as a percentage of the available time, which means if a certain activity has an 8-hour shift per day and the activity was busy for 4 hours per day, the utilization will be 50%. Block time percentage is the percentage of time during which a certain activity is unable to move the logs to the next activity because a bottleneck is congesting the system. In that case the activity is idle because the logs cannot be moved forward in the supply chain, not because there is a lack in the supply or in the resources of the particular activity. This represents the lost capacity because of the bottle neck.

5.2- Results

This section presents the results of running four scenarios representing the logistical network in the lower North Island, New Plymouth, and Napier regions during the closure of Wellington port after different improvements are introduced in the network. The base scenario (scenario zero) simulates the logistical network after closing Wellington port without introducing any improvement in the logistical network. The consequent scenarios simulate the network after introducing a certain improvement in the network. The improvements accumulate for one scenario to the next, which means once an improvement is introduced into the model it is not removed from the next scenario one rather it is built upon it.

5.2.1- Wellington Port Closure Simulation (Scenario Zero)

This simulation scenario estimates what the network can process without making any improvements to the logistical network after closing Wellington Port. The results of the base scenario simulation showed that the total throughput of the logistical network will be 2.98 million m^3 JAS of logs, which is less than 50% of the total allocation to Napier and New Plymouth ports after closing Wellington port. From Figure 25, it is noted that most of the activities are underutilized and the highest utilization is for the train scaling and unloading at Napier Port (72%). Although this activity has the highest utilization, it remains underutilised, so the bottleneck is somewhere else in the supply chain.

It is also noted from Figure 25 that the truck scaling and loading activities at New Plymouth port are blocked for 71% of the time. By looking at the stock level charts in Figure 26, it is noted that stock levels at Napier port and the train sidings remained below the full capacity of the yard for most of the simulation time. However, New Plymouth yard is full at most of the time so it can be concluded that New Plymouth yard is the reason for the blocking and accordingly it is the bottle neck. The current congestion in the system, caused by New Plymouth's yard, was affecting the throughput of both Napier and New Plymouth ports because it was blocking the trucks from unloading. This caused the truck resource to be held for longer times and consequently constraining the trucking of logs to Napier port and to the train sidings.

In real life this probably will not happen because trucks will stop going to New Plymouth port until the congestion is released. It might also be argued that more trucks might be pulled into the region from other parts of the country, however, the number of trucks that can be dispatched to transport logs to Napier port is limited given that there are only 1750 logging trucks in the whole country. This does not mean that a congestion will not happen at New Plymouth port or that it will not affect Napier port, it only means it will be less severe than its shown in the model and the bottleneck will need to be exploited to improve the logistical network throughput.

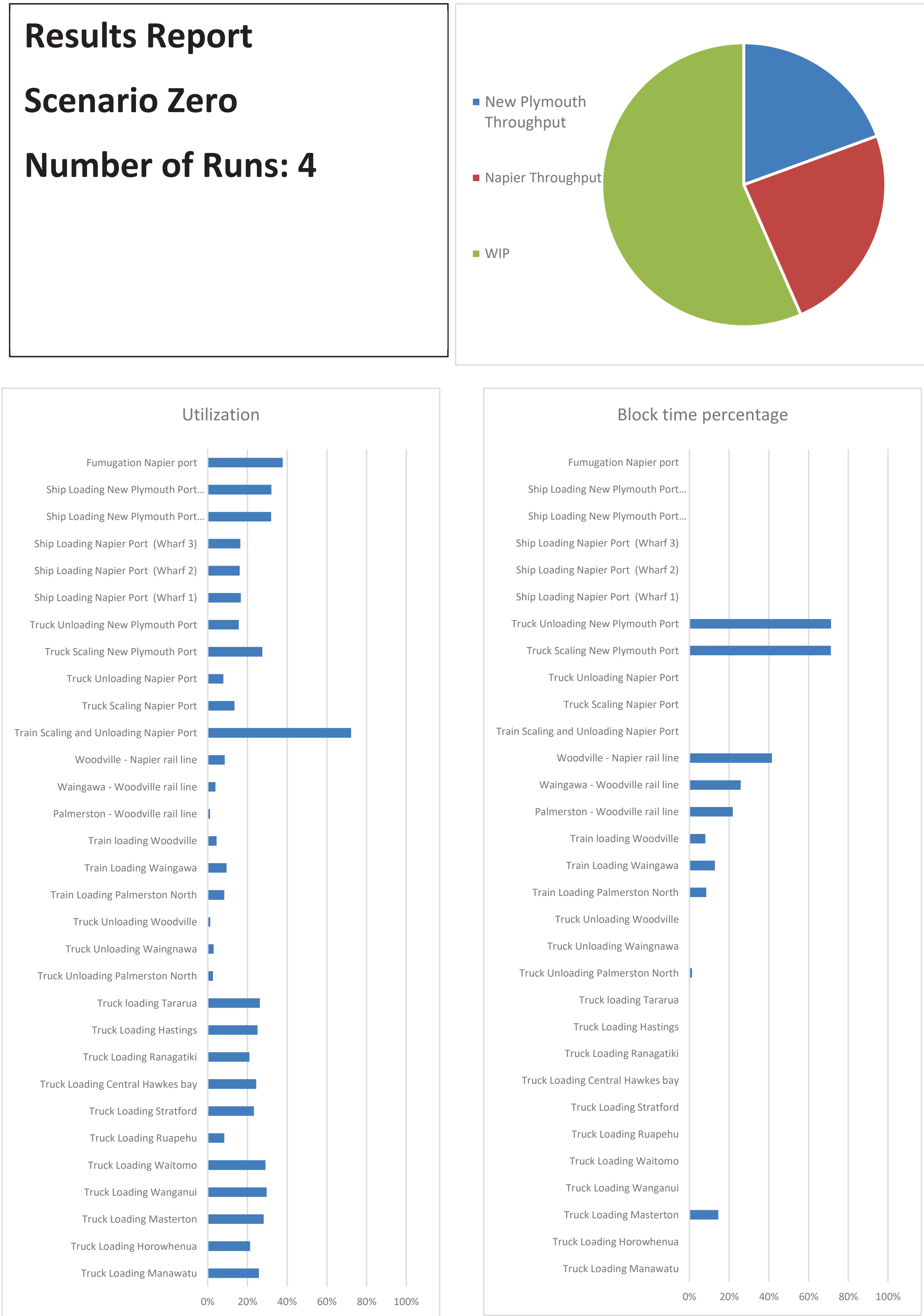


Figure 25 Results report for Scenario Zero

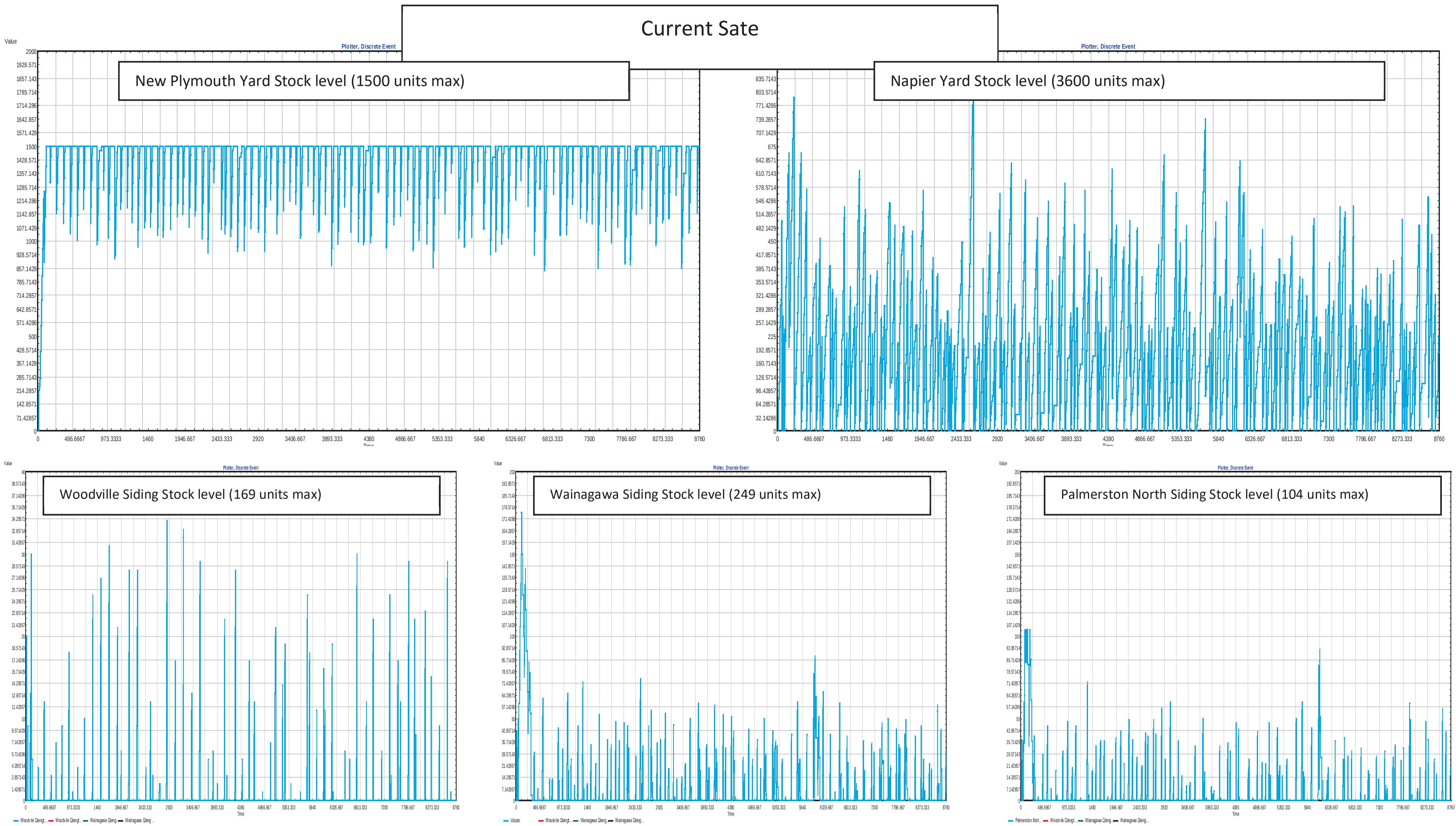


Figure 26 Stock Level Charts For Scenario Zero

5.2.2- Exploiting Constraint Number (1): New Plymouth Yard

Adding more trucks to the system might slightly improve the throughput, but it will not solve the problem, as the trucks will que again when the yard is full. Increasing the size of the yard at New Plymouth Port will not be enough to exploit the constraint either, as the yard will fill up again at a higher quantity and, after that, the system will be congested again. To solve the problem, stock levels at the yard needed to be lowered by increasing the ship arrival rates. However, it is important to maintain the wharf utilization by log ships below 40% to allow other ship types to use the wharf as well. To maintain this level of utilization, the ships need to be loaded faster by using all the available cranes on the ship during the loading process to increase the loading rate to 390 m^3 JAS/hr/Wharf. This will require the port to make a relatively small investment in machinery and hiring more people.

The new throughput of the system after increasing the loading rate had increased from 2.98 million to 4.88 million m^3 JAS (64% increase). Figure 27 reports the state of the logistical network after increasing the loading rate at New Plymouth port to 390 m^3 JAS/hr/Wharf. The utilization of the other activities in the supply chain increased because the quantity of logs handled increased as well. It is also noted from the stock level charts (Figure 28) that the stock levels in New Plymouth and Napier ports yards are below the maximum capacity for most of the time, which means that the trucks remain unloaded as they arrive most of the time. Although the improvement was done only to New Plymouth port, the throughput of both ports increased because of the improved efficiency in the shared truck resource. This increase was not sufficient to discharge all the allocated quantity to the logistical network. The total throughput of 4.88 million m^3 JAS represents 71% of the total allocated quantity. Further improvements was needed to export all the allocated logs through these two ports.

Exploiting this constraint reveals new bottlenecks in the logistical network, it is noted from Figure 27 that the activities at the three train sidings was blocked for a large proportion of time. This includes truck unloading, train loading and the rail lines themselves. It is also noted from the stock level charts (Figure 28) that Waingawa siding was full most of the time and that Palmerston North siding was also full for a substantial proportion of time at the beginning of the simulation. To identify the bottleneck that causes this congestion, the utilization chart in Figure 27 was considered. From Figure 27 it is noted that the utilization of the train scaling and unloading activity at Napier port was 100%. This suggests that this activity is the new bottleneck causing the congestion in the new network.

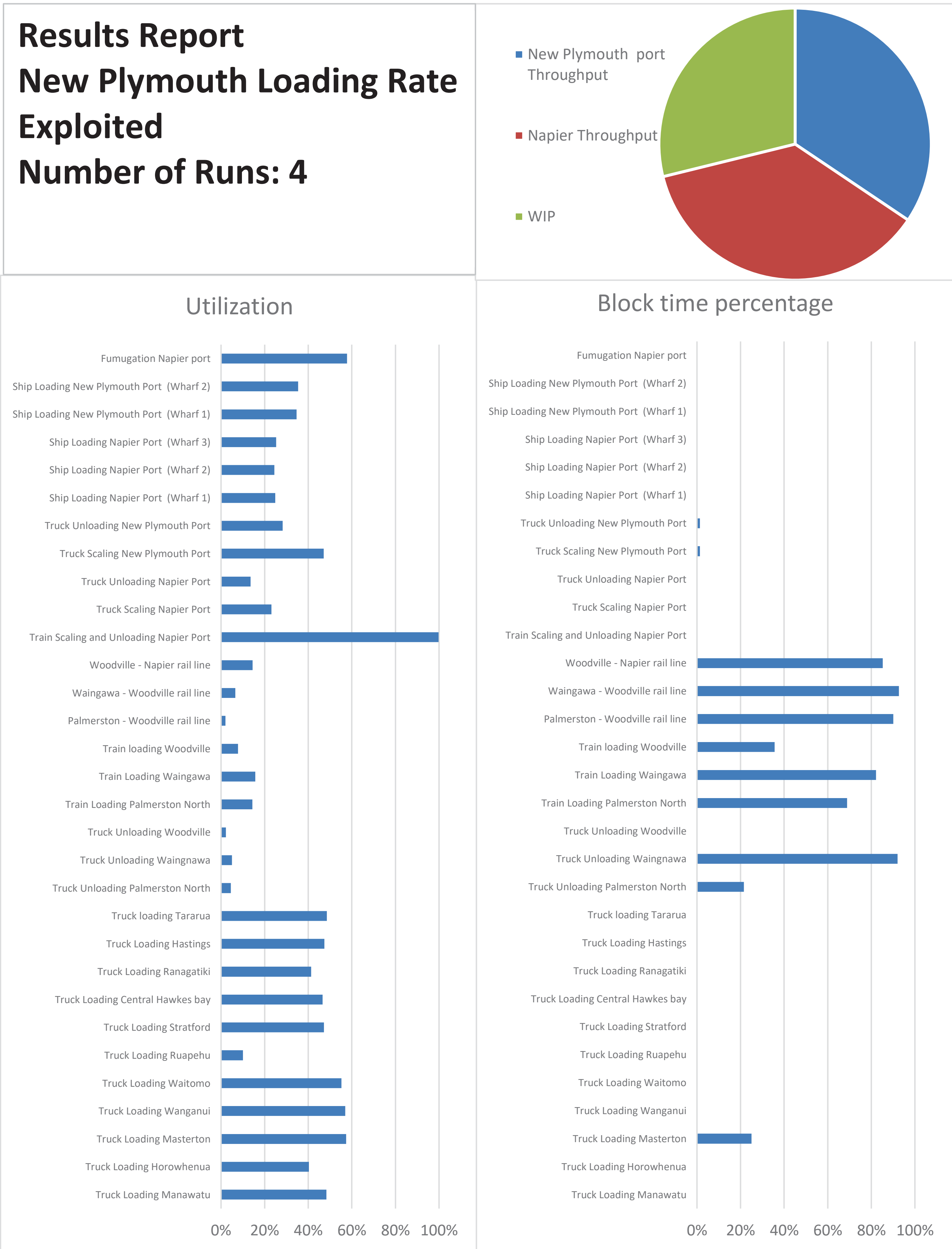


Figure 27 Simulation Results Report After Exploiting Ship Loading Rate at New Plymouth

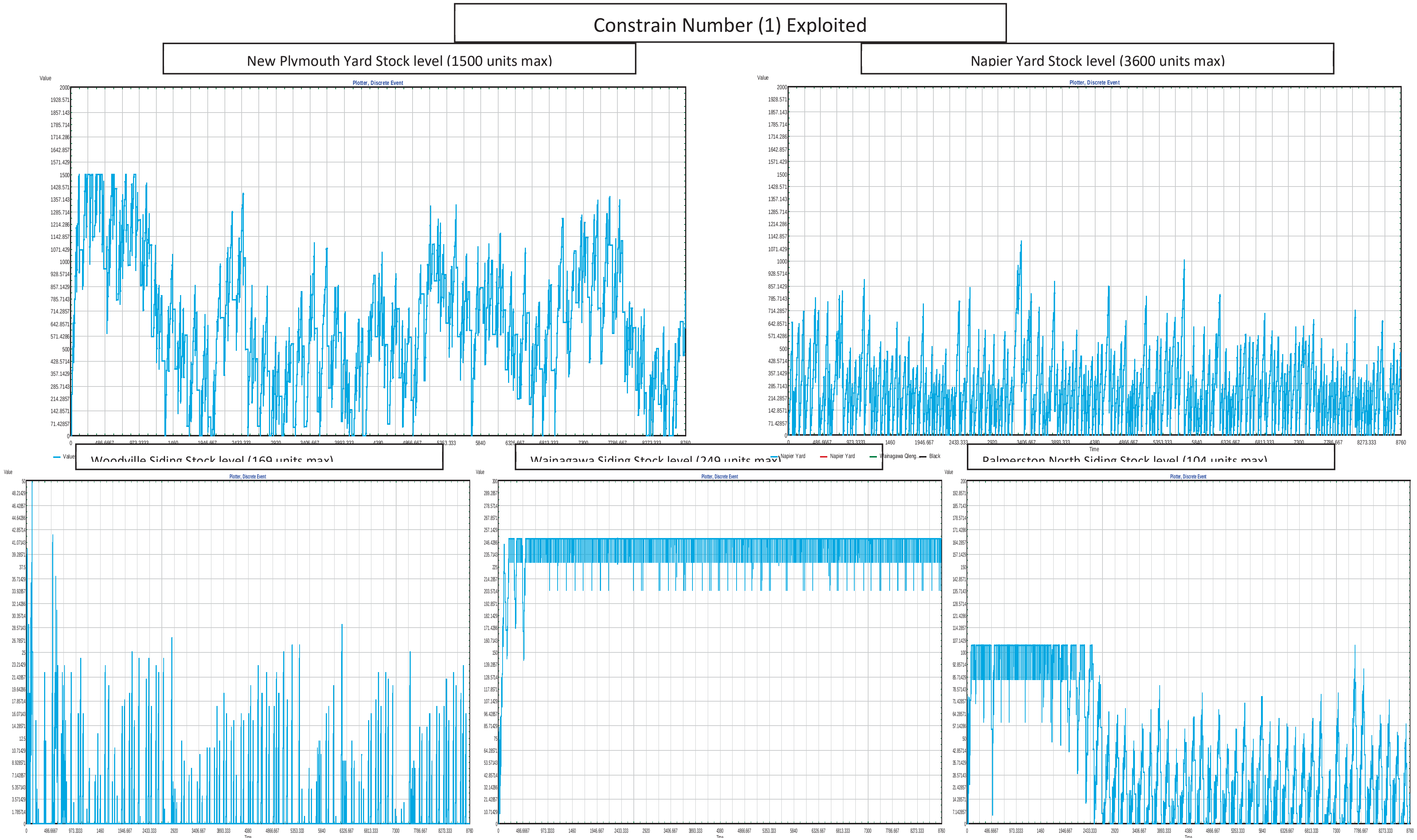


Figure 28 Stock Level Charts After Exploiting Ship Loading Rate

5.2.3- Exploiting Constraint Number (2): Train Scaling /Unloading at Napier Port

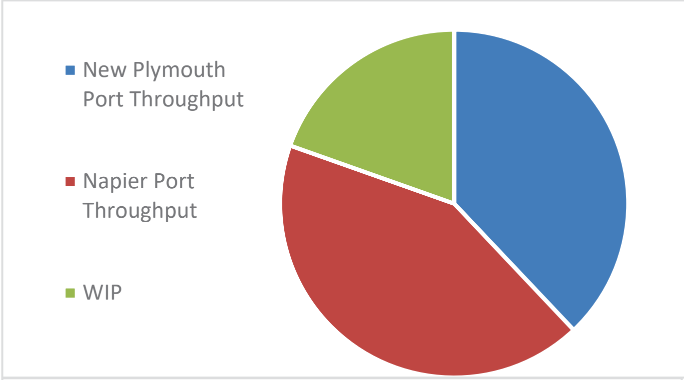
Similar to the previous constraint, the train scaling/unloading activity at Napier port impairs the throughput of both ports because it has a ripple effect. The slow unloading activity at Napier port was blocking the trains on the rail line from entering the port, which was causing a congestion in the rail lines. The congestion in the rail line was preventing the train sidings from loading more trains, which caused the accumulation of logs at the train sidings. When the train sidings yards reached their maximum capacities, they blocked the trucks from unloading because there was no place to store the logs. This in turn caused the trucks to be held for longer times to unload, which affected the throughput at both ports.

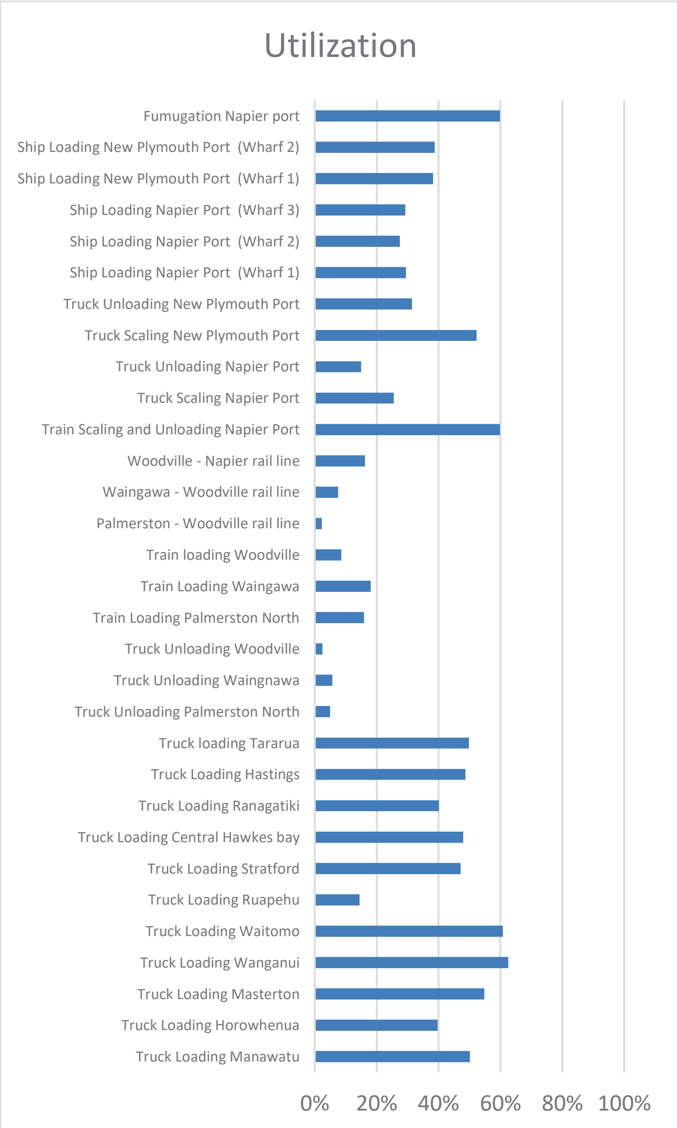
This constraint is similar to the previous one since increasing the number of trucks or the size of the train sidings will not help. To exploit this constraint, the train scaling and unloading activity had to be done faster. This activity starts with scaling the first three wagons of the train, which will give space for the unloading machinery to unload the train safely. Once the scaling team finishes the three wagons the unloading process starts and then both processes are carried out in parallel on the same train. To lower the scaling and unloading time, two scaling teams should work on the train from both ends. Once they have finished three wagons at each side, the unloading machinery can start unloading the train from both sides as well. This will lower the time needed to execute this activity by approximately 50%.

Figure 29 shows the result report for the logistical network after the time needed for train scaling and unloading activity was reduced by 50%. The throughput of the system increased to 5.52 million m^3 JAS, which is 0.64 million higher (13% increase) than the throughput before the constraint was exploited. It is also noted from the stock levels charts in Figure 30 that the stock levels in Napier port and the train siding yards remained below the maximum capacity most of the time, which means that the trucks are unloaded as they arrive most of the time. The new throughput was still insufficient to export the full allocated through the two ports. The total throughput of 5.49 million m^3 JAS represents 80% of the total allocation. Further improvements were still needed to export all the allocated logs through these ports.

The utilization chart shows that all the activities in the supply chain are underutilized, but the block time chart shows that truck scaling and truck unloading activities are blocked for 30% of the time. By looking at the stock levels chart it is noticed that New Plymouth Port yard is full most of the time, which means that this is the bottleneck. New Plymouth yard was exploited in the first constraint (scenario 1) by increasing the loading rate at the wharf. However, after exploiting the train unloading and scaling activity the truck efficiency was indirectly increased, which in turn increased the log arrival rate at New Plymouth port. This caused the already improved system unable to absorb the increased number of logs arriving at the port, which caused the logs to accumulate at New Plymouth port yard and congesting the system.

Results Report
Scenario (3): Train Unloading Exploited
Number of Runs: 4





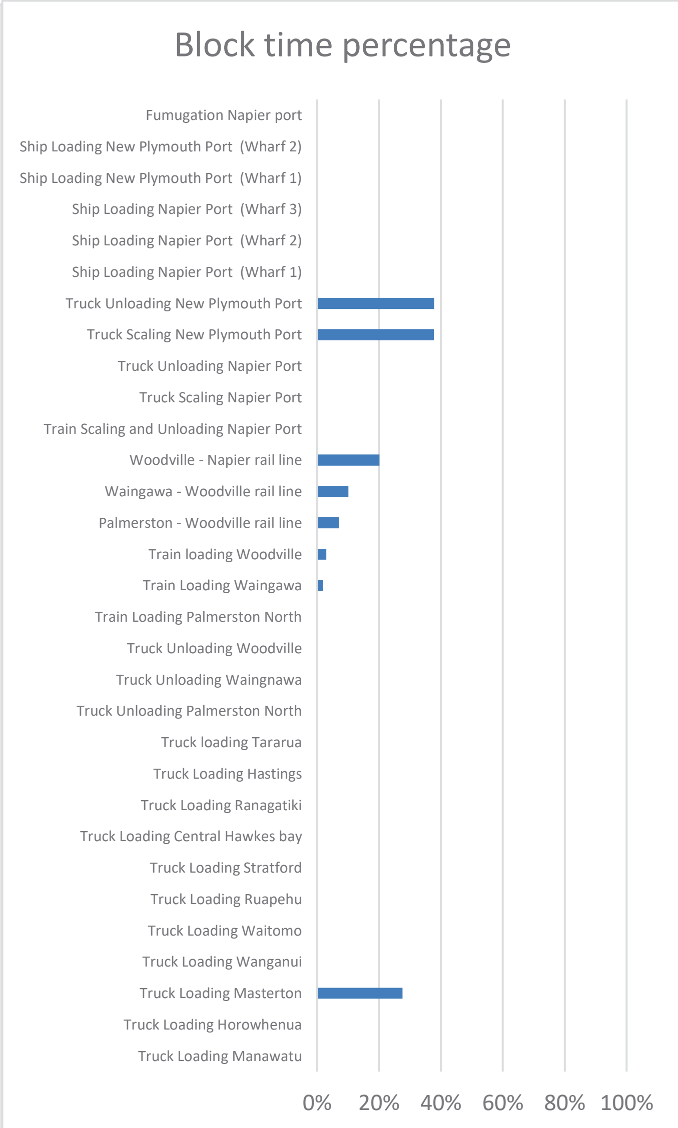


Figure 29 Simulation Result Report After Exploiting Train Scaling and Unloading Activity at Napier Port

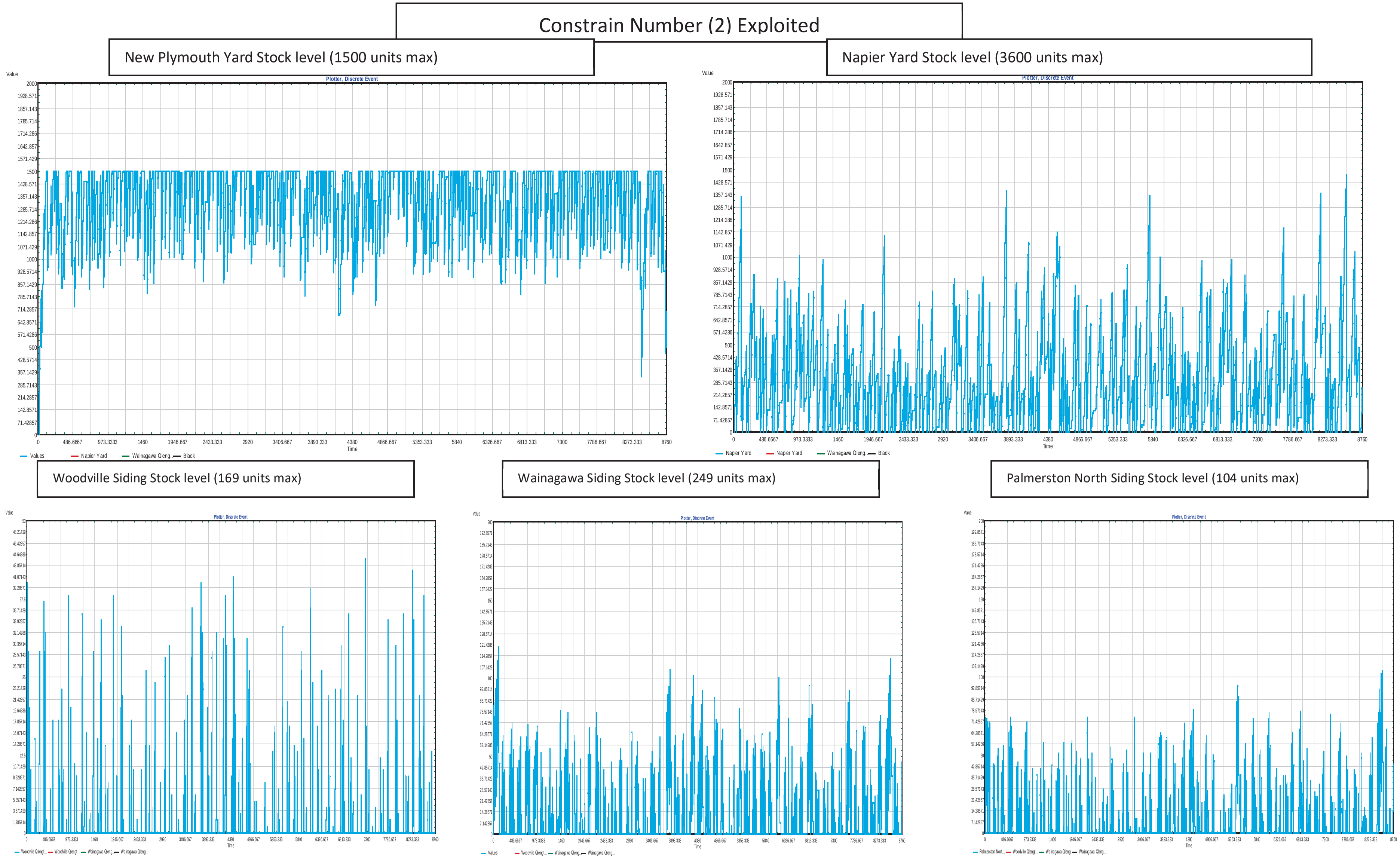


Figure 30 Stock Level Charts After Exploiting Train Scaling and Unloading Activity at Napier Port

5.2.4- Exploiting Constraint Number (3): Ship Arrival Rate at New Plymouth Port.

There are multiple ways to increase the discharge rate from New Plymouth port yard. In the first constraint, this was done by using all the available cranes of the log ships to increase the loading rate. However, after exploiting the second constraint the improved loading rate was insufficient to maintain the yard operating below capacity, which means the ship arrival rate had to be increased. Upsizing the yard at the same discharge rate will not solve the problem as the yard will reach its capacity at a later point in time after which the logistical network will be congested again. Increasing the ship arrival rate will increase the wharf utilization by log ships above 40%, which will affect the other ship types that need to use the wharf. Accordingly, there were three options to exploit this constraint:

Option 1: Build a New Wharf:

Building a new wharf will allow more log and other types of ships to call at the port, which will increase the yard discharge rate resolving the constraint. However, building a new wharf is an expensive project that will take a significant amount of time to be executed. Given that the emergency caused by the port closure was assumed to be temporary, it was difficult to justify building a new wharf at New Plymouth. If other factors were present to justify building a new wharf, the previously mentioned reason could be used to support the idea. However, it is not sufficient by itself to justify the commencement of such a project.

Option 2: Install a Land Crane

Installing a land crane at the port with loading rates above 390 m^3 JAS /hr (maximum rate that can be achieved by the log ship cranes) will reduce the time needed to load the ships and allow more ships to call at the port. This in turn will increase the discharge rate at the yard and release the congestion in the logistical network. This option is less expensive than the previous one, but it was still hard to justify the required investment based on a temporary emergency.

Option 3: Rerouting other types of ships to other ports

Since the logs allocated to Wellington port are rerouted to Napier and New Plymouth ports only, then the other ports might still have capacity to handle non-log ships. Rerouting some of the non-log ships calling to New Plymouth will allow the log ships to use the wharfs for more than 40% of the time. This will reduce the accumulation of logs at the yard. This option does not require any additional investment so it was the most reasonable option to handle a temporary emergency. However, the port officials might resist the proposal because handling containerized shipments is preferable, so it is a decision to be made by the management to see overall benefit and costs of such increase in log ships. Using trial and error it was concluded that by increasing the wharf utilization allowance for log ships to 50% of the time (at New Plymouth port only) will enable the network to export almost all the allocated quantity of logs through Napier and New Plymouth ports.

Figure 31 summarises the results of simulating the logistical network after increasing the ship arrival rate at New Plymouth port. It is noted the throughput of the system had increased to 6.82 million m^3 JAS, which is 1.30 million higher (24% increase) compared to the throughput before the constraint was exploited. It is also noted from Figure 32 that the stock levels in New Plymouth, Napier port and the train siding yards were below the maximum capacity most of the time. This means that the trucks are unloaded as they arrive most of the time. The stock levels at the train sidings show a clear cycle that is not apparent in the stock levels at the ports' yards. Although the arrival rate of logs at the sidings and the port yards became predictable after releasing the constraint as the trucking activities are no longer blocked, the discharge rate from the port yards remained random because ship arrival rate and load quantity did not follow a predetermined schedule. The discharge rate from the train was governed by a constant allocation for each train and scheduled train arrivals allowed for a pattern to be visible in the stock level charts. The new throughput (6.82 million m^3 JAS) represents 99.4% of the total allocation, which is almost equal to the required throughput.

It is noted from Figure 31 that the other activities utilization had increased and that the block time percentage had decreased. Even though, it is noted that there are some blocked activities for up to 35% of the time, this blocking did not prevent the logistical network from achieving the target throughput. Furthermore, some activities ,like truck loading at Waitomo and Wanganui districts, have a utilization level of 94% and 96%, respectively. Having such high utilization of some activities in the supply chain will make it more vulnerable to small disruptions, so it was worth adding some buffer capacity to these activities to make the supply chain more resilient. Improving these activities would not have a significant effect since 99.4% of the allocated quantity was already exported after the previous improvements, but it might be important for a more robust supply chain.

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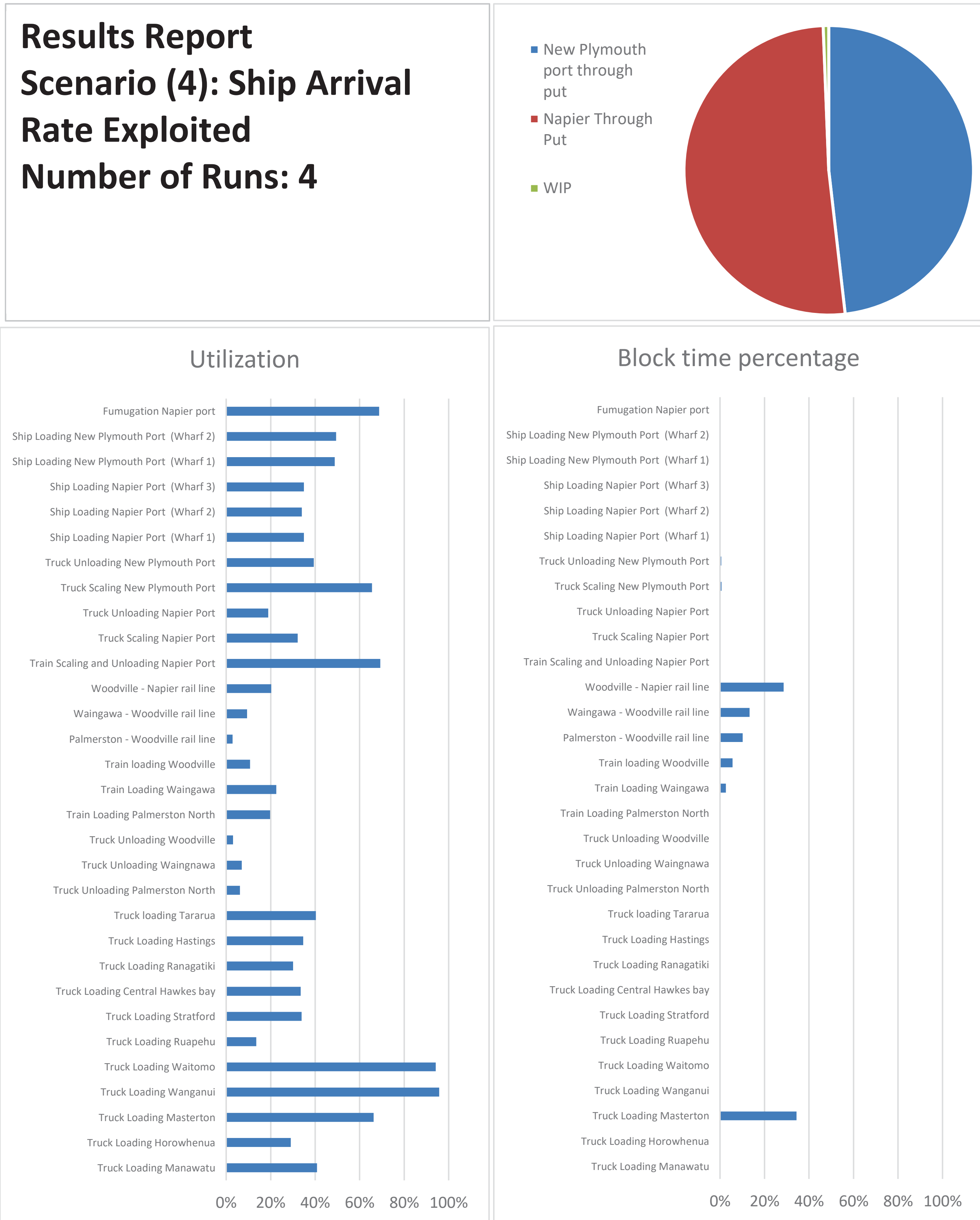

Figure 31 Results report After Increasing Ship Arrival Rate at New Plymouth Port

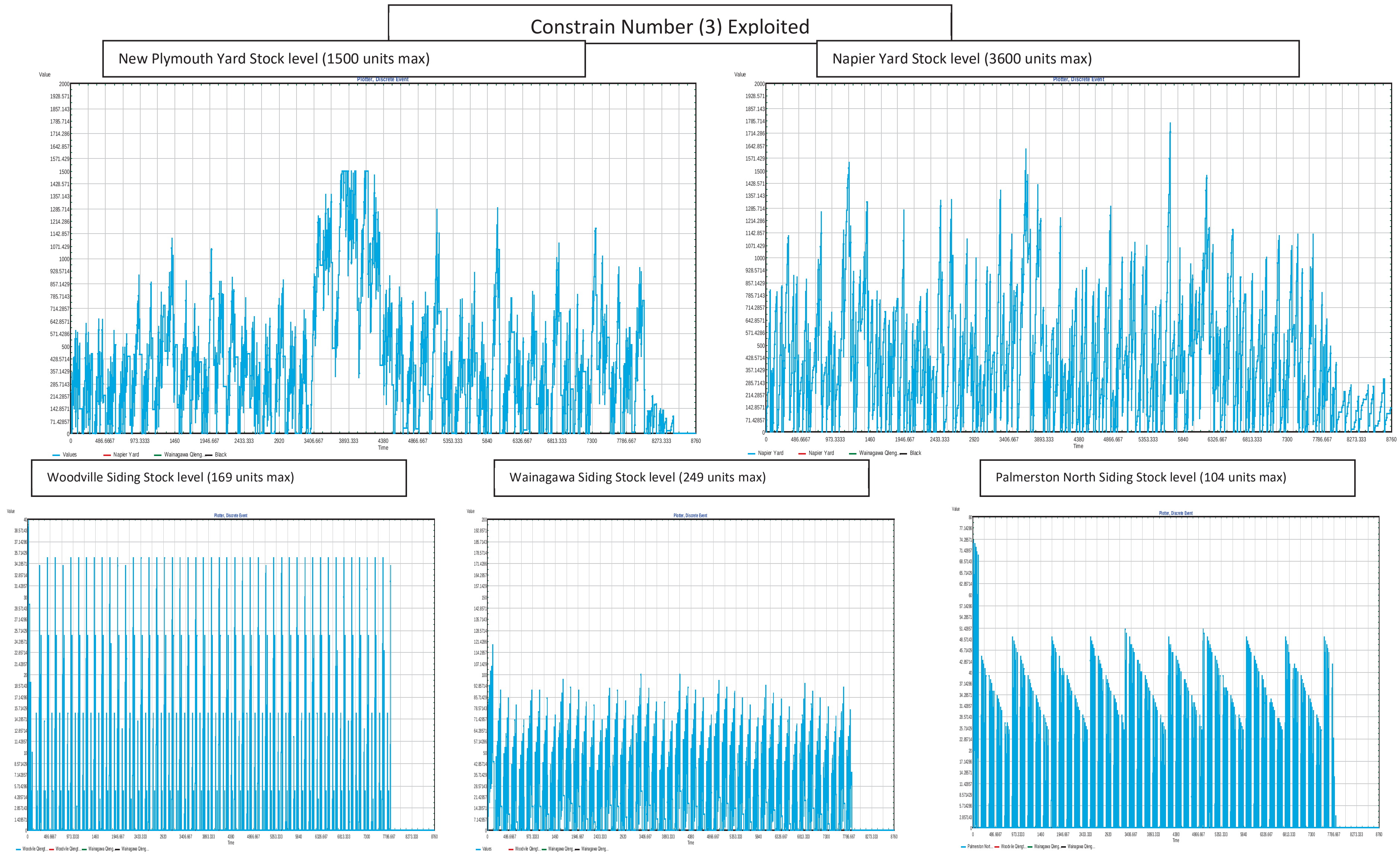

Figure 32 Stock Level Charts After Increasing Ship Arrival Rate at New Plymouth Port

5.3- Summary

The simulation of the current logistical network resulted in a throughput that was below 50% of the allocated quantity, this was mainly because of the limitation caused by New Plymouth yard. As mentioned earlier, the allocated quantity to New Plymouth port was bigger than the quantity exported through this port in the past years. Putting more pressure on New Plymouth and Napier Ports by shutting down Wellington port magnified the bottleneck at New Plymouth. This constraint was blocking the trucks from unloading the logs as they arrived at the yard while it was full. This caused the common truck resource to be held up for longer times and consequently constraining the transport of logs to Napier port and to the train sidings.

Releasing the previous constraint, revealed another bottleneck in the logistical network by increasing the log arrival rate to the train siding. The increased logs arrival rate to the train siding increased the train arrival rate to the train scaling and unloading station at Napier Port, which became the new bottleneck. Exploiting this Constraint had moved the bottleneck back to New Plymouth port as the yard was getting congested again. As reducing the scaling and unloading time at Napier port allowed the truck to unload as they arrived to the train sidings, which in turn enabled them to transport more logs to New Plymouth Port. To resolve this problem, the discharge rate at New Plymouth yard was increased by allowing more log ships to call to the port

Figure 33 shows the impact of exploiting each constraint on the throughput of each port and on the work in process (WIP) inventory level in the supply chain. It is noted that WIP level in the first simulation scenario was higher than both ports throughput combined. Releasing the first constraint significantly improved the throughput of both ports, which caused the WIP levels to drop. Reducing the train unloading time also increased the exports volume in both ports, but Napier Port was more affected by exploiting this constraint. Increasing the ship arrival rate caused the WIP to drop to almost zero level, which meant that the logistical network was able to export most of the allocated quantity during the simulation period (one year).

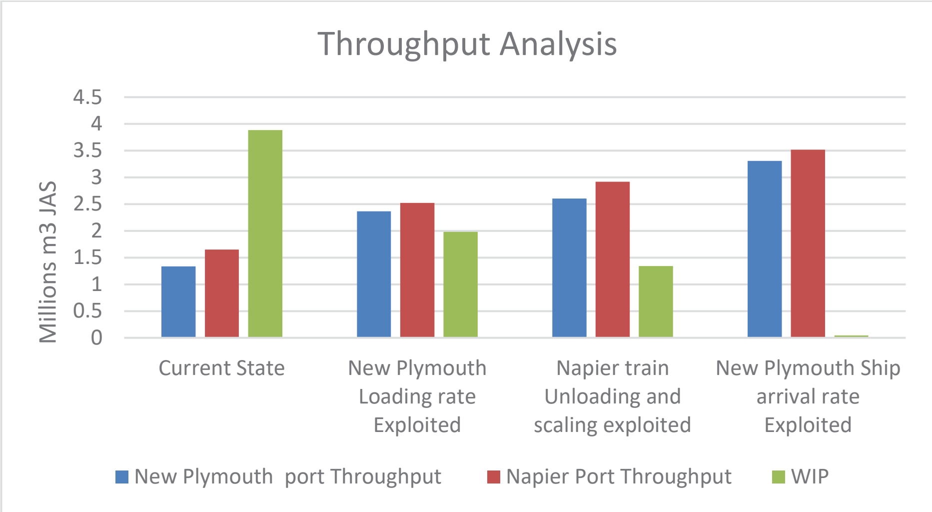

Figure 33 Impact of Releasing Constraints on the Logistical Network Throughput

Three recommendations that give some insight on directing the investments on improving the logistical network resilience summarises the findings in this chapter:

- Increase log ship loading rate at New Plymouth port by providing the needed machinery and personnel to operate all the ship cranes at the same time.
- Reduce the train scaling and unloading time by investing in the needed machinery and communicating this objective with the product handling companies operating at the port.
- Study the possibility of rerouting non –log ships calling to New Plymouth port during the closure of Wellington Port to allow log ships to use the wharfs for longer periods of time.

These recommendations will increase the logistical network resilience in Napier, New Plymouth and lower north island regions. The third recommendation is to be considered by New Plymouth port officials to prioritise the different types of ships calling to the port. Knowing that logs is low value commodity when compared to diary and meat products, makes it important to consider other aspects in the prioritisation process. It would be an opportunity for future research to study the impact of rerouting the ships on the country's' GDP.

The linear optimisation model in the previous chapter provided an aggregate view of the country's logistical network and potential solutions for different emergency scenarios. In this chapter, the simulation model provided some more insight on the potential bottlenecks that might be encountered in a specific scenario in a certain region. The process followed in this chapter can be repeated for each scenario to study the potential bottlenecks in each region. Such a practice might reveal some common bottleneck under different scenarios, these bottlenecks would represent a high priority for contingency improvements.

Chapter 6: Discussion

The previous chapters presented the numerical results of the proposed models along with some insight into their significance. This chapter discusses the theoretical and managerial implications of the findings of this research. In the first section, a reflection on the conceptual model is presented to check whether the findings confirm or contradict the predicted relations that were assumed at the beginning of the research. The second section discusses the methodology used to create the models compared to other researchers' work. The third section addresses the theoretical implications and its contribution to the existing literature. The fourth section presents some strategic and operational level recommendations for policy makers and practitioners operating in New Zealand logistical network and log industry. At the end, some of the research limitation are presented followed by direction for future research.

6.1 Conceptual Implications

In the initial stages, it has been proposed that exogenous risks can possibly pose significant capacity risks from governmental and transportation risks from commercial perspectives (see figure 5). In other words, considerable difficulties in transporting import and export products are anticipated if a major disaster occurs because of the lowered capacity of the facilities affected by the disaster. The increase in capacity risk is then reflected on the infrastructure capabilities of the affected country, which can in turn amplify the transportation risks of the companies using that country's infrastructure. It was proposed that setting up an efficient decision support system, which is continuously updated with information about the status of the infrastructure, will help both policy makers and companies to respond promptly to such unexpected events, and thus diminish any potentially devastating impacts.

It was concluded that the exogenous risk that leads to a port closure might possibly force log exporters to reroute their logs to other ports, which in turn puts enormous pressure on the trains and trucks used in transporting the logs to more distant ports. This impact of macro risks was demonstrated in the previous chapter, in which remarkable improvements were recommended to allow the logistical network to cope with Wellington port closure scenario. The amount of logs put on hold till the port reopens represents the losses incurred by exporters due to an increased transportation risk. This confirms the assumed relation between exogenous and transportation risks as presented in figure 5.

In the case of a port closure, it is logical to reroute the forests to the nearest port with excess capacity without rerouting the previously allocated forests to the same port. This will allow a certain amount of the logs (previously allocated to the closed port) to be exported through other ports while the rest is kept till the closed port reopens. However, in Chapter 4 it was concluded that in the case of port closure, the linear program repeated the distribution process of all the forests on the available ports, while considering the waiting option or rerouting the forests allocated to the open ports in order to maximise profit. Consequently, the amount of logs waiting until the closed port opens was reduced when compared to the seemingly logical option of only rerouting the forests allocated to the closed port. In Chapter 5 the logistical network of the lower North Island, Napier and New Plymouth regions were studied in depth to identify the potential bottlenecks that might hinder the rerouting process (during Wellington port closure). Recommendations were then made in an attempt to resolve these bottlenecks. It was discussed that using a decision support system can present key recommendations that would reduce the amount of logs waiting, which is an indicator of reducing the impact of the exogenous risks on the capacity, infrastructural and transportation risks. This confirms the moderating effect of the DSS on the impact of capacity and transportation risks as presented in figure 5.

It has been pointed out in previous chapters that exogenous risk can directly affect the infrastructure (i.e. leading to a port closure), which can in turn affect the country's capacity of exporting and importing. Based on these findings, Figure 34 shows an overview of the concluded relations between different types of risks and the DSS. A major contradiction could be detected between the new figure and the initial conceptual model, as highlighted in a number of points (figure 5). .It was then suggested that capacity risks will increase the infrastructural risks while in reality it has proved the opposite. Other factors that the initial conceptual model failed to capture include the available supply, transportation costs, product pricing and their effect on the decision-making process. Figure 34 also shows that the capacity of all the facilities in the logistical network, the status of the infrastructure, transportation costs, product pricing and the available product supply to be exported all need to be reviewed and considered by decision makers. These factors also need to be included because a change in one of these factors might lead to a change of the major decisions in a certain scenario. The modified conceptual model provides a more comprehensive presentation of the interaction between the different types of risks and the major contributory factors influencing the decision-making process.

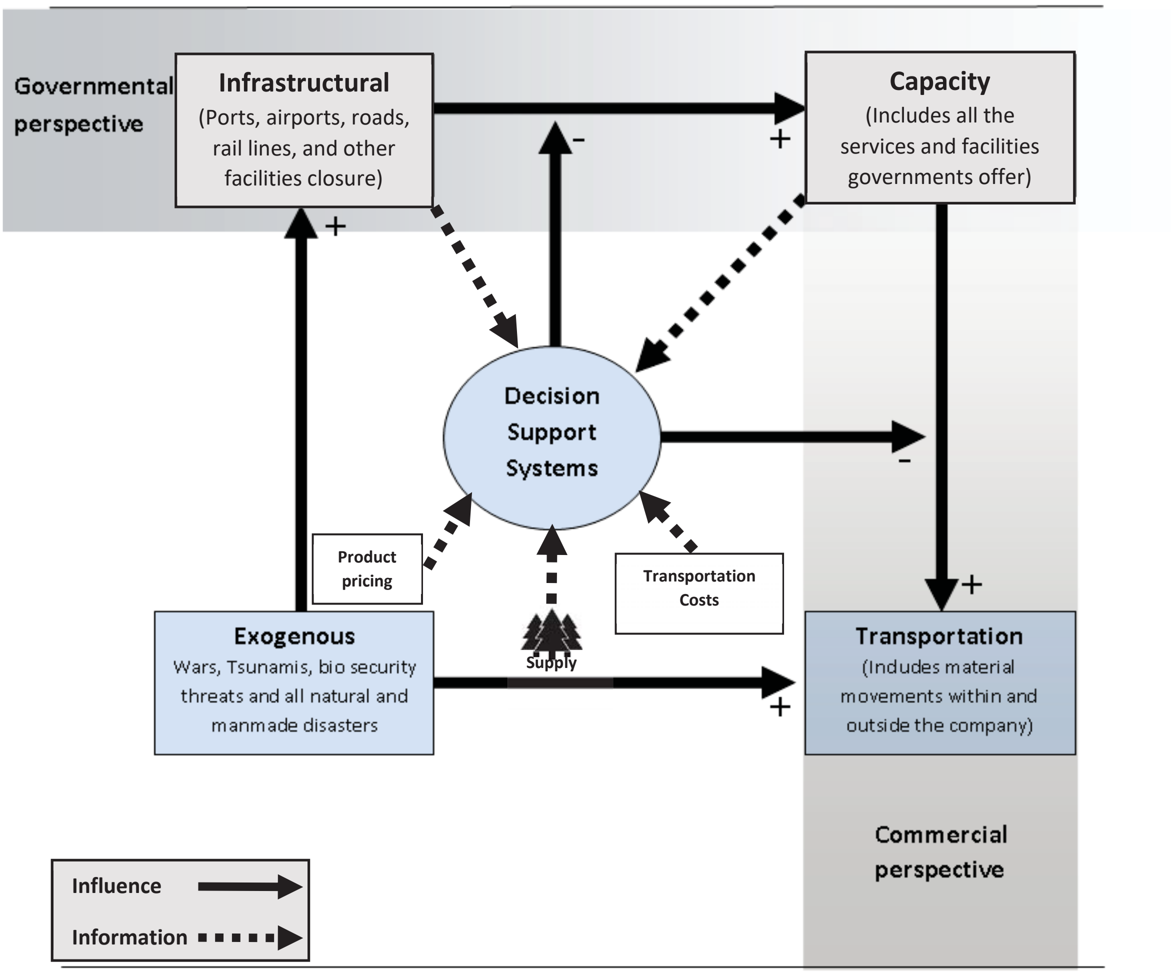

Figure 34 Modified conceptual model of the moderating effect of the DSS

6.2 Integrating Analytical Tools

Logistical network resilience and supply chain resilience related issues have been widely addressed in literature using qualitative and quantitative methods (Bellamy & Basole, 2013). Qualitative researches, for example, mainly focused on developing strategies that can help in enhancing the ability of a supply chain to cope with disruptions such as postponement, assortment planning, multicarrier transportation, and other strategies (Rudberg, & Olhager, 2003; Tang, 2006). Selection of the proper strategy that suites business needs, product type and market has been previously investigated (Pagh & Cooper, 1998). Quantitative literature, however, mainly addressed supply chain resilience improvement through developing empirical methods and mathematical models for improving the resilience of the supply chain of interest. It is noteworthy that these models have been developed primarily to find the optimal design of a logistical network which can minimize the impact of a certain disruption. In addition, these models had to meet certain standards, e.g. a minimum resilience level, or achieve a certain goal such as maximising the profit. This research thus fits in this part of literature, as empirical methods were used tp produce the results and recommendations presented earlier.

6.2.1 Macro Level Analytical tools

Linear programming was used in this research as a high level analytical tool that reflects the general picture of the logistical network status under different scenarios. It has also shown how different ports react to a certain port closure and it provided some insight on the severity of different closure scenarios. Application of such high level analysis on logistical networks resilience has been reported in recent literature. For example, Meepetchdee and Shah (2007) developed a mathematical model using MILP with an objective function of minimising the cost while maintaining a minimum level of resilience to obtain a logistical network configuration that satisfies the prescribed requirements. The model assisted decision makers in determining the number and location of distribution centres to be established to maintain a certain level of robustness. The model was also used for assigning customers to primary warehouses as well as for establishing contingency links between customers and the other warehouses to determine which warehouse will be assigned to serve each customer should a disruption happen for ease of distribution of goods to customers. In another empirical study, Ishfaq and Sox (2011) developed a mathematical model to function as a DSS for Hub location-allocation in intermodal logistical network using the multiple-allocation *p*-hub median approach. Similarly, Bauer (2005) used modular node model for warehousing strategic decision making by dividing the problem into smaller sub-problems employing the introduced model.

Previous analysis seems to correspond to the linear program level, in which the optimization of the entire network performance was stressed. The linear program provided optimal configurations of the forest distributions under different scenarios, while only considering major constraints. The proposed linear program in this research is similar to the work of Meepetchdee and Shah (2007) in that both of them attempt to present strategic level recommendations. However, these models are simplified and do not address the details of the constraints that might be faced in the logistical network. It only provides a bird eye configuration of the product flow by allocating the available facilities to the customers to achieve the highest profit possible while satisfying some high-level constraints. Accordingly, presenting the recommendations based on the results of such aggregate level models might be misleading ,and thus further analysis could be needed to present more reliable recommendations.

6.2.2 Micro Level Analytical tools

The recommended forests distribution by the linear program should be studied in depth using a different tool that is able to capture lower level constraints. The use of discrete event simulation to analyse the proposed configurations by the linear program made the DSS more realistic by including the operational capacities of the different facilities along the supply chain. In so doing, Legato and Mazza (2001) used discrete event simulation to model the container terminal activities, i.e. arrival, berthing and departure processes, at Gioia Tauro container terminal in Italy. They used the model to spot the congestion points along the processes that vessels go through from arrival to departure. The simulation model they developed was proposed to function as a berth planning system that helps the berth planner in the decision-making process at a marine container terminal. The berth planning system objective is to allocate the constrained berth space to the incoming ships. The system takes into consideration the location of the containers in the yard and the penalty of delaying the berthing time of a ship.

Discrete event simulation has been extensively referred to and used as a tool in literature for over a decade. For example, it was used to conduct activity based costing in a manufacturing plant (Spedding & Sun, 1999). It was also used to simulate both the logistics of oil transport (Cheng & Duran, 2004) and the patients flow in the health system (Jacobson, Hall, & Swisher, 2006). The extensive use of discrete event simulation in the literature and it demonstrated in this research emphasize the effectiveness of using this tool in a supply chain context.

Researchers used discrete event simulation to model detailed processes and they have used it as their analytical tool because it allowed them to capture the needed level of accuracy. Similar to the simulation model in this research, this approach allowed the DSS to capture the process activities and details and identify the potential bottlenecks. The integration of TOC in this research made the DSS an effective tool to identify improvement opportunities in the process flow and provided some insight into resolving the bottlenecks found in the logistical network. Moreover, using this tool also provided more comprehensive understanding of the activities taking place in the logistical network and allowed the DSS to endorse more robust recommendations.

6.2.3 The Two-tiered Methodology

Approaches used so far tended to focus on strategic or operational level analysis yet failed to capture both levels in their proposed decision support systems. Some researchers such as Meepetchdee and Shah (2007) work had succeeded in capturing the macro analysis of the logistical network, which is useful in making high level decisions. On the other hand, the work of other researchers like Legato and Mazza (2001) had provided an effective tool for analysing sections of the logistical network in depth, which can help decision-makers at the operational level. The methodology used in this research is a combination of both approaches that aims at encompassing both macro and micro level analysis of the logistical network.

In view of the logistical network major constraints, the two-tiered methodology used in this research allowed for maximizing the profitability of the supply chain at first. The use of linear programming as stage one analytical tool yielded profound insights which can presumably help in strategic decision making. The linear program had an overarching objective function that is to maximise the profitability of the supply chain. Therefore, this objective should not be obstructed by minor constraints. This tool assisted in emphasizing strategic level constraints and therefore enabled the linear program to provide more profitable configurations through overlooking operational level constraints.

The second step attempted to analyse - logistical network details through underscoring more constraints than done in the first step so that the logistical network flaws are identified and practical solutions are suggested accordingly. The purpose of this step was to consider the operational level constraints, which were not included in the first step to provide a more holistic risk mitigation plan that includes both strategic and operational level insights. In this part of the analysis, the thinking process (TP) of TOC was employed to spot, investigate, and release bottlenecks. The simulation model allowed the DSS to consider recommendations that would ensure the feasibility of the optimal forest distribution that is recommended by the linear program. Other researchers integrated different types of tools to produce the desired insights of their research. Mackenzie and colleagues (2012) integrated the use of simulation and dynamic inoperability input–output model (DIIM) to evaluate the impact of closing an inland waterway. This integration allowed for capturing multiple levels of the simulated network. Similarly, Longo and Mirabelli (2008) used simulation in conjunction with the Design Of Experiment (DOE) and analysis of variance (ANOVA) to develop an advanced supply chain management tool. The integration of macro and micro level analysis in the proposed decision supports systems provided an iterative validating process for the proposed recommendations by the DSS.

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6.3 Theoretical Implications

This section discusses this research findings and provides some insight into the underlying relations between different factors in the supply chain. It also seeks to inform the academic audience about the implications of this research and its contribution to the available literature.

6.3.1 Guidance on integrating Analytical tools

The approach adopted in this research provides researchers with some guidance on the benefit of using multiple analytical tools in the same DSS. Each analytical tool has its own inherent weaknesses and strengths, for example, it is hard to capture the details and dynamics of a certain system in a linear program, and thus solving linear programs allows us to find comprehensive optimal solutions for a certain model. On the other hand, although discrete event simulation models cannot provide global optimal solutions , system dynamic and details can be captured using these models. Using single analytical tool in a DSS highlights its weaknesses and therefore reduces the proposed DSS efficiency. Overall, integrating multiple analytical tools would help in eliminating the shortcomings of each tool when used independently.

In this research, linear programing ensured that the proposed solution is optimal .Additionally; discrete event simulation established the details that were hard to develop in the linear program. The theory of constraints helped in directing the recommendations to have the highest impact on the logistical network throughput. The use of linear programing in conjunction with discrete event simulation and theory of constraints provides a unique perspective for decision makers to tackle the risks that might be encountered in their supply chains. Researchers intending to use similar approaches should consider the compatibility of the tools being integrated to make sure that they would augment the resulting insights and recommendations. The selection of tools should be done carefully to ensure that the weaknesses of one tool has been overcome by the other tools to create a reliable DSS.

6.3.2 Hidden Factors affecting Supply Chain Robustness

This research identified relations between different factors and their effect on the supply chain performance -. It has been previously noted that the more the logistical network is geographically diverse the more it is vulnerable to disruptions. This was demonstrated in the results of the South Island model, in which it was concluded that almost all ports are isolated from each other because of due to the long distances among one port and the other. This finding confirms Nair & Vidal’s (2011) conclusions that one unit increase in the average path length between the nodes in a logistical network can significantly increase its vulnerability to disruptions. However, this relation is affected by transportation costs and the handled product price. Mackenzie and colleagues (2012) have also integrated the use of simulation and dynamic inoperability input–output model (DIIM) to evaluate the impact of closing an inland waterway port called Port of Catoosa in Oklahoma in the USA, while considering two viable options, i.e. either rerouting using the rail line or waiting until the port is open. The model included different types of products coming from different states to be transported to main ports via this port. They have noted that when there is a percentage for penalty on waiting, the high value commodities are pushed to the rerouting option that becomes more profitable in case of an imposed penalty. This finding is consistent with the relation identified in Chapter 4 in the sensitivity analysis part between the log price and the amount of logs put on hold, in which it has been concluded that the higher the log price is the lower the amount of logs put on hold are.

It can be argued that the ratio between unit transport cost and unit profit margin is a decisive factor in determining how profitable rerouting the product is. Therefore, increasing the product price may make the supply chain less vulnerable to disruptions as higher transport costs will probably continue to be feasible if the product price was high enough. Furthermore, reducing transport costs can have similar effects on supply chain robustness as lower transport costs will make the rerouting option more feasible for low value products should a disruption happen. Given the interconnection between the uncontrollable product prices and the unstable world market, more cost-effective transportation modes should be used to improve the robustness of supply chains.

6.3.3 Resource Sharing and Theory of Constraints

Resource sharing or bundling between multiple independent supply chains or organizations is usually presented as a method to build a competitive edge and improve supply chain resilience (Brandon-Jones, et al., 2014; Barney, 1991; Sirmon et. al., 2011;). However, this research found that resource sharing had adversely affected Napier Port supply chain. The truck pool shared between the forests using Napier and New Plymouth Ports for exporting logs resulted in a greater reduction in Napier port throughput lest a bottle neck is present in the activities taking place at New Plymouth Port. Consistent with earlier studies, despite the multiple benefits sharing resources can have, the consequent interdependency between the involved members should be carefully considered. This interdependency necessitates investigating the compatibility between all members intending to share their resources. Research findings also showed that sharing resources between incompatible supply chains adversely affect the more efficient one. Furthermore, it has been found that less efficient supply chains may not gain a significant improvement in its throughput by accessing more resources. As demonstrated in the previous chapter, increasing the number of trucks did not improve New Plymouth port. nevertheless, it got improved by identifying and releasing the bottleneck using the theory of constraints. Therefore, it is important that all supply chains intending to share resources are brought to a similar level of efficiency to maximize the benefits of resource sharing.

The theory of constraints' philosophical basis has progressed from merely preparing production schedules into a comprehensive set of managerial tools capable of addressing complicated problems associated with project and supply chain management (Watson et al., 2007). Simatupang and colleagues (2004) note that the current literature on TOC has mainly focused on applying this tool from one enterprise’s perspective ,e.g. Pegels, & Watrous, 2005; Umble et al., 2006, Moreover, it has rarely been applied in multi-independent organizations context that is operating in the same supply chain. Despite the considerable increase in the available literature on TOC application in supply chain collaboration since 2004 (e.g: Cai et al., 2009; Kampstra, Ashayeri, & Gattorna, 2006), its application in the supply chain context remains under addressed. The application of theory of constraints in this research was unique; firstly, because it was applied in the broad supply chain rather than in a certain organization. Secondly, it was used as a supporting tool to ensure the success of resource sharing. Accordingly, this research helped in bridging the previously mentioned gap in the literature.

The application of TOC has been expanded in the context of this research to ensure all independently operated nodes are included in the analysis as well as to confirm that the flow of materials is streamlined through the entire supply chain rather than within a certain part of it. Adopting this approach has also emphasized essential interdependence between apparently unrelated activities in different parts of the supply chain and thus grasped its significance on the supply chain throughput. Employing TOC was particularly important in light of the subtle interdependence between supply chains due to resource sharing. It is worth noting that,the integration of TOC in the analysis has noticeably facilitated resource sharing for both supply chains. . Overall, it can be concluded that employing TOC ensures potential long-term benefits for all involved parties without the risk of undermining or overriding resource sharing benefits.

6.4 Policy Implications

This research addressed the strategic importance of some focal ports in New Zealand’s logistical network, which would be of interest for policy makers. Napier port is a good example as it is almost fully utilized in three out of five closure scenarios. In other words, expanding this port will possibly improve the resilience of the network against three closure scenarios. In addition, Otago and Wellington ports are good examples of well-located ports that can reroute their loads, in case of a closure to the other ports while remaining more profitable than putting these loads on the hold, which makes studying the dynamics of their closure interesting. The forecasted significant increase in log exports during 2020-2025, will put pressure on New Zealand’s logistical network. This pressure might cause congestions in the less efficient parts of the logistical network New Plymouth port reveals a remarkable weakness in the North Island's logistical network for two reasons. First, the capacity (as calculated from historical data not the one used in the linear program) of the port is so small and will not be enough to satisfy the forecasted future demand. However, it was mentioned earlier that using historical data is a very simplified way for calculating the port capacity, so this statement needs to be investigated and verified in further research. Second, being the only port on New Zealand's west coast makes rerouting the allocated forest to New Plymouth to other ports in case of a closure event so costly. The South Island's ports are almost isolated from each other because of the vast geographical area, which makes finding cost effective transportation modes necessary to solve the problem.

6.5 Managerial Implications

This research included some recommendations at the operational level offered to improve the logistical network resilience in the lower north island, New Plymouth and Napier regions. A number of recommendations were drawn up from simulating the closure of Wellington port, as indicated below:

- Increase log ship loading rate at New Plymouth port by providing extra machinery and staff to simultaneously operate all ship cranes .
- Reduce train scaling and unloading time at Napier port by investing in the essential machinery and sharing this objective with all product handling companies operating at the port.
- Study the possibility of rerouting non–log ships arriving at New Plymouth port during Wellington Port closure to allow log ships to use the wharves for longer periods of time.

The proposed recommendations aim at streamlining logs flow in order to to cope with any overload in case of a sudden port closure.

The findings of this research can be used to provide beneficial insights for practitioners operating in the log industry. The model configuration results (Appendix F and Appendix G) can be used to analyze the behavior the forests districts under different closure scenarios to identify the most resilient districts that were least affected by the port closures. Transportation costs under different scenarios and forest productivity should be included in such type of analysis. This will help forest owners in selecting their forest locations to make their supply chains more resilient and capable to cope with sudden port closures.

The dearth of research on New Zealand logistical network and infrastructure makes it hard to compare this research results with other findings obtained using different approaches. Therefore, further research is needed to examine the implications of these findings on New Zealand's logistical network. Hopefully, in the future more researchers will address this area to validate the findings presented in this research. However, the proposed decision-making approach and the suggested improvements in this research provide an in-depth insight for policy makers and practitioners operating in the logistical network in New Zealand. Moreover, it also provides a solid analytical approach for decision-makers to direct their investments to the corresponding part of the supply chain they are operating to ensure that they make a far-reaching impact on the supply chain throughput. This model can be employed to generate improvement recommendations for different regions and decision-makers can prioritize the presented recommendations in line with their strategic goals.

6.6 Limitations and direction for future research

The proposed research approach will possibly benefit researchers in the logistical network resilience improvement field. These researchers are urged to use the results of this research as a starting point for their research in simulation optimization in a supply chain context. In addition, it will be interesting to devise some techniques to identify and debug pitfalls in the simulation model so as to explore its applicability. As previously discussed, the concept and application of TOC have been considered in this research by investigating the extended supply chain rather than a single facility operation.

Implementing this approach has shown interdependence between apparently independent activities in various supply chain parts. Researchers investigating logistical network resilience can build on this study's expansion of TOC to create more applicable models by including more variables to bridge this gap in the literature. The findings in the previous chapters provide researchers interested in supply chain exogenous risks with some estimation of the potential impact of such risks on New Zealand's logistical network

The limitations in the proposed decision support system stims from the inherent nature of the analytical tools used. Even though, the use of linear programming and discrete event simulation allowed the DSS to capture more details of the logistical network, it is inevitable to make some assumptions about the real world. These assumptions limit the ability of the model to reflect the growing complexity of the real world. However, it is accepted to have assumption in modeling as it is impossible to simulate the real world with its full complexity. Retrieved data need to be validated as it included a fair amount of historical secondary data and professional best guesses. Moreover, this model also ignored the behavioral aspects of different companies operating in the industry as well as their preferences, contracts and other factors that might affect their decision during a port closure. More work is also needed to evaluate ports' real capacity rather than using historical data to evaluate it. The optimal solution of the linear program and the consequent recommendations of the simulation model can be considerably affected by the accuracy of the forecasted export quantities during the period of interest. Accordingly, any forecast change might lead to a change in the decision support system output. Hence, investigating the recommendations proposed by DSS under different forecast values might prove an informative area for further research.

Chapter 7: Conclusion

The conclusions derived from this research are divided into two categories depending on the targeted audience of these conclusions. The first category of the targeted audience is the academics researching the supply chain resilience field, the second category is policy makers and practitioners operating in New Zealand's logistical network and log industry.

7.1- Conclusions for Academics

It was concluded that exogenous risks, infrastructural risks, capacity risks and transportation risks in a supply chain are all interrelated, which amplify their impact on the affected logistical network. The findings of this research also showed that if the supply chains sharing resources are incompatible. then it will adversely affect the more efficient supply chain. Furthermore, the less efficient supply chain would not gain a significant improvement in its throughput from the access to more resources. This incompatibility will furtherly amplify the adverse effect of supply chain risks. Therefore, it is important to bring the supply chains intending to share resources to a similar level of efficiency to maximize the benefit of resource sharing and minimize the impact of supply chain risks. The undesired effect of the disruption events can be reduced using decision support systems. These decision support systems should be updated with (but not limited to) the status of the affected infrastructure, the capacity of different facilities along the logistical network, costs of different transportation modes used in the logistical network, pricing of the handled product(s) in the logistical network of interest, and the quantity of product(s) to be processed through the logistical network. Having such systems in place would help in minimizing the losses incurred by the supply chain members if a disruption event happens.

The use of an optimisation tool that optimises the performance of the overall logistical network in conjunction with another modelling tool that addresses the fine details of the logistical network allow the researcher to capture both the strategic and operational level analysis. The use of a two-tiered analytical approach provides more validity for the practicality of the proposed recommendations, when compared to researches conducted using a single tool that capture either the strategic or the operational level of analysis. The use of theory of constraints in the context of the extended supply chain is proved in this research to be effective. The integration of TOC approach had helped in identifying bottlenecks in the independent facilities of the supply chain that were hindering the supply chain from achieving its target throughput. It had also helped in discovering the interdependency between activities done in independent facilities in the supply chain. Researchers intending to use similar approaches should consider the compatibility of the tools being integrated to make sure that they would augment the resulting insights and recommendations. The selection of tools should be done carefully to ensure that the weaknesses of one tool is covered by the other tools to create a reliable DSS.

7.2- Conclusions for Policy Makers and Practitioners

The second set of conclusions are targeting practitioners and policy makers operating in New Zealand's Logistical networks and log industry, this set is divided in two parts. The first part addresses the strategic importance of some focal ports in New Zealand's logistical network. Starting with the North Island, Napier port was almost fully utilized in three out of five closure simulation scenarios, which means expanding this port will improve the resilience of the North Island logistical network against three closure scenarios. Wellington and Otago ports are good examples of well-located ports that can reroute their loads to the other ports (in the case of closure) while remaining more profitable than waiting, which makes studying the dynamics of their closure interesting. New Plymouth port is a clear weakness point in the North Island's logistical network; the port is the only port on New Zealand's west coast making rerouting the allocated forest of that port during a closure too costly. The South Island's ports are almost isolated from each other because of the big geographical area, which necessitates finding cost effective transportation modes to solve the problem.

The research had also presented some recommendations at the operational level to improve the resilience of the logistical network in the lower north island, New Plymouth and Napier regions. The below recommendations resulted from simulating the closure of Wellington port:

- Increase log ship loading rate at New Plymouth port by providing the needed machinery and personnel to operate all the ship cranes at the same time.
- Reduce the train scaling and unloading time at Napier port by investing in the needed machinery and communicating this objective with the product handling companies operating at the port.
- Study the possibility of rerouting non–log ships calling to New Plymouth port during the closure of Wellington port to allow log ships to use the wharfs for longer periods of time

The proposed decision support system will not make the logistical network of New Zealand immune to any disruption. However, it would provide a guidance of how to reduce the impact of such disruptions and minimise the incurred costs because of it. More research is needed to improve the proposed decision support system and make it more realistic. Future researchers are encouraged to use the findings and the models of this research to produce more reliable decision support systems.

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Appendices

Appendix A

Appendix A.1 Ports Description

North Island Ports

The north island has seven seaports, a rail link with eight public train sidings that can handle logs and a well-connected road network. All the ports in the north island except Auckland Port have the facilities to handle bulk cargo, hence Auckland port will not be included as an alternative port where logs could be exported in case of port closure. In the following subsections, each of the six ports will be discussed.

Tauranga Port

Tauranga city is situated in the western Bay of Plenty, the city's port is considered to be the largest seaport in the country with a total of 1,555 ship calls in 2014 including logs' ships. The number of log ships calls in 2014 was 287 calls, which compromises 18.5% of the total. The port has 4 berths that can be used by log ships, a link to rail and 294,000 m^3 JAS of storage area. The storage area is divided into two categories, leased to exporter (264,000 m^3 JAS) and common storage area (30,000 m^3 JAS). Figure 1 shows the amount of log handled by the port of Tauranga per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the third quarter of 2013, during which the port exported 1,678,174 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 8,726,503 m^3 JAS.

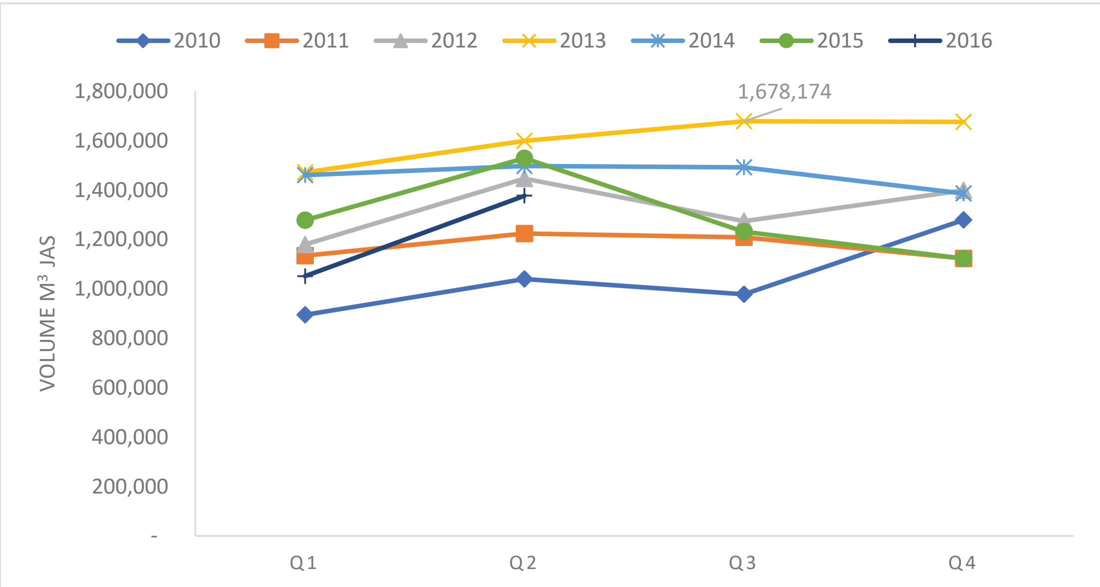

Figure (1) : Total quarterly log volume exported from the port of Tauranga during the period from Jan 2010-Jun 2016.

Wellington Port

The total number of ship calling to Wellington port in 2014 was 1,725 ship calls including logs' ships. The number of log ships calls in 2014was 75 calls, which compromises 4.35% of the total. The port has 1 berth that can be used by log ships, a link to rail and 85,000 m^3 JAS of storage area. Figure 2 shows the amount of log handled by the port of Wellington port per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the second quarter of 2016, during which the port exported 326,880 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 1,699,778 m^3 JAS. According to Scion (2017) the port capacity will be expanded in the near future by at least 1 million m^3 JAS.

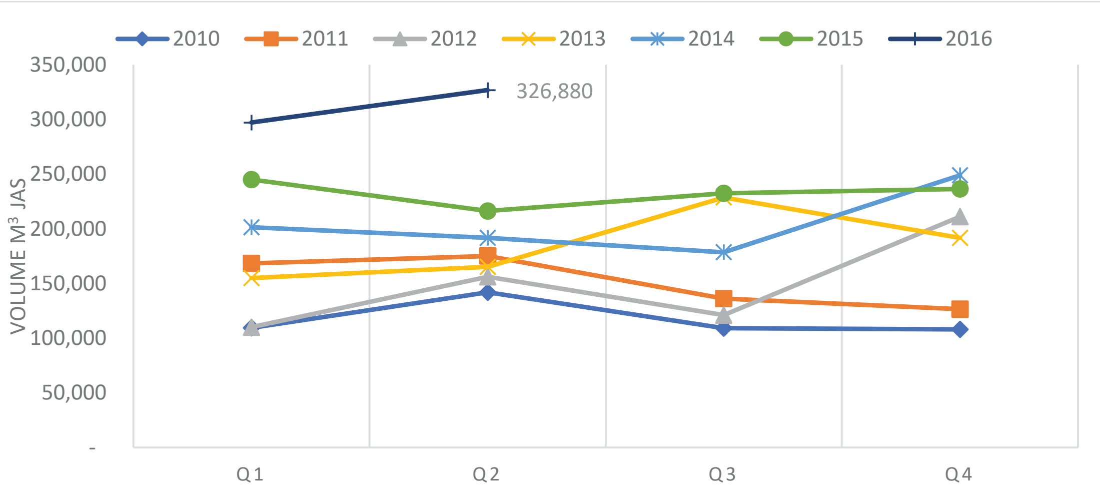

Figure (2) : Total quarterly log volume exported from the port of Wellington during the period from Jan 2010-Jun 2016.

Napier Port

The total number of ship calls to Napier port in 2014 was 636 ship calls including logs' ships. The number of log ships calls in 2014was 80 calls, which compromises 12.58% of the total. The port has 3 berth that can be used by log ships, a link to rail and 44,000 m^3 JAS of storage area. Figure 3 shows the amount of log handled by the port of Napier per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the fourth quarter of 2013, during which the port exported 361,053 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 1,877,476 m^3 JAS

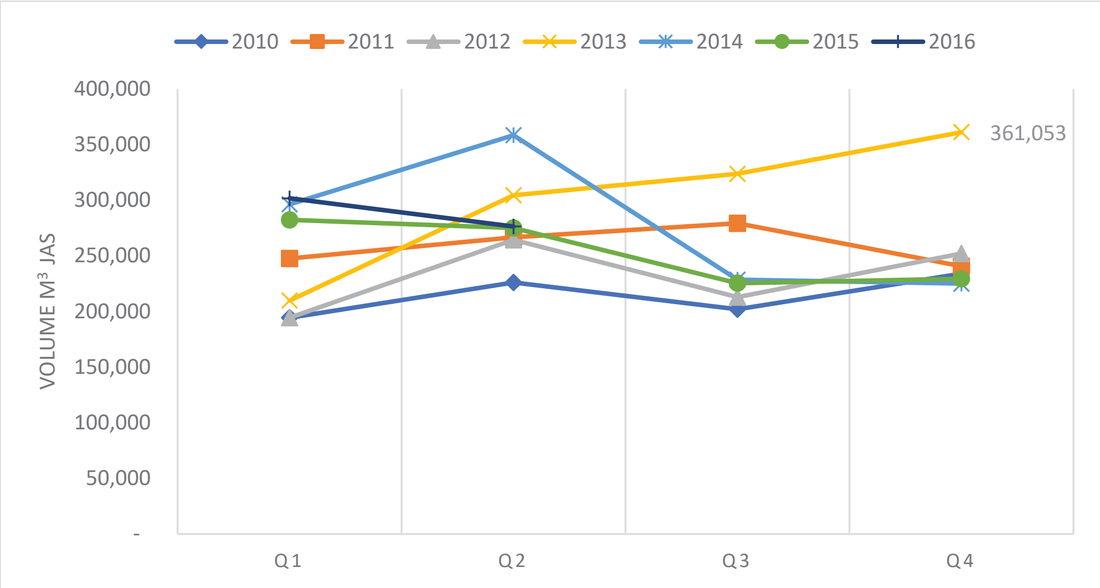

Figure (3) : Total quarterly log volume exported from the port of Napier during the period from Jan 2010-Jun 2016.

New Plymouth Port

New Plymouth city is located on the western part of New Zealand. The total number of ship calls to New Plymouth port in 2014 was 899 ship calls including logs' ships. The number of log ships calls in 2014was 25 calls, which compromises 2.78% of the total. The port has 2 berths that can be used by log ships, a link to rail and 45,000 m^3 JAS of storage area. Figure 4 shows the amount of log handled by the port of New Plymouth per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the second quarter of 2012, during which the port exported 132,554 m^3 JAS logs. According to equation 1, the port's maximum annual handling capacity is 689,282 m3 JAS.

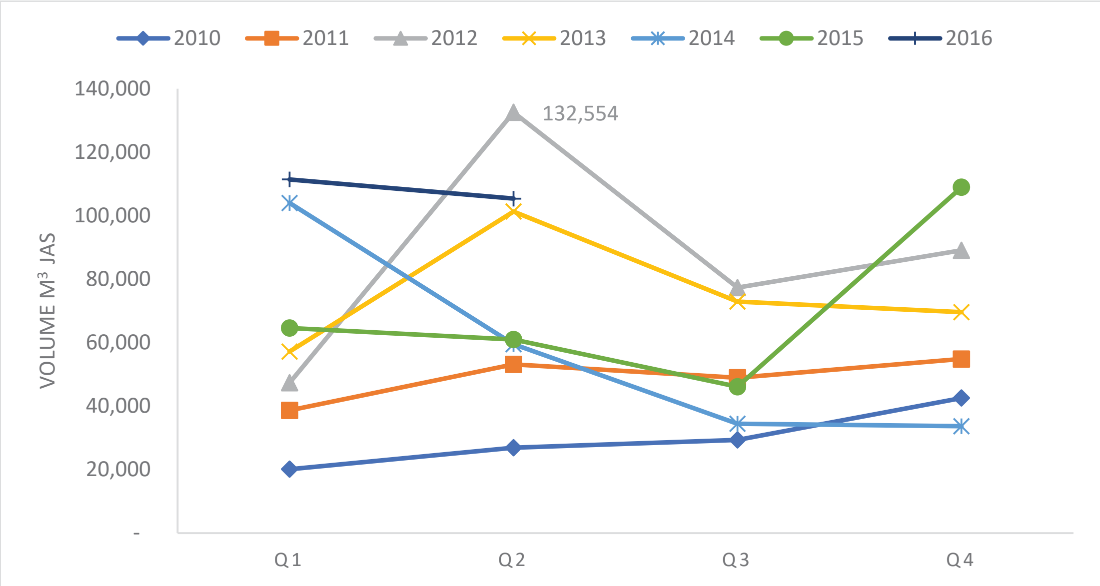

Figure (4) : Total quarterly log volume exported from the port of New Plymouth during the period from Jan 2010-Jun 2016.

Whangarie Port

Whangarie city is located on the far north New Zealand , the total number of ship calls to Whangarie port in 2014 was confidential for commercial reasons. The port has 2 berths that can be used by log ships, 247,000 m^3 JAS of storage area but it does not have any link to rail. Figure 4 shows the amount of log handled by the port of Whangarie per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the fourth quarter of 2015, during which the port exported 732,792 m^3 JAS of logs.

According to equation 1, the port's maximum annual handling capacity is 3,810,516 m^3 JAS.

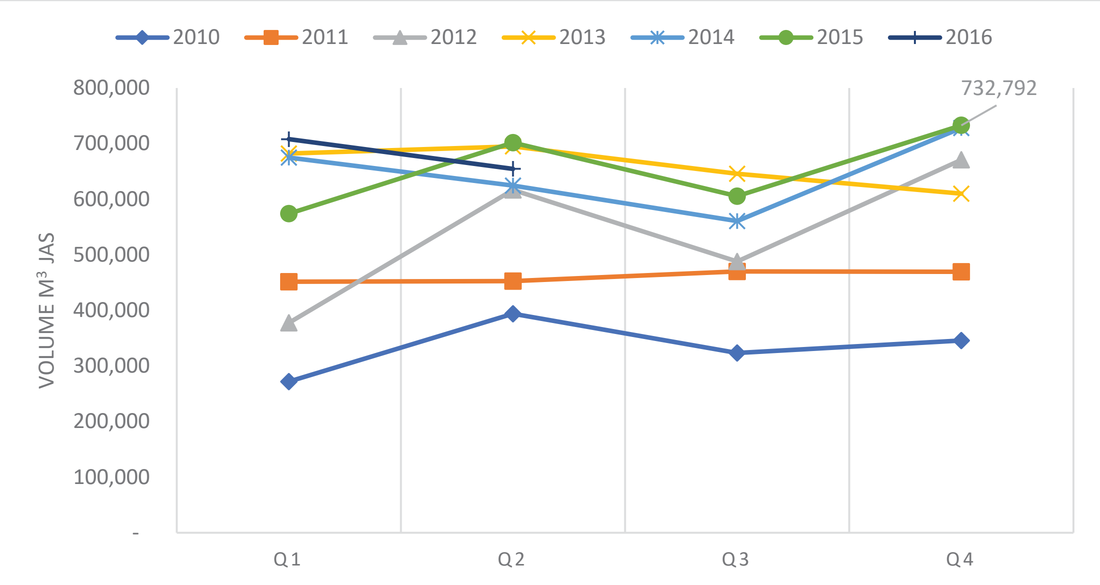

Figure (5) : Total quarterly log volume exported from the port of Whangarie during the period from Jan 2010-Jun 2016.

Gisborne Port

Gisborne city is located in the north east of New Zealand. The total number of ship calls to the port of Gisborne in 2014 was 112 ship calls including logs' ships. The number of log ships calls in 2014 was 98 calls, which compromises 87.50% of the total. The port has 1 berth that can be used by log ships, 130,000 m^3 JAS of storage area but it does not have any link to rail. Figure 6 shows the amount of log handled by the port of Gisborne per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the fourth quarter of 2014, during which the port exported 631,109 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 3,281,768 m^3 JAS.

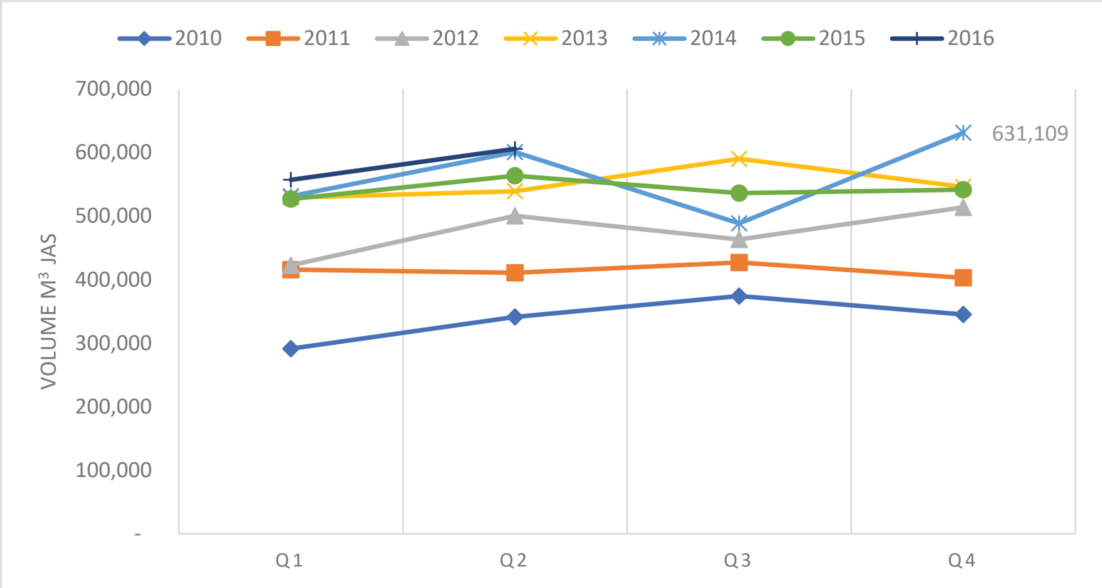

Figure (6) : Total quarterly log volume exported from the port of Gisborne during the period from Jan 2010-Jun 2016.

South Island

The south island has a bigger geographical area than the north island but it has lower population. It has six seaports, a rail link with only one public train sidings that can handle logs and a well-connected road network. All the ports in the south island have the facilities to handle bulk cargo. In the following subsections each of the six ports will be discussed.

Nelson Port

The total number of ship calls to the port of Nelson in 2014 was 786 ship calls including logs' ships. The number of log ships calls in 2014 was 35 calls, which compromises 4.45% of the total. The port has 1 berth that can be used by log ships, 75,000 m^3 JAS of storage area but it does not have any link to rail. Figure 7 shows the amount of log handled by the port of Nelson per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the second quarter of 2012, during which the port exported 224,780 m^3 JAS of logs. Using equation 1, the port's maximum annual handling capacity is 1,168,856 m^3 JAS.

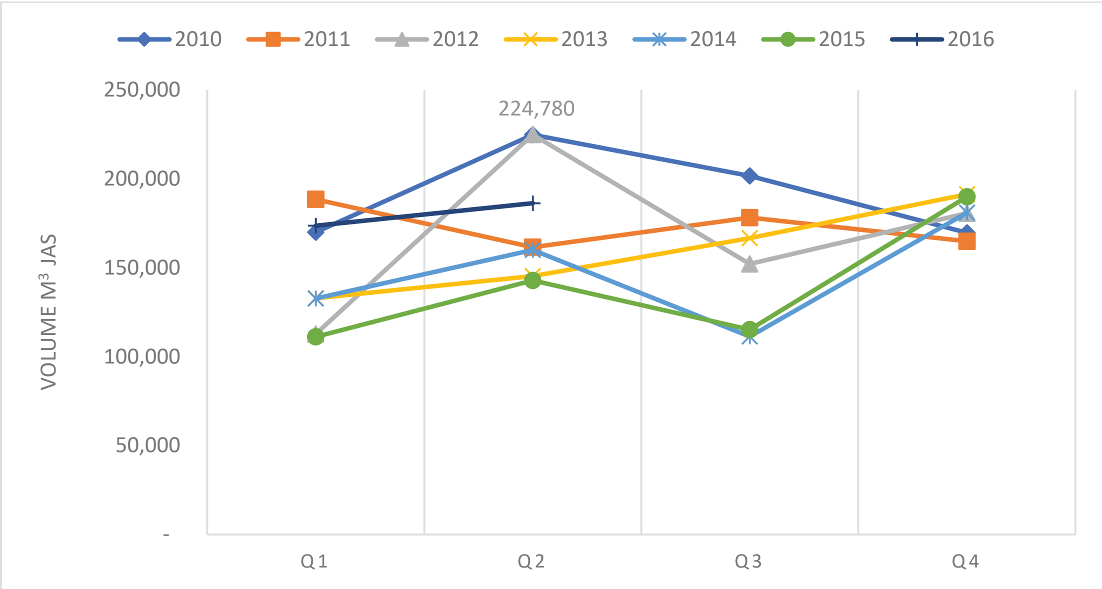

Figure (7) : Total quarterly log volume exported from the port of Nelson during the period from Jan 2010-Jun 2016.

Christchurch Port

Christchurch city is located in the eastern part of New Zealand's South Island. The total number of ship calls to the port of Christchurch in 2014 was 1059 ship calls including logs' ships. The number of log ships calls in 2014 was 39 calls, which compromises 3.68% of the total. The port has 3 berths that can be used by log ships, a link to rail and 48,000 m^3 JAS of storage. Figure 7 shows the amount of log handled by the port of Gisborne per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the first quarter of 2014, during which the port exported 194,852 m3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 802,032 m^3 JAS.

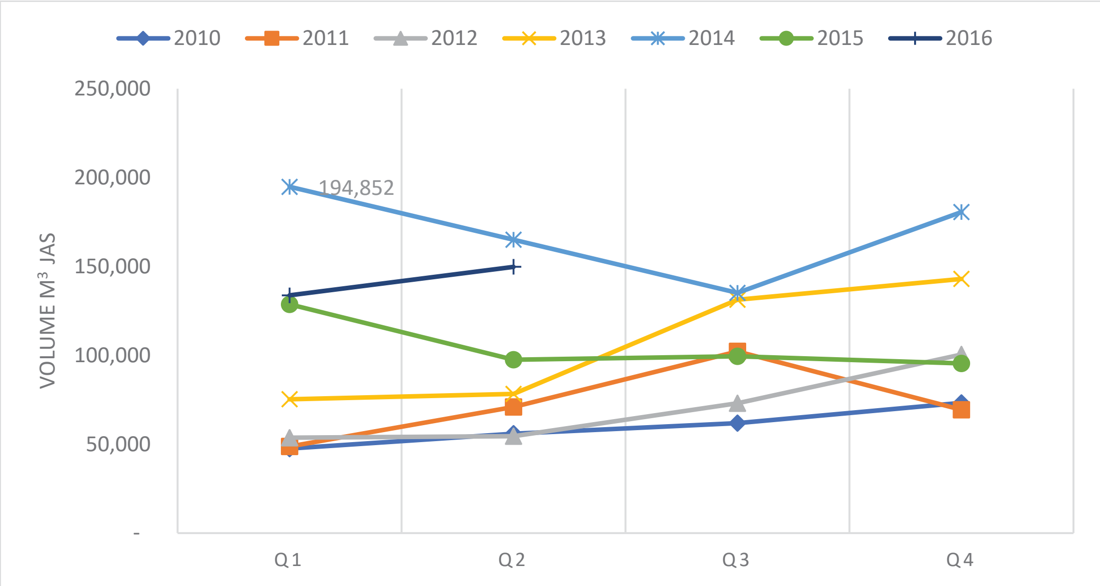

Figure (8) : Total quarterly log volume exported from the port of Christchurch during the period from Jan 2010-Jun 2016.

Otago Port

Otago is located in southeastern part of New Zealand's South Island. Otago port consist of two ports Dunedin port and Chalmers port, the two ports are close to each other and will be considered as one port. The total number of ship calls to the port of Otago in 2014 was 503 ship calls including logs' ships. The number of log ships calls in 2014 was 56 calls, which compromises 11.13% of the total. The port has 2 berth that can be used by log ships, alint to rail and 75,600 m^3 JAS of storage area. Figure 8 shows the amount of log handled by the port of Otago per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the second quarter of 2016, during which the port exported 260,725 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 1,355,769 m^3 JAS.

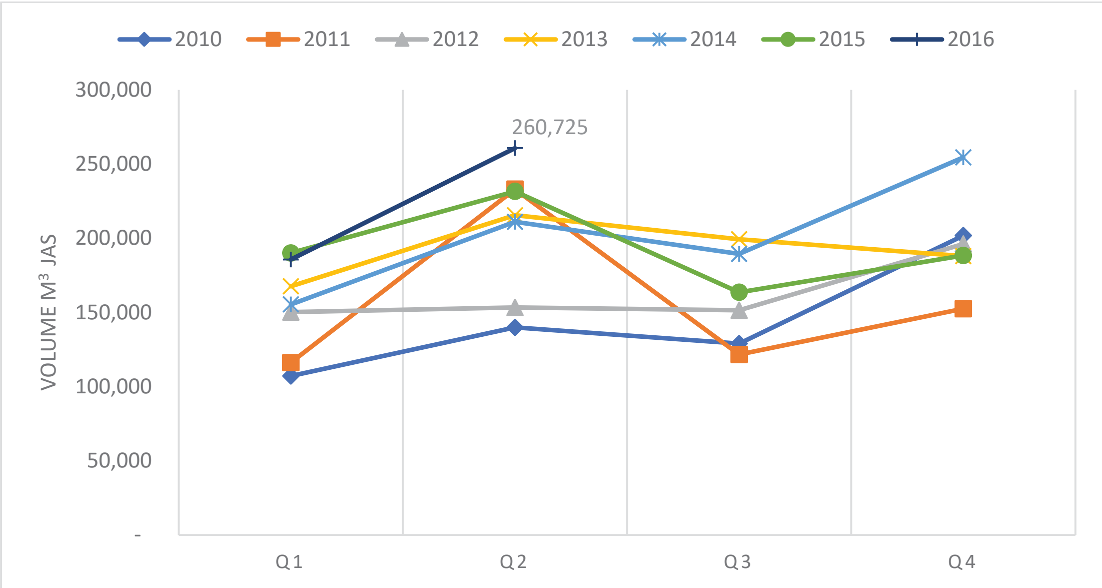

Figure (9) : Total quarterly log volume exported from the port of Otago during the period from Jan 2010-Jun 2016.

Invercargill Port

Invercargill southernmost city in New Zealand. The total number of ship calls to the port of Invercargill in 2014 was 301 ship calls including logs' ships. The number of log ships calls in 2014 was 28 calls, which compromises 9.30% of the total. The port has 1 berth that can be used by log ships, 36,000 m3 JAS of storage area but it does not have any link to rail. Figure 9 shows the amount of log handled by the port of Invercargill per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the first quarter of 2016, during which the port exported 154,237 m^3 JAS of logs. According to equation 1, the port's maximum annual handling capacity is 802,032 m^3 JAS.

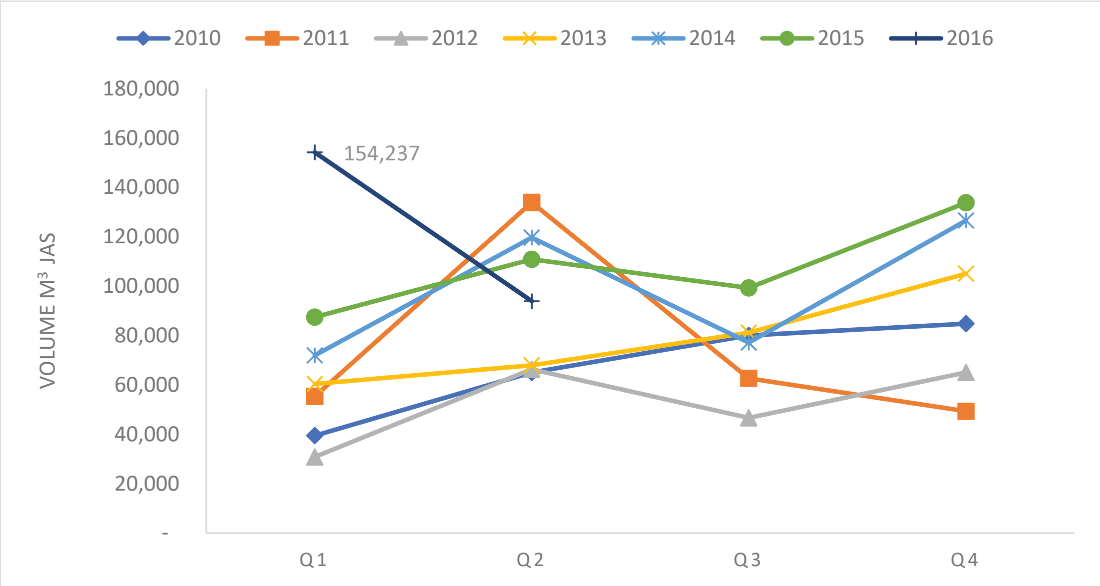

Figure (10) : Total quarterly log volume exported from the port of Tauranga during the period from Jan 2010-Jun 2016.

Timaru Port

Timaru city is located in Canterbury region in the South Island. The total number of ship calls to Timaru port in 2014 was confidential for commercial. The port has 1 berth that can be used by log ships, 96,000 m^3 JAS of storage area but it does not have any link to rail. Figure 6 shows the amount of log handled by the port of Timaru per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the first quarter of 2014, during which the port exported 165,074 m^3 JAS of logs. Per equation 1, the port's maximum annual handling capacity is 858,382 m^3 JAS.

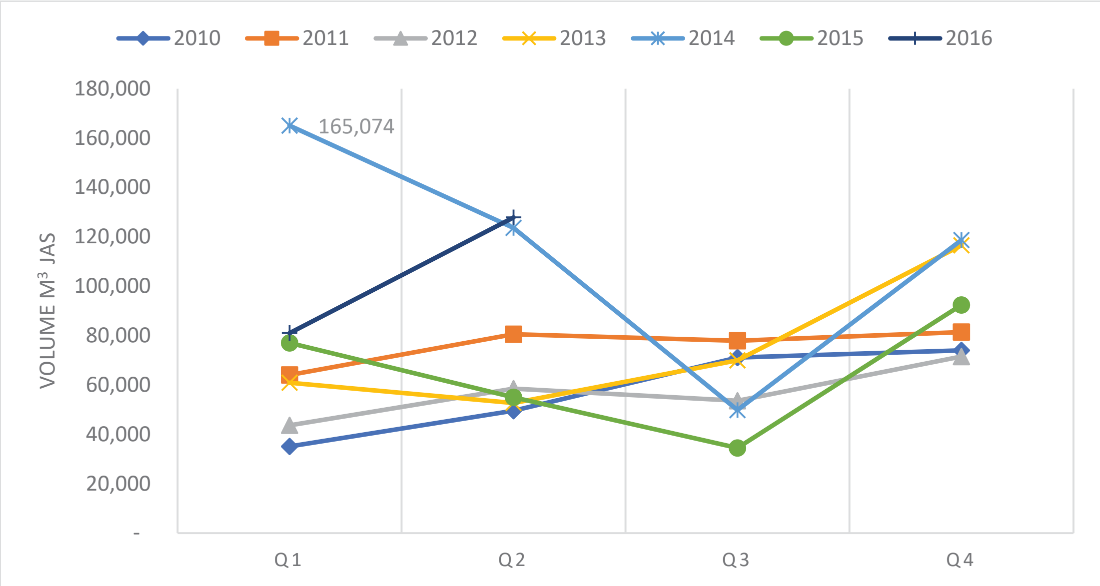

Figure (11) : Total quarterly log volume exported from the port of Timaru during the period from Jan 2010-Jun 2016.

Picton Port

Picton is a town in the Marlborough Region of New Zealand's South Island. The total number of ship calls to Picton port in 2014 was confidential for commercial reasons. The port has 55,950 m3 JAS of storage area but it does not have any link to rail. Figure 6 shows the amount of log handled by the port of Picton per quarter for the period from Jan 2010-Jun 2016. It is noticed from the Figure that the maximum volume handled was in the fourth quarter of 2014, during which the port exported 206,154 m^3 JAS of logs. Per equation 1, the port's maximum annual handling capacity is 1,072,001 m^3 JAS.

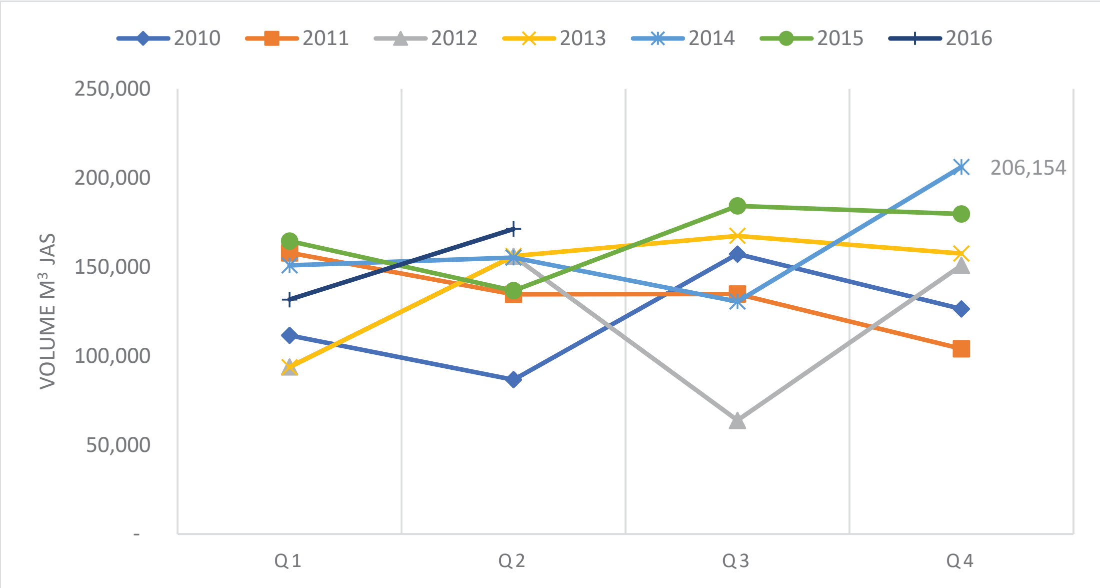

Figure (12) : Total quarterly log volume exported from the port of Picton during the period from Jan 2010-Jun 2016.

Appendix A.2 Yield, Processing And Exporting Volumes By District

Territorial authority	Harveting area Total 2020-2025 (Hec)	Annual harveting area 2020-2025 (Hec)	Total Recoverable Volume TRV (annual) (m3)	Export Volume (M3)	Processing volume (m3)	Conversion Factor Hec to m3
Far North District	11 583	2 317	1,139,767	500,767	639,000.00	492
Whangarei District	4 800	960	472,320.00	- 211,680	684,000.00	492
Kaipara District	5 312	1 062	522,701	472,701	50,000.00	492
Auckland Council	7 680	1 536	755,712	690,712	65,000.00	492
Thames-Coromandel District	2 565	513	348,043	158,043	190,000.00	678
Hauraki District	1 038	208	140,846	140,846	-	678
Waikato District	4 612	922	625,799	625,799	-	678
Matamata-Piako District	388	78	52,647	52,647	-	678
Hamilton City	0	0	-	-	-	678
Waipa District	635	127	86,163	86,163	-	678
Otorohanga District	1 635	327	221,852	221,852	-	678
Waitomo District	4 970	994	674,376	674,376	-	678
Ruapehu District	6 398	1 280	868,140	128,140	740,000.00	678
South Waikato District	18 055	3 611	2,449,870	- 28,130	2,478,000.00	678
Taupo District	19 440	3 888	2,637,800	2,217,800	420,000.00	678
Tauranga District	10	2	1,357	1,357	-	678
Western Bay Of Plenty District	5 831	1 166	791,204	666,204	125,000.00	678
Rotorua District	8 657	1 731	1,174,662	- 352,838	1,527,500.00	678
Kawerau District	0	0	-	- 2,870,000	2,870,000.00	678
Whakatane District	22 265	4 453	3,021,122	2,866,122	155,000.00	678
Opotiki District	1 099	220	149,123	149,123	-	678
Gisborne District	36 156	7 231	4,266,408	3,993,408	273,000.00	590
Wairoa District	11 572	2 314	1,286,806	1,286,806	-	556
Hastings District	14 294	2 859	1,589,493	1,589,493	-	556
Napier City	12	2	1,334	- 1,404,666	1,406,000.00	556
Central Hawkes Bay District	4 100	820	455,920	413,920	42,000.00	556
New Plymouth District	11 572	2 314	1,113,226	992,726	120,500.00	481
Stratford District	14 294	2 859	1,375,083	1,375,083	-	481
South Taranaki District	12	2	1,154	1,154	-	481
Wanganui District	4 100	820	394,420	360,220	34,200.00	481
Rangitikei District	4 334	867	416,931	416,931	-	481
Manawatu District	2 477	495	238,287	233,487	4,800.00	481
Palmerston North City	656	131	63,107	63,107	-	481
Tararua District	3 184	637	306,301	271,301	35,000.00	481
Masterton District	9 344	1 869	898,893	736,893	162,000.00	481
Horowhenua District	2 758	552	265,320	227,320	38,000.00	481
Carterton District	1 642	328	157,960	157,960	-	481
South Wairarapa District	2 294	459	220,683	209,683	11,000.00	481
Kapiti Coast District	1 241	248	119,384	119,384	-	481
Upper Hutt City	743	149	71,477	71,477	-	481
Porirua City	761	152	73,208	73,208	-	481
Wellington City	248	50	23,858	23,858	-	481
Lower Hutt City	47	9	4,521	4,521	-	481

Table 1: North Island's yield, processing and exporting volumes by district (Scion, 2017).

Territorial authority	Harveting Area Total 2020-2025 (Hec)	Annual Harveting Area 2020-2025 (Hec)	Total Recoverable Volume TRV (annual) (m3)	Export Volume (M3)	Processing volume (m3)	Conversion Factor (Hec to m3)
Nelson City	1 653	331	162,785	- 1,730,215	1,893,000	492
Tasman District	17 029	3 406	1,676,988	1,635,988	41,000	492
Marlborough District	15 550	3 110	1,531,338	1,361,338	170,000	492
Kaikoura District	338	68	33,286	33,286	-	492
Buller District	621	124	26,951	18,951	8,000	217
Grey District	1 256	251	54,510	- 120,490	175,000	217
Westland District	1 397	279	60,630	60,630	-	217
Hurunui District	5 515	1 103	478,702	464,202	14,500	434
Waimakariri District	3 314	663	287,655	287,655		434
Christchurch City	3 962	792	343,902	- 51,098	395,000	434
Selwyn District	2 710	542	235,228	58,228	177,000	434
Ashburton District	517	103	44,876	39,876	5,000	434
Timaru District	2 007	401	174,208	159,208	15,000	434
Mackenzie District	1 528	306	132,630	121,630	11,000	434
Waimate District	1 206	241	104,681	92,681	12,000	434
Waitaki District	2 493	499	234,259	229,259	5,000	470
Dunedin City	3 287	657	308,868	- 188,132	497,000	470
Queenstown-Lakes District	183	37	17,196	17,196	-	470
Central Otago District	1 240	248	116,519	116,519	-	470
Clutha District	14 978	2 996	1,407,431	1,230,431	177,000	470
Gore District	1 238	248	116,331	116,331	-	470
Southland District	11 126	2 225	1,045,472	368,472	677,000	470
Invercargill City	171	34	16,068	- 233,932	250,000	470

Table 2: South Island's yield, processing and exporting volumes by district (Scion, 2017).

Appendix A.3 Model Districts With their Corresponding Exporting Volumes

North Island District	*Total annual Exporting Volume*
Far North District	339,223
Kaipara District	514,193
Auckland Council	785,493
Thames-Coromandel District	179,730
Hauraki District	160,173
Waikato District	701,851
Waipa District	85,205
Otorohanga District	208,418
Waitomo District	633,539
Ruapehu District	114,045
Taupo District	287,710
Western Bay Of Plenty District	693,151
Whakatane District	1,556,935
Opotiki District	162,212
Gisborne District	3,850,311
Wairoa District	543,253
Hastings District	842,576
Central Hawkes Bay District	409,321
Stratford District	2,240,542
Wanganui District	320,596
Rangitikei District	371,068
Manawatu District	281,754
Tararua District	281,701
Masterton District	765,140
Horowhenua District	236,034
Carterton District	148,395
South Wairarapa District	217,721
Upper Hutt City	310,727

South Island District	Total annual Exporting Volume
Nelson City	-
Tasman District	633,991
Marlborough District	564,325
Kaikoura District	29,624
Buller District	-
Grey District	-
Westland District	-
Hurunui District	359,234
Waimakariri District	241,508
Christchurch City	-
Selwyn District	57,581
Ashburton District	39,433
Timaru District	149,567
Mackenzie District	114,265
Waimate District	87,068
Waitaki District	204,040
Dunedin City	-
Queenstown-Lakes District	15,304
Central Otago District	103,702
Clutha District	969,880
Gore District	109,286
Southland District	110,631
Invercargill City	-

Appendix B

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Appendix B.1 (Distances between districts and ports)

North Island

Distance from districts to ports	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	518	369	210	128	93	140	103	137	178	258	164	38	86	129
Wellington	950	800	641	581	550	559	494	463	443	330	363	496	525	572
Napier	722	572	413	351	319	331	278	283	285	245	145	265	294	341
New Plymouth	674	525	366	344	313	284	232	185	144	208	276	330	381	428
Whangarei	156	58	159	280	276	245	322	337	378	479	442	383	446	489
Gisborne	790	640	481	394	359	404	366	397	425	433	333	276	186	143

Distance from districts to ports	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tuaranga	270	354	308	362	343	400	301	391	446	485	430	498	537	505
Wellington	524	426	293	245	311	222	235	172	191	97	97	82	90	32
Napier	215	117	23	78	373	284	162	193	194	234	223	247	286	299
New Plymouth	596	512	393	346	45	181	280	251	305	343	262	357	387	337
Whangarei	630	659	586	640	544	628	576	666	721	760	705	773	812	780
Gisborne	2.5	100	232	286	581	492	370	402	404	442	432	456	494	507

South Island

Distance from districts to ports	*Nelson City*	*Tasman District*	*Marlborough District*	*Kaikoura District*	*Buller District*	*Grey District*	*Westland District*	*Hurunui District*	*Waimakariri District*	*Christchurch City*	*Selwyn District*	*Ashburton District*
Nelson	2	73	133	244	201	278	635	329	418	415	424	497
Christchurch	424	415	371	189	282	226	566	110	55	8	87	93
Otago	764	755	711	529	607	517	465	450	378	355	378	267
Invercargill	998	990	945	764	822	752	449	685	613	590	613	502
Timaru	574	565	521	340	417	327	445	260	188	166	188	78
Picton port	134	207	72	157	264	341	702	272	340	337	393	420

Distance from districts to ports	*Timaru District*	*Mackenzie District*	*Waimate District*	*Waitaki District*	*Dunedin City*	*Queenstown-Lakes District*	*Central Otago District*	*Clutha District*	*Gore District*	*Southland District*	*Invercargill City*
Nelson	574	682	682	686	770	817	851	861	924	991	975
Christchurch	169	278	277	281	365	495	454	457	520	670	570
Otago	191	272	209	131	14	304	191	105	168	308	218
Invercargill	426	418	444	365	229	235	256	151	91	130	27
Timaru	1	153	128	113	197	341	286	289	352	492	402
Picton port	496	605	604	608	692	822	781	784	842	986	897

Appendix B.2 (Distance between districts train log siding)

North Island

Distance between districts and train log siding	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Eastown	NA	NA	NA	427	396	361	309	263	243	129	211	344	374	420
Palmerston North	NA	NA	NA	453	422	431	366	335	316	202	234	367	396	443
Woodville	NA	NA	NA	464	433	442	377	346	327	213	245	378	407	454
Waiangawa	NA	NA	NA	547	516	525	460	429	410	296	328	461	490	537
Waiouru	NA	NA	NA	325	293	303	237	207	187	73	106	239	268	315
Murupara	NA	NA	NA	222	188	210	157	184	199	188	88	107	78	121
Kawerau	NA	NA	NA	211	176	205	154	181	200	246	146	93	32	75
OJS Kinleith	NA	NA	NA	155	124	136	78	93	113	170	70	96	133	180
Wairoa	NA	NA	NA	441	410	422	316	342	368	335	235	355	237	225

Distance between districts and train log siding	Gisborne	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Eastown	463	365	232	184	122	29	115	89	141	182	100	195	226	176
Palmerston North	388	290	157	110	193	104	106	29	68	95	48	108	147	124
Woodville	215	262	130	83	220	129	117	40	40	79	70	92	131	144
Waiangawa	445	347	214	213	290	200	200	123	100	6	131	10	48	61
Waiouru	326	277	156	222	226	134	35	125	181	219	164	233	271	239
Murupara	250	160	232	286	343	325	225	315	370	409	354	422	461	429
Kawerau	229	303	290	344	372	382	283	373	428	467	412	480	519	487
OJS inleith	321	286	214	267	289	306	206	296	352	391	335	404	442	410
Wairoa	97	2	135	188	484	394	272	304	306	344	334	358	397	409

South Island

Distance between districts and train sidings	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District

Stillwater	272	263	338	311	84	28	367	229	207	235	153	263

Distance between districts and train sidings	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Stillwater	340	439	438	452	536	545	580	628	691	720	711

Appendix B.3 (Rail Distances From Train sidings to ports)

North Island

Rail distance from each siding to each port	***Eastown***	***Palmerston North***	***Woodville***	***Waiangawa***	***Waiouru***	***Murupara***	***Kawerau***	***OJS Kinleith***	***wairoa***
Tauranga	547	506	535	611	354	142	84	121	798
Wellington	225	140	183	83	245	799	742	607	544
Napier	267	183	153	237	333	887	830	695	116
New Plymouth	294	253	281	358	317	871	813	678	430
Whangarei	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gisborne	NA	NA	NA	NA	NA	NA	NA	NA	NA

South Island

Rail distance from each siding to each port	***Stillwater***
Nelson	NA
Christchurch	228
Otago	565

Invercargill	824
Timaru	NA
Picton	559

Appendix C (Allocation matrices)

Appendix C.1 (Primary port Allocation)

North Island

Primary port Allocation	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	0	0	0	1	1	1	1	1	0	0	0	1	1	1
Wellington	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Napier	0	0	0	0	0	0	0	0	0	0	1	0	0	0
New Plymouth	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Whangarei	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Gisborne	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Primary port Allocation	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tuaranga	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wellington	0	0	0	0	0	1	0	1	1	1	1	1	1	1
Napier	0	1	1	1	0	0	1	0	0	0	0	0	0	0
New Plymouth	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Whangarei	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gisborne	1	0	0	0	0	0	0	0	0	0	0	0	0	0

South Island

Primary port Allocation	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	1	1	0	0	1	0	0	0	0	0	0	0
Christchurch	0	0	0	0	0	1	0	1	1	1	1	0
Otago	0	0	0	0	0	0	0	0	0	0	0	0
Invercargill	0	0	0	0	0	0	0	0	0	0	0	0
Timaru	0	0	0	0	0	0	1	0	0	0	0	1
Picton port	0	0	1	1	0	0	0	0	0	0	0	0

Primary port Allocation	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	0	0	0	0	0	0	0	0	0	0	0
Christchurch	0	0	0	0	0	0	0	0	0	0	0
Otago	0	0	0	0	1	0	1	1	0	0	0
Invercargill	0	0	0	0	0	0	0	0	1	1	1
Timaru	1	1	1	1	0	1	0	0	0	0	0
Picton port	0	0	0	0	0	0	0	0	0	0	0

Appendix C.2 (Secondary port Allocation)

North Island

Secondary Port Allocation	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	1	1	1	0	0	0	0	0	1	1	1	0	0	0
Wellington	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Napier	1	1	1	1	1	1	1	1	1	1	0	1	1	1
New Plymouth	1	1	1	1	1	1	1	1	0	0	1	1	1	1
Whangarei	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Gisborne	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Waiting	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Secondary Port Allocation	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wellington	1	1	1	1	1	0	1	0	0	0	0	0	0	0
Napier	1	0	0	0	1	1	0	1	1	1	1	1	1	1
New Plymouth	1	1	1	1	0	1	1	1	1	1	1	1	1	1
Whangarei	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Gisborne	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Waiting	1	1	1	1	1	1	1	1	1	1	1	1	1	1

South Island

Secondary Port Allocation	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	0	0	1	1	0	1	1	1	1	1	1	1
Christchurch	1	1	1	1	1	0	1	0	0	0	0	1
Otago	1	1	1	1	1	1	1	1	1	1	1	1
Invercargill	1	1	1	1	1	1	1	1	1	1	1	1
Timaru	1	1	1	1	1	1	0	1	1	1	1	0
Picton port	1	1	0	0	1	1	1	1	1	1	1	1
Waiting	1	1	1	1	1	1	1	1	1	1	1	1

Secondary Port Allocation	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	1	1	1	1	1	1	1	1	1	1	1
Christchurch	1	1	1	1	1	1	1	1	1	1	1
Otago	1	1	1	1	0	1	0	0	1	1	1
Invercargill	1	1	1	1	1	1	1	1	0	0	0

Timaru	0	0	0	0	1	0	1	1	1	1	1
Picton port	1	1	1	1	1	1	1	1	1	1	1
Waiting	1	1	1	1	1	1	1	1	1	1	1

Appendix C.3 (Train Sidings Allocation)

North Island

Train Siding Allocation	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Eastown	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmerston North	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Woodville	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waiangawa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waiouru	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Murupara	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kawerau	0	0	0	0	0	0	0	0	0	0	0	1	1	1
OJS Kinleith	0	0	0	1	1	1	1	1	1	0	1	0	0	0
Wairoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Train Siding Allocation	Gisborn	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Eastown	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Palmerston North	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Woodville	0	0	1	1	0	0	0	0	1	0	0	0	0	0
Waiangawa	0	0	0	0	0	0	0	0	0	1	0	1	1	1
Waiouru	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Murupara	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kawerau	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OJS Kinleith	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wairoa	1	1	0	0	0	0	0	0	0	0	0	0	0	0

South Island

Train Siding Allocation	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Stillwater	1	1	1	1	1	1	1	1	1	1	1	1

Train Siding Allocation	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Srillwater	1	1	1	1	1	1	1	1	1	1	1

Appendix D (Train and trucking rates)

Distance (Km)	***0-59***	***60-99***	***99-119***	***120-149***	***150-175***	***176-195***	***196-224***	***225-350***	***350-500***	***500-700***	***701-1000***	***>1000***
Trucking cost NZD/Ton	16	25	29	36	39	43	48	56	65	75	95	115

Distance	Any distance (constant rate per km per ton)
Train Rate	0.105 NZD/ton/km

Appendix E (Costs)

Port costs (Wharfage +Berthage +Tugs)

North Island Ports	Cost NZD/M3
Tauranga	4.781
Wellington	5.939
Napier	4.998
New Ply	5.700
Marsden	6.694
Gisborne	7.813

South Island Ports	Cost NZD/M3
Nelson	4.44
Christchurch	5.531
Otago	8.68
Invercargill	5.862
Timaru	5.631
Picton	5.254

Density Conversion Rates

North Island

Territorial authority	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District	Far North District
Conversion factor from M3 to Ton	1. 137 222	1. 087 778	1. 137 222	1. 137 222	1. 137 222	1. 038 333	. 988 889	. 939 444	. 939 444	. 89 0	. 939 444	1. 038 333	1. 038 333	1. 087 778	. 964 167

Territorial authority	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Conversion factor from M3 to Ton	0.964167	0.9888 89	0. 988 889	. 988 889	. 914 722	. 89 0	. 89 0	. 939 444	1. 038 333	1. 038 333	1. 038 333	. 939 444	1. 038 333	1. 137 222

South Island

Territorial authority	*Nelson City*	*Tasman District*	*Marlborough District*	*Kaikoura District*	*Buller District*	*Grey District*	*Westland District*	*Hurunui District*	*Waimakariri District*	*Christchurch City*	*Selwyn District*	*Ashburton District*
Conversion factor from M3 to Ton	1. 137 0	. 989 0	1. 137 0	. 89 0	. 989 0	1. 038 0	. 865 0	. 89 0	. 989 0	. 841 0	. 989 0	. 989 0
Territorial authority	**Ashburton District**	**Timaru District**	**Mackenzie District**	**Waimate District**	**Waitaki District**	**Dunedin City**	**Queenstown-Lakes District**	**Central Otago District**	**Clutha District**	**Gore District**	**Southland District**	**Invercargill City**
Conversion factor from M3 to Ton	. 989 0	. 939 0	. 939 0	. 939 0	. 89 0	. 989 0	. 89 0	. 89 0	. 939 0	. 939 0	. 865 0	. 89 0

Appendix F (Results)

North Island results (Forests Allocation with Quantities)

Scenario (1) All Ports Working

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Tauranga Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	701,851	85,205	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	179,730	-	-	-	208,418	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	992,881	162,212
Wait	-	-	-	-	160,173	-	-	-	-	-	-	693,151	564,054	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Wellington Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-		-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	543,253	842,576	409,321	-	-	371,068	281,754	281,701	590,611	236,034			-
New Plymouth	-	-	-	-	2,240,542	320,596	-	-	-		-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	174,529		148,395	217,721	310,727

Scenario (4) Napier Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	351,937	-	-	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	320,596	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	543,253	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	842,576	57,384	-	-	-	-	-	-	-	-	-	-

Scenario (5) New Plymouth Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	633,539	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	114,045	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-

Scenario (6) Whangarei Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	785,493	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	339,223	514,193	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (7) Gisborne Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	1,761,168	543,253	842,576	409,321	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	2,089,143	-	-	-	-	-	-	-	-	-	-	-	-	-

South Island Results

Scenario (1) All Ports Working

Weight handled by port for each district (Ton)	*Nelson City*	*Tasman District*	*Marlborough District*	*Kaikoura District*	*Buller District*	*Grey District*	*Westland District*	*Hurunui District*	*Waimakariri District*	*Christchurch City*	*Selwyn District*	*Ashburton District*
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	*Timaru District*	*Mackenzie District*	*Waimate District*	*Waitaki District*	*Dunedin City*	*Queenstown-Lakes District*	*Central Otago District*	*Clutha District*	*Gore District*	*Southland District*	*Invercargill City*
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	-	-	-	109,286	110,631.42	-
Timaru	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Nelson Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	633,991	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	-	-	-	109,286	110,631.42	-
Timaru	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Scenario (3)Christchurch Port Shut Down

Weight handled by port for each district (Ton)	*Nelson City*	*Tasman District*	*Marlborough District*	*Kaikoura District*	*Buller District*	*Grey District*	*Westland District*	*Hurunui District*	*Waimakariri District*	*Christchurch City*	*Selwyn District*
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	359,234	241,508	-	57,581

Weight handled by port for each district (Ton)	*Timaru District*	*Mackenzie District*	*Waimate District*	*Waitaki District*	*Dunedin City*	*Queenstown-Lakes District*	*Central Otago District*	*Clutha District*	*Gore District*	*Southland District*	*Invercargill City*
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	-	-	-	109,286	110,631.42	-
Timaru	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Scenario (4) Otago Ports Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***	***Ashburton District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	39,433
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	359,234	241,508	-	57,581	-

Weight handled by port for each district (Ton)	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	542,167	109,286	110,631.42	-
Timaru	149,567	114,265	87,068	204,040	-	15,304	103,702	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	427,713	-	-	-

Scenario (5) Invercargill Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	109,286	110,631	-

Scenario (6) Timaru Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	15,304	-	-	109,286	110,631.42	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	149,567	114,265	87,068	204,040	-	-	-	-	-	-	-

Scenario (7) Picton Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-

Christchurch	-	-	-	29,624	-	-	-	359,233.86	241,507.99	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	564,325	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	-	-	-	109,286	110,631.42	-
Timaru	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Appendix G Sensitivity Analysis (Forest Allocation Results)

North Island

20% cost decrease Scenario (1) All ports working

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Tuaranga Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	171,430	85,205	-	-	-	287,710	-	564,054	-
New Plymouth	-	-	-	-	157,599	530,421	-	208,418	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	179,730	2,573	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	992,881	162,212
Wait	-	-	-	-	-	-	-	-	-	-	-	693,151	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Wellington Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-		-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	2,608	842,576	409,321	-	-	371,068	281,754	281,701	765,140	236,034	148,395	217,721	-
New Plymouth	-	-	-	-	2,240,542	320,596	-	-	-		-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	540,645	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	310,727

Scenario (4) Napier Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	409,321	-	-	313,684	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	320,596	57,384	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	543,253	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	842,576	-	-	-	-	-	-	-	-	-	-	-

Scenario (4) New Plymouth Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	633,539	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	114,045	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-

Scenario (6) Whangarei Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	785,493	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	339,223	514,193	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (7) Gisborne Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	836,592	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	31,341	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	1,792,509	543,253	842,576	377,980	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	1,221,210	-	-	-	-	-	-	-	-	-	-	-	-	-

20% Cost Increase

Scenario (1) All Ports Working

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Tauranga Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	701,851	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	179,730	-	-	-	208,418	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	992,881	162,212
Wait	-	-	-	-	160,173	-	85,205	-	-	-	-	693,151	564,054	-

Weight handled by port for each district (Ton)	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Wellington Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	543,253	842,576	409,321	-	-	371,068	281,754	281,701	302,901	236,034	-		-
New Plymouth	-	-	-	-	2,240,542	320,596	-	-	-		-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	462,239	-	148,395	217,721	310,727

Scenario (4) Napier Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	31,341	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	543,253	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	842,576	377,980	-	-	-	-	-	-	-	-	-	-

Scenario (5) New Plymouth Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	633,539	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	114,045	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-

Scenario (6) Whangrei Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	785,493	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	339,223	514,193	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (7) Gisborne Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212

Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,223	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	1,761,168	543,253	842,576	409,321	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	2,089,143	-	-	-	-	-	-	-	-	-	-	-	-	-

20% Price Decrease Configuration

Scenario (1) All ports are Working

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-

New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Tauranga Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	701,851	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	179,730	-	-	-	208,418	633,539	114,045	-	-	-	-

Whangarei	339,222	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	992,881	162,212
Wait	-	-	-	-	160,173	-	85,205.35	-	-	-	-	693,151	564,054	-

Weight handled by port for each district (Ton)	*Gisborne District*	*Wairoa District*	*Hastings District*	*Central Hawkes Bay District*	*Stratford District*	*Wanganui District*	*Rangitikei District*	*Manawatu District*	*Tararua District*	*Masterton District*	*Horowhenua District*	*Carterton District*	*South Wairarapa District*	*Upper Hutt City*
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Wellington Port Shut Down

Weight handled by port for each district (Ton)	*Far North District*	*Kaipara District*	*Auckland Council*	*Thames-Coromandel District*	*Hauraki District*	*Waikato District*	*Waipa District*	*Otorohanga District*	*Waitomo District*	*Ruapehu District*	*Taupo District*	*Western Bay Of Plenty District*	*Whakatane District*	*Opotiki District*
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	543,253	842,576	409,321	-	-	371,068	281,754	281,701	-	236,034	-	-	-
New Plymouth	-	-	-	-	2,240,542	320,596	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	765,140	-	148,395	217,721	310,727

Scenario (4) Napier Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542.	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	543,253	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	842,576	409,321	-	-	-	-	-	-	-	-	-	-

Scenario (5) New Plymouth Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	633,539	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	114,045	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	339,222	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-

Scenario (6) Whangarei Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	785,493	179,730	160,173	701,851	85,205	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	339,222.79	514,193	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-

Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (7) Gisborne Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222.79	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	1,761,168	543,253	842,576	409,321	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	2,089,143	-	-	-	-	-	-	-	-	-	-	-	-	-

20% Price Increase Configuration

Scenario (1) All port Working

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205.348	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222.79	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Tauranga Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	171,430	85,205	-	-	-	287,710	-	564,054	-
New Plymouth	-	-	-	-	157,599	530,421	-	208,418	633,539	114,045	-	-	-	-
Whangarei	339,222.79	514,193	785,493	179,730	2,573	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	992,881	162,212
Wait	-	-	-	-	-	-	-	-	-	-	-	693,151.11	-	-

Weight handled by port for each district (Ton)	**Gisborne District**	**Wairoa District**	**Hastings District**	**Central Hawkes Bay District**	**Stratford District**	**Wanganui District**	**Rangitikei District**	**Manawatu District**	**Tararua District**	**Masterton District**	**Horowhenua District**	**Carterton District**	**South Wairarapa District**	**Upper Hutt City**
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Wellington Port Shut Down

Weight handled by port for each district (Ton)	**Far North District**	**Kaipara District**	**Auckland Council**	**Thames-Coromandel District**	**Hauraki District**	**Waikato District**	**Waipa District**	**Otorohanga District**	**Waitomo District**	**Ruapehu District**	**Taupo District**	**Western Bay Of Plenty District**	**Whakatane District**	**Opotiki District**

Tauranga	-	-	-	179,730	160,173	701,851	85,205.348	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-		-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222.79	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	**_Gisborne District_**	**_Wairoa District_**	**_Hastings District_**	**_Central Hawkes Bay District_**	**_Stratford District_**	**_Wanganui District_**	**_Rangitikei District_**	**_Manawatu District_**	**_Tararua District_**	**_Masterton District_**	**_Horowhenua District_**	**_Carterton District_**	**_South Wairarapa District_**	**_Upper Hutt City_**
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	2,608	842,576	409,321	-	-	371,068	281,754	281,701	765,140	236,034	148,395	217,721	-
New Plymouth	-	-	-	-	2,240,542	320,596	-	-	-		-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	540,645	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	310,727

Scenario (4) Napier Port Shut Down

Weight handled by port for each district (Ton)	**_Far North District_**	**_Kaipara District_**	**_Auckland Council_**	**_Thames-Coromandel District_**	**_Hauraki District_**	**_Waikato District_**	**_Waipa District_**	**_Otorohanga District_**	**_Waitomo District_**	**_Ruapehu District_**	**_Taupo District_**	**_Western Bay Of Plenty District_**	**_Whakatane District_**	**_Opotiki District_**
Tauranga	-	-	-	179,730	160,173	701,851	85,205.348	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-

New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222.79	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Gisborne District***	***Wairoa District***	***Hastings District***	***Central Hawkes Bay District***	***Stratford District***	***Wanganui District***	***Rangitikei District***	***Manawatu District***	***Tararua District***	***Masterton District***	***Horowhenua District***	***Carterton District***	***South Wairarapa District***	***Upper Hutt City***
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	409,321	-	-	313,684	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	320,596	57,384	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	543,253	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	842,576	-	-	-	-	-	-	-	-	-	-	-

Scenario (5) New Plymouth Port Shut Down

Weight handled by port for each district (Ton)	***Far North District***	***Kaipara District***	***Auckland Council***	***Thames-Coromandel District***	***Hauraki District***	***Waikato District***	***Waipa District***	***Otorohanga District***	***Waitomo District***	***Ruapehu District***	***Taupo District***	***Western Bay Of Plenty District***	***Whakatane District***	***Opotiki District***
Tauranga	-	-	-	179,730	160,173	701,851	85,205.348	208,418	633,539	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	114,045	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	339,222.79	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-

Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-

Scenario (5) Whangarei Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	785,493	179,730	160,173	701,851	85,205.348	208,418	-	-	-	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	287,710	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	339,222.79	514,193.43	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	-	-	320,596	-	281,754	-	765,140	236,034	148,395	217,721	310,727
Napier	-	543,253	842,576	409,321	-	-	371,068	-	281,701	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	3,850,311	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (7) Gisborne Port Shut Down

Weight handled by port for each district (Ton)	Far North District	Kaipara District	Auckland Council	Thames-Coromandel District	Hauraki District	Waikato District	Waipa District	Otorohanga District	Waitomo District	Ruapehu District	Taupo District	Western Bay Of Plenty District	Whakatane District	Opotiki District
Tauranga	-	-	-	179,730	160,173	701,851	85,205.348	208,418	-	-	287,710	693,151	1,556,935	162,212
Wellington	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Napier	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	-	-	-	-	633,539	114,045	-	-	-	-
Whangarei	339,222.79	514,193	785,493	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Gisborne District	Wairoa District	Hastings District	Central Hawkes Bay District	Stratford District	Wanganui District	Rangitikei District	Manawatu District	Tararua District	Masterton District	Horowhenua District	Carterton District	South Wairarapa District	Upper Hutt City
Tauranga	836,592	-	-	-	-	-	-	-	-	-	-	-	-	-
Wellington	-	-	-	31,341	-	320,596	371,068	281,754	281,701	765,140	236,034	148,395	217,721	310,727
Napier	1,792,509	543,253	842,576	377,980	-	-	-	-	-	-	-	-	-	-
New Plymouth	-	-	-	-	2,240,542	-	-	-	-	-	-	-	-	-
Whangarei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gisborne	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	1,221,210	-	-	-	-	-	-	-	-	-	-	-	-	-

South Island

20% Cost Decrease

Scenario (1) All Ports Working

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District

Nelson	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	103,702	969,880	-	-
invercargill	-	-	-	-	-	-	-	-	109,286	110,63
Timaru	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-

Scenario (2) Nelson Port Closure

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	633,991	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Selwyn District***	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	57,581	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	103,702	969,880.25	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	109,286	110,631.42	-
Timaru	-	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-

Picton	-	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Christchurch Port Closure

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	359,234	241,508	-	57,581

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***
Nelson	0	0	0	0	0	0	0	0	0	0	0
Christchurch	0	0	0	0	0	0	0	0	0	0	0
Otago (Dunedin +Chalmers)	0	0	0	0	0	0	0	103701.5032	969880.2508	0	0
Invercargill	0	0	0	0	0	0	0	0	0	109286.1451	110631.4249
Timaru	39432.53778	149566.6953	114265.0036	87068.46267	204040.1995	0	15304.33474	0	0	0	0
Picton	0	0	0	0	0	0	0	0	0	0	0
Wait	0	0	0	0	0	0	0	0	0	0	0

Scenario (4) Otago Port Closure

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	0	0	0	0	0	0	0	0	0	0	0	0
Christchurch	39432.53778	0	0	0	0	0	0	0	0	0	0	0
Otago (Dunedin +Chalmers)	0	0	0	0	0	0	0	0	0	0	0	0
invercargill	0	0	0	0	0	0	0	0	542167.367	109286.1451	110631.4249	0
Timaru	0	149566.6953	114265.0036	87068.46267	204040.1995	0	15304.33474	0	0	0	0	0
Picton	0	0	0	0	0	0	0	0	0	0	0	0
Wait	0	0	0	0	0	0	0	103701.5032	427712.8838	0	0	0

Scenario (5) Invercargill Port Closure

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown -Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	0	0	0	0	0	0	0	0	0	0	0	0
Christchurch	39432.53778	0	0	0	0	0	0	0	0	0	0	0
Otago (Dunedin +Chalmers)	0	0	0	0	0	0	0	103701.	969880.2508	0	0	0
invercargill	0	0	0	0	0	0	0	0	0	0	0	0
Timaru	0	149566.6953	114265.0036	87068.46267	204040.1995	0	15304.33474	0	0	0	0	0
Picton	0	0	0	0	0	0	0	0	0	0	0	0
Wait	0	0	0	0	0	0	0	0	0	109286.1451	110631.4249	0

Scenario (6) Timaru Port Closure

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,233.86	241,507.99	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	0	0	0	0	0	0	0	0	0	0	0	0
Christchurch	39432.53778	0	0	0	0	0	0	0	0	0	0	0
Otago (Dunedin +Chalmers)	0	0	0	0	0	0	0	103701.5032	969880.2508	0	0	0
invercargill	0	0	0	0	0	0	15304.33474	0	0	109286.1451	110631.4249	0
Timaru	0	0	0	0	0	0	0	0	0	0	0	0
Picton	0	0	0	0	0	0	0	0	0	0	0	0
Wait	0	149566.6953	114265.0036	87068.46267	204040.1995	0	0	0	0	0	0	0

Scenario (7) Picton Port Closure

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	29,624	-	-	-	359,233.86	241,507.99	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	564,325	-	-	-	-	-	-	-	-

.

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	0	0	0	0	0	0	0	0	0	0	0	0
Christchurch	39432.53778	0	0	0	0	0	0	0	0	0	0	0
Otago (Dunedin +Chalmers)	0	0	0	0	0	0	0	103701.5032	969880.2508	0	0	0
Invercargill	0	0	0	0	0	0	0	0	0	109286.1451	110631.4249	0
Timaru	0	149566.6953	114265.0036	87068.46267	204040.1995	0	15304.33474	0	0	0	0	0
Picton	0	0	0	0	0	0	0	0	0	0	0	0
Wait	0	0	0	0	0	0	0	0	0	0	0	0

20% Cost Increase

Scenario (1) All Ports Working

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Qeenstown Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait												

Scenario (2) Nelson Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	633,991	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago Dunedin +Chalmer	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Christchurch Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District

Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	359,234	241,508	-	57,581

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	39,433	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait												

Scenario (4) Otago Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-

Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-LakesDistrict***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	542,167	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	103,702	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait			-		-	-	-		-	427,713	-	- -

Scenario (4) Invercargill Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581

Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	109,286	110,631	-

Scenario (5) Invercargill Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-

invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown -Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargi ll City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchu rch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargi ll	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	109,286	110,631	-

Scenario (6) Timaru Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-

Wait	-	-	-	-	-	-	-	-	-	-	-

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargill	-	-	-	-	-	-	15,304	-	-	109,286	110,631	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	149,567	114,265	87,068	204,040	-	-	-	-	-	-	-

Scenario (7) Picton Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	29,624	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	564,325	-	-	-	-	-	-	-	-

	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

20% Price Decrease

Scenario (1) All Port Working

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	0	0	0	0	0	0	0	0	0	0	0	0
Christchurch	39432.54	0	0	0	0	0	0	0	0	0	0	0
Otago (Dunedin +Chalmers)	0	0	0	0	0	0	0	103701.5	969880.3	0	0	0
invercargill	0	0	0	0	0	0	0	0	0	109286.1	110631.4	0
Timaru	0	149566.7	114265	87068.46	204040.2	0	15304.33	0	0	0	0	0
Picton	0	0	0	0	0	0	0	0	0	0	0	0
Wait	0	0	0	0	0	0	0	0	0	0	0	0

Scenario (2) Nelson Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	633,991	-	-	-	-	-	-	-	-	-

(Ton)	Ashbur ton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercar gill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christ church	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dune	-	-	-	-	-	-	-	103,702	969,880	-	-	-

din +Chalmers)												
Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Christchurch Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	359,234	241,508	-	57,581

)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-

Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	39,433	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (4) Otago Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***	***Ashburton District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	542,167	109,286	110,631	-

Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	103,702	427,713	-	-	-

Scenario (5) Invercargill Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	109,286	110,631	-

Scenario (6) Timaru Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	15,304	-	-	109,286	110,631	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	149,567	114,265	87,068	204,040	-	-	-	-	-	-	-

Scenario (7) Picton Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District	Ashburton District

Nelson	-	633,991	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	29,624	-	-	-	359,234	241,508	-	57,581	39,433
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	564,325	-	-	-	-	-	-	-	-	-

	Ashburton District	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

20% Increase In Price

Scenario (1) All Ports Working

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581

Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (2) Nelson Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-

Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	633,991	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (3) Christchurch Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	359,234	241,508	-	57,581

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	39,433	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-

Scenario (4) Otago Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-

Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-	-
Invercargill	-	-	-	-	-	-	-	-	542,167	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	103,702	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	427,713	-	-	-

Scenario (5) Invercargill Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Invercargill	-	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	109,286	110,631	-

Scenario (6) Timaru Port Shut Down

Weight handled by port for each district (Ton)	Nelson City	Tasman District	Marlborough District	Kaikoura District	Buller District	Grey District	Westland District	Hurunui District	Waimakariri District	Christchurch City	Selwyn District
Nelson	-	633,991	-	-	-	-	-	-	-	-	-
Christchurch	-	-	-	-	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	564,325	29,624	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	Ashburton District	Timaru District	Mackenzie District	Waimate District	Waitaki District	Dunedin City	Queenstown-Lakes District	Central Otago District	Clutha District	Gore District	Southland District	Invercargill City
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	204,040	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	15,304	-	-	109,286	110,631	-
Timaru	-	-	-	-	-	-	-	-	-	-	-	-

Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	149,567	114,265	87,068	-	-	-	-	-	-	-	-

Scenario (7) Picton Port Shut Down

Weight handled by port for each district (Ton)	***Nelson City***	***Tasman District***	***Marlborough District***	***Kaikoura District***	***Buller District***	***Grey District***	***Westland District***	***Hurunui District***	***Waimakariri District***	***Christchurch City***	***Selwyn District***
Nelson	-	633,991	476,648	-	-	-	-	-	-	-	-
Christchurch	-	-	-	29,624	-	-	-	359,234	241,508	-	57,581
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	-	-	-	-
invercargill	-	-	-	-	-	-	-	-	-	-	-
Timaru	-	-	-	-	-	-	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	87,676	-	-	-	-	-	-	-	-

Weight handled by port for each district (Ton)	***Ashburton District***	***Timaru District***	***Mackenzie District***	***Waimate District***	***Waitaki District***	***Dunedin City***	***Queenstown-Lakes District***	***Central Otago District***	***Clutha District***	***Gore District***	***Southland District***	***Invercargill City***
Nelson	-	-	-	-	-	-	-	-	-	-	-	-
Christchurch	39,433	-	-	-	-	-	-	-	-	-	-	-
Otago (Dunedin +Chalmers)	-	-	-	-	-	-	-	103,702	969,880	-	-	-
Invercargill	-	-	-	-	-	-	-	-	-	109,286	110,631	-
Timaru	-	149,567	114,265	87,068	204,040	-	15,304	-	-	-	-	-
Picton	-	-	-	-	-	-	-	-	-	-	-	-
Wait	-	-	-	-	-	-	-	-	-	-	-	-