Impact of the Ruakura Inland Port on the Golden Triangle

– a System Dynamics Simulation Study

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Abstract

The Ruakura Inland Port, a project developed in anticipation of the increasing freight flows in the future, is an inland port that is expected to add an additional one million TEUs per annum to the Golden Triangle's freight capacities. Such a change to the system will result in impacts to the other members within it, but traditional research methods cannot fully capture the complexities of a freight system that involves so many variables, hence the need for simulation modelling.

This pragmatic study presents a pilot simulation model using a system dynamics approach so that the relationships within the complex freight system could be better understood. Constructed using the *iThink* software, not only does this evolvable model show how the addition of the Ruakura Inland Port is going to affect the current freight flows with the Golden Triangle, it was also designed with the aim of helping practitioners identify drivers and enablers within the system so that informed decisions can be made. The results from the simulation showed that the in the first 20 years it is unlikely that the Ruakura Inland Port will have significant impacts on the system until much higher utilisation rates can be achieved. It was also found that the addition of the Third Main and the Waikato Expressway will have relatively small to none impacts.

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1. Chapter One: Introduction

This section provides an overview of the topic of this thesis, along with the sequence of its contents.

With the increase in international trade due to trends such as globalization and containerization, there is greater focus on how the freight infrastructure of each country will be able to cope with the projected increase in freight volumes. New Zealand is of no exception – the ability to move freight in and out of the country (as well as within) is especially crucial to its trade-focused economy. The two major seaports – Ports of Auckland, and Port of Tauranga – within the Golden Triangle area (a region bordered by Auckland, Tauranga, and Hamilton) in the Upper North Island alone accounts for 45 per cent of all freight tonnage produced in New Zealand (Deloitte, 2018), and that number is expected to increase to 62 per cent by 2031 (Castalia, 2012). Therefore, it is important that the freight infrastructure will be capable of handling such a large volume of freight, as both Ports of Auckland and Port of Tauranga are expected to reach maximum capacity in the foreseeable future. If New Zealand's freight infrastructure fails to accommodate for the increasing freight volumes, the efficiency of its logistics system will be impacted, as well as the sustainability of the economic advantage of their ports.

Proposed by Tainui Group Holdings, the Ruakura Inland Port is one such way of relieving the pressure of the increased freight volumes on the current freight infrastructure. Located in Hamilton, the Ruakura Inland Port will provide a multitude of functions and benefits. For example, the site will have customs clearance capabilities, thus allowing containers to be cleared at the inland port rather than the seaports, saving customers time and increasing convenience. Like other inland ports, the Ruakura Inland Port will also bring in economic benefits to the region while reducing the overall environmental impacts of freight movement as it will increase the use of rail to transport freight and decrease road usage. Not only will this significantly reduce the amount of greenhouse gas emissions, but it will also result in lower congestion levels, an increasingly problematic situation in the Auckland region where the largest population in New Zealand is located. There is therefore significant value to be gained from understanding how the Ruakura Inland Port will impact the current freight flows in the Golden Triangle. However, freight systems are very dynamic and complicated as there are several actors and elements involved. Each of these actors and elements are also interrelated, so traditional research approaches such as qualitative or quantitative methods will not be able to adequately capture the flows and relationships of the system. System dynamics, on the other hand, will be able to better reflect reality as it can account for complicated processes and decisions that may be influenced by several external factors.

Through the use of system dynamics and simulation modelling with the aid of system dynamics software *iThink*, this research aims to construct an evolvable model that can account for the significant enablers and challenges that are likely to affect port throughput. The model is designed to assist decision makers to develop strategies to mitigate the risks and capitalise on the opportunities they may encounter in the future. While the model is unable to provide outputs that are or will be identical to reality due to the lack of availability of data and the complexity of this system, it is still a useful tool in decision making as it can show the relationships between each of the different actors and variables. The model will first show the current freight flows within the Golden Triangle region and how each of the major players – Ports of Auckland, Port of Tauranga, Wiri Inland Port, and MetroPort are connected by rail and road lines. The impact of the opening of Ruakura Inland Port will then be simulated by investigating how different levels of utilisation rates will affect current freight flows. This will be followed by the inclusion of the impacts of the completion of the Waikato Expressway and the Third Main rail line between Wiri to Westfield into the model so that the effects of these scenarios can be observed. An analysis as to the maximum capacity the Ruakura Inland Port can handle under the current conditions before the amount of available freight is depleted is also conducted to provide an indication of how much capacity the inland port should make available at the first stages.

More information regarding the Ruakura Inland Port will first be provided in the background section of this thesis, followed by a literature review investigating the available studies in the fields of inland ports and system dynamics. The current freight situation of New Zealand will be described next, then the gap in practitioner's understanding will be identified to explain the goals of this research. The methodology and method to achieve these goals will be detailed in the next section before the findings are presented and discussed. Finally, a conclusion that also includes a recommendation as to what practitioners could do will be provided, as well as any future research gaps that could be of interest to practitioners or other stakeholders. While not a typical component of academic writing, behind the appendices at the very end is a reflection of the long journey it took to complete this thesis.

2. Chapter Two: Background

This section provides an introduction to the motivations behind the inception of the Ruakura Inland Port, the justification of its existence, the timeline of the project, as well as a description of the inland port and the benefits it is expected to bring to the region.

In 2009, a strategic document titled ‘The Future Proof Strategy and Implementation Plan 2009’ was introduced by then Prime Minister John Key and Kiingi Tūheitia (Future Proof, n.d.). The document presented a growth strategy developed by the Hamilton City Council, Environment Waikato, and Waipa and Waikato District Councils, with the assistance of Tangata Whenua, New Zealand Transport Agency, and Matamata-Piako District Council. The strategy outlined the increasing importance of the Waikato region because of the population growth in Hamilton, Waipa, and Waikato region, estimating that the population in the region will almost double in the next fifty years, bringing the number of residents to nearly half a million (Future Proof, n.d.). Intended as a “visionary exercise” (Future Proof, 2009, p.2), the strategy aims to provide “a framework for ongoing co-operation and implementation” (Future Proof, n.d., para. 4) for the region to ensure its long-term sustainability. The strategy encompasses four key areas of development – residential development/ settlement patterns, rural land, business and industrial land, and land and commercial development (Future Proof, n.d.).

In the document, the Ruakura area was identified as a growth area with the potential to become a strategic industrial zone with a technology and innovation focus due to its proximity to both road and rail links (Future Proof, 2009; Castalia, 2012), thereby making it an ideal location as an intermodal terminal for freight handling and associated value-added services (e.g. storage facilities). Key institutions such as Ag Research, the University of Waikato, and the Waikato Innovation Park are also within proximity to the area, which means that there is the ability to leverage off these institutions to develop Ruakura into an employment precinct (Hamilton City Council, n.d.-a). Another major reason why the Ruakura area was of particular interest was because of its location within the Golden Triangle – the Waikato region is “at the centre of a market of 1.5 million people within a 90-minute drive” (Future Proof, 2009, p.185).

This proximity means that there may be cost savings for importers and exporters as domestic freight costs will be lower. The availability of both land and labour also make Hamilton a significantly better option than Auckland and Tauranga in terms of cost advantages (Ruakura, n.d.). Additionally, the business case for a five-year trial of a commuter train service between Hamilton and Auckland was approved by the New Zealand Transport Agency in 2018 (Ensor, 2018). Expected to start in March 2020, the service will further reduce congestion and decrease the time commuters spend on travelling between the two cities, thus also reducing the distance as well.

With issues such as traffic congestion problems in the Auckland region and PoAL and PoT reaching maximum capacity in the foreseeable future, Ruakura was seen as an ideal location to provide more capacity for the industry. The Ruakura structure plan that included an inland port was therefore proposed by Tainui Group Holdings – in conjunction with Chedworth Properties and Hamilton City Council – in 2012, following the transfer of the area from the Waikato District to Hamilton City in July 2011 (Ruakura, n.d.). Located within the eastern section of Hamilton City, this transfer increased the city's urban area by 822 hectares (Ruakura, n.d.). As shown in Appendix 1, the area stretches from Silverdale to the Gordonton Road/Wairere Drive roundabout and the Waikato Expressway currently still under construction (Fairview Downs Residents and Owners Association, 2015).

While the focus of the project is on the inland port that will be approximately six kilometres away from the Hamilton Central Business District, the structure plan also proposed a range of other uses for the area. For example, the 373 hectares of employment land not only includes the inland port but also a freight and logistics hub, and new commercial and retail areas (Hamilton City Council, n.d.-a). Other proposed uses included an Innovation and Research precinct, housing and residential neighbourhoods, and other open spaces that link each parts of the estate together (Hamilton City Council, n.d.-a). Advisory firm Castalia was engaged to provide an evaluation on the viability of the plans, and the following four areas were investigated – commercial viability, social and environmental impacts, regional economic impacts, and the impacts on associated infrastructure investments (Castalia, 2012). The investigation reported that once Wiri and MetroPort have reached their capacities at around 2030, the freight flow through Ruakura will increase significantly (Castalia, 2012). Ruakura would be able to capture up to 15 per cent of the upper North Island freight flow (which equates to approximately 530,000 TEU by 2040) whilst reducing carbon emissions and accidents (Castalia, 2012). The Ruakura development will also be able to provide significant economic benefits to the Waikato region, which is expected to add $4.4 billion to the region's Gross Regional Product between 2019 and 2061, while simultaneously doubling the cost benefit ratio of the Waikato Expressway by reducing congestion in Auckland (Castalia, 2012). It was estimated that the inland port will result in 50,000 fewer truck trips through the Auckland region per year, as well as shorten travel distances and subsequently, travel times and costs (Castalia, 2012). The multitude of benefits that the area is expected to bring in has led to it eventually being identified as a project of national significance by the New Zealand government (Barclay & LaSalle, 2017). It is, however, worth noting that the Ruakura Inland Port is not being developed with the intention of competing with other inland ports but rather to assist PoAL and PoT in handling the increase of freight volumes in the future (AmZ, 2009).

Despite being praised as an "unique opportunity" (AmZ, 2009), the project was met with criticism as well. Opponents cited issues such as the inland port being a biosecurity risk that has not been adequately addressed, which is a threat to both residents and "Waikato's highly productive farmland" (Leaman, 2014, para. 1). Other concerns include air pollution and the hazardous risks – for example, fire risks, explosions, and chemical leaks – involved in having multiple hazardous sites and facilities within proximity of each other (Fairview Downs Residents and Owners Association, 2015). Various changes were therefore made to the plan in the subsequent years, until the first resource consent for the project was granted by the Hamilton City Council and Waikato Regional Council in 2016 (Ruakura, n.d.). The consent covered 85 hectares of land for the Logistics precinct (i.e. the inland hub and surrounding areas for freight handling) which also includes part of the rail infrastructure for the inland port, as well as the Explore precinct which is the open space that joins each parts of the development together (Rukaura, n.d.). Other parts of the development include a state-of-the-art Work precinct zoned for light industry, a Learn precinct for knowledge and innovation, a Live precinct for residential development, and three Shop precincts that will house a wide variety of retail shops, restaurants, medical services, etc. for convenient access for residents and businesses in the Work precinct (Ruakura, n.d.).

Construction of the first six hectares of the inland port began in 2017, with the aim of opening in 2019. In 2017, TGH also signed a 50/50 joint venture with logistics provider LINX Cargo Care Group and one of its subsidiaries C3 Limited (Tainui Group Holdings, 2017). The agreement will allow LINX Cargo Care Group to lease the inland port land at Ruakura for 30 years (Tainui Group Holdings, 2017). The first stage of the inland port will be a road vehicle only operation with relatively low container-handling capabilities of around 5,000 containers per annum (Castalia, 2012). A rail siding directly off the East Coast Main Trunk line will be constructed in the second stage, and while the initial rail volumes will also be low, once fully established the port is expected to be able to load and unload 120 containers each during every two hour period, which equates to approximately 964,000 containers per annum (AmZ, 2009). This shift to a road/ rail configuration is also expected to reduce the total distance travelled by road by 1.1 million kilometres (Castalia, 2013). The construction of the whole inland port is set to be completed in 2041, which will then be capable of handling up to 1 million TEU per year (Ruakura, n.d.), but it may take around 40 to 50 years to reach its full capacity (AmZ, 2009). As well as the potential to support 6,000 to 12,000 jobs in the future (Tainui Group Holdings, 2017), the port will also have custom clearance capabilities, as the Ministry of Primary Industries and New Zealand Customs will both have facilities on site (Ruakura, n.d.), thereby increasing convenience and saving time for customers. Once the Hamilton section of the Waikato Expressway is completed in 2019, the travel times between Waikato and Auckland will be reduced and the freight movement between the Golden Triangle and Rotorua will be more reliable and efficient as well (Ruakura, n.d.). Despite the benefits though, the effects of the Ruakura Inland Port on the freight flows in the Golden Triangle is unlikely to be immediately apparent. Factors such as contractual agreements with other ports or supply chain partners will prevent some businesses from being able to change from their current operations to a Ruakura-inclusive one (Castalia, 2012). However, if Ruakura is able to remain consistently competitive in terms of price, user uptake will likely gradually increase once their contracts start expiring (Castalia, 2012).

3. Chapter Three: Literature Review

This section defines what inland ports are through the review of the existing academic literature in the field of inland ports, starting from the broader topic of seaports and trade to explain the existence of inland ports and its impacts. Different methods of research used in seaport and inland port studies are then introduced before explaining why a simulation using system dynamics principles is chosen as the method for this research. This reasoning is followed by a literature review on system dynamics to provide background and a definition for system dynamics and systems thinking, as it is a relatively new approach to studying freight dynamics. The benefits and other impacts are investigated to further justify why system dynamics is the chosen approach to simulation modelling. The steps to system dynamics thinking that are introduced in this section as well are also followed in the later stages when the simulation model was constructed.

3.1 Inland ports

3.1.1 Trade and seaports

Trade has long been recognized as a key factor in economic development and growth (Bernhofen, El-Sahli, & Kneller, 2016). Since World War II, there has been "a tremendous growth in international trade" (Bernhofen et al., 2016, p.2) following trends such as globalization and containerisation. Globalisation increased the interdependency of the global economy due to the flows of goods, services, people, and capital between regions of the world (Rodrigue, Comtois, & Slack, 2016). These flows show that the increase in globalization leads to growth in trade and subsequently, global shipping activity. Conatinerisation on the other hand, has resulted in the significant increase in shipping capacity and is often credited with helping to create the modern intermodal transport system (Bernhofen et al., 2016). It also reduces the amount of time vessels spend in seaports loading and unloading cargo, which increases the return on investment and ultimately results in the development in larger, faster ships (Organisation for Economic Co-operation and Development, 2010).

Both containerization and globalization show that trade and shipping are explicably and closely related (Organisation for Economic Co-operation and Development, 2010).

With 89.6 per cent of the world's trade being carried by sea as of 2008 (Rodrigue et al., 2016), seaports are therefore an integral component in global trade as they connect ocean and land modes of transportation (Bassan, 2007). Not only have seaports played a major part in urban development as cities and towns have historically been developed around areas with sea or river access (Fabling, Grimes, & Sanderson, 2011), but seaports are also crucial in international supply chains (Panayides & Song, 2009; Becker et al., 2013) and the commercial health of countries (Hershman, 1999). Rodrigue et al. (2016) emphasised the importance and necessity of seaports, as other alternatives to moving large amounts of freight across long distances are not as effective. Since the demand for maritime transportation, like all other modes of transportation, arises from the need to support trade relations, maritime shipping capabilities and trade are therefore interrelated (Rodrigue et al., 2016). The increase in trade volumes results in the increased demand for larger freight transport capacities in the form of larger freight vessels, thereby reducing the cost of shipping due to economies of scale, which in turn creates incentive for shippers to increase their transported volumes and consequently translates into the growth in trade volumes (Frémont & Franc, 2010; Bask, Roso, Andersson, & Hämäläinen, 2014).

However, the rapid growth in international trade places a lot of pressure on intermodal transportation systems (Hershman, 1999; Wan, Zhang, & Yuen, 2013). Two of the biggest pressures are the availability of container storage space in seaports and the congestion in the surrounding areas – these are considered to be two major bottlenecks that affect the efficiency of port operations (Cullinane, Bergqvist, & Wilmsmeier, 2012; Talley & Ng, 2017). If a port's efficiency is affected, a sustainable economic advantage will be difficult to achieve (Ogunsiji & Ogunsiji, 2011). Despite heavy investments in seaport capacities, ports are still constrained by storage capacity (Roso, Woxenius, & Lumsden, 2009). Having sufficient cargo storage capacity is crucial to the success of a seaport - Min, Ahn, Lee, & Park (2017) identified it as being a critical success factor for seaport operations. To combat this issue of container storage space, there are several ways to increase port storage capacity. For example, physically expanding existing seaport facilities, using technologies and information systems to improve productivity, adding more equipment, etc., (Roso et al., 2009). While seaports across the world are expanding their capacities, Min et al. (2017) caution that port capacity expansion must be carefully planned and not executed rapidly as it would result in the deterioration of port finances. This deterioration not only affects the seaports themselves but also other players (such as terminal operators) in the freight moving industry (Min et al., 2017). When faced with increasing financial pressures seaports tend to keep their prices deliberately low to entice more carriers and shippers, which in turn means that the cost drivers are passed onto other players within the industry from the seaports (Min et al., 2017).

Congestion, on the other hand, has also become a bigger problem in seaport zones and surrounding regions as traffic volumes have increased because of the freight flow trends (Dooms & Macharis, 2003; Crainic, Dell'Olmo, Ricciardi, & Sgalambro, 2015). In fact, Wan et al. (2013) determine congestion as "one of the essential factors that influences a port's ability to sustain its competitiveness" (p. 418), and that congestion and port throughput are inversely related. An increase in congestion in the surrounding areas of the seaport is not only associated with a decrease in container throughput of the port, it also results in an increase in the throughput levels of its competing port (Wan et al., 2013). One solution to reduce the congestion caused by trucks is the Chassis Exchange Terminal (CET) solution, proposed by Dekker, van der Heide, Asperen, and Ypsilantis (2012). The CET is a container terminal that is not located at a seaport (Dekker et al., 2012). Containers are transported between CETs and seaports during off-peak hours as to avoid traffic, and truckers then pick up or drop off the containers from the CET and shipper or recipient (Dekker et al., 2012). CET not only reduces congestion levels at and near the seaport, but also consolidates all container movement onto and off of trucks within one location to reduce turnaround time so trucks will not have to visit different sites on a terminal (Dekker et al., 2012). Another way to relieve seaports areas of congestion is the hub and spoke configuration, an increasingly popular method utilized in the shipping industry (Rahimi et al., 2008). This method changes from the traditional configuration where trans-ocean vessels call into several ports in an area into the hub and spoke configuration where vessels visit a single port only (i.e. the 'hub') and transshipment vessels then connect the hub to other smaller ports (i.e. the 'spokes'), thereby reducing congestion levels at main ports (Roso et al., 2009).

3.1.1.1 Seaport competition

As mentioned previously, the increase in trade triggers the increase in the demand for seaport services. There is therefore also increased competition between seaports, which means that these ports compete on more than just efficiency and tariffs – the quality of services offered (such as speed and reliability) are also becoming increasingly important (Bask et al., 2014). Seaports no longer occupy a monopoly position in logistics chains and are instead just a node within the chain nowadays (Monios & Wang, 2013), hence why how they utilise their hinterlands to provide these additional services and capacity is becoming more important. In fact, Beresford, Pettit, Xu, and Williams (2012) stated that it is now the transport chains that are competing against each other, instead of the ports amongst themselves, thereby forcing these ports to change their commercial strategies so they can remain competitive. Roso et al. (2009) agreed, adding that many shippers now choose to outsource customs, packaging, and other value-adding services to logistics service providers located at strategically placed nodes as it is a more attractive option. Intensive competition between seaports also provides shippers with more alternatives, which means that seaports are vulnerable to shippers changing to other ports that offer better terms (Beresford et al., 2012). It is therefore crucial for seaports to cater to the growing demands of shipping lines. Ports need to improve their accessibility (e.g. transport service frequency and transit times) to areas outside of their traditional reach (Roso et al., 2009).

Thus, inland ports are being established to expand seaport capacities and allow these ports to sustain or enhance their competitiveness (Hentu & Hilmola, 2011), a process that Notteboom and Rodrigue (2005) have termed ‘port regionalisation’. Port regionalisation refers to when seaports and inland freight distribution systems are integrated so seaports have more influence over the management of inland freight movements (Notteboom & Rodrigue, 2005; Monios & Wilmsmeier, 2013). It includes a variety of strategies in integration and cooperation and considers the goals of the players involved (Monios & Wilmsmeier, 2013). This regionalization has resulted in inland freight transport shifting from being mainly a national strategy to be more region-specific with the rise of major trends such as globalization, economic integration, and intermodal transportation (Rodrigue & Notteboom, 2010). In addition, port regionalisation aims to reduce congestion as well (Notteboom & Rodrigue, 2008), and is further supported by factors like the improvements in technology, commercial interests, and public policies (Rodrigue, Debrie, Fremont, & Gouvernal, 2010).

3.1.2 Inland ports

3.1.2.1 Definition and classification

Depending on the country and region, inland ports are also known by other names such as dry port (Roso & Lumsden, 2009; Vejvar, Lai, Lo, & Fürst, 2018), Inland Clearance Depot, intermodal terminal, and inland terminal (Monios & Wang, 2013). While most authors use these terms interchangeably, there are some that argue the terms are slightly different. For example, Roso et al., (2009) defined inland ports as intermodal terminals that provide transshipment services and is viewed as an extension of a port as it only serves the one port. Dry ports on the one hand, provide all the services that inland ports provide amongst other functions such as storage, consolidation, and customs clearance (Roso et al., 2009). They also act as "an adequate interface" between the shipper/forwarder, the port, and the shipping lines, and can serve more than one seaport (Roso et al., 2009, p.4). Meanwhile, Rodrigue et al. (2010) argued that the term 'inland port' is the most suitable as it is the one term that can best capture the various geographies, functions, and actors of such infrastructure.

As such, there is no consensus for the definition of 'inland port' (Henttu & Hilmola, 2011; Wiegmans, Witte, & Spit, 2015). The definition given in the United Nations Conference on Trade and Development (UNCTAD) report in which the inland port concept was first introduced in 1982 was "an inland terminal to which shipping companies issue their own import bills of lading for import cargoes assuming full responsibility of costs and conditions and from which shipping companies issue their own bills of lading for export cargoes" (United Nations Conference on Trade and Development, 1982, as cited in Crainic et al., 2015). Talley and Ng (2017) offered a much simpler definition, stating that both a seaport and an inland port are part of a hinterland network but while the former is the sea node, the latter is the inland node. Another common definition is that inland ports are intermodal transportation hubs located inland (often in the hinterland of seaports or in the centre of highly dense regions) that also serve as distribution and logistics centres (Dooms & Macharis, 2003; Rahimi, Asef-Vaziri, & Harrison, 2008). Bask et al. (2014) concur, adding that other main features of inland ports include the handling of containerized units and a rail connection to a seaport. Initially inland ports provided “fairly simple container services, such as deports and container repairs” (Bask et al., 2014, p.88), but due to the increasing interest the number of value-added services provided have also increased. Such services include consolidation, customs clearance, storage, and maintenance etc. (Henttu & Hilmola, 2011; Vejvar et al., 2018), but their main purpose is to support the operations of seaports (Bask et al., 2014; Witte, Wiegmans, & Rodrigue, 2017) and help relieve pressure on the terminals (Notteboom & Rodrigue, 2009).

Due to the lack of consensus about the term and its definition, there is therefore confusion over the role and function of inland ports (Rodrigue et al., 2010). According to Rodrigue and Notteboom (2011), however, inland ports serve three major functions – satellite terminal, load centre, and transshipment facility. It is important to note the three functions are not mutually exclusive as inland ports can service several functions at once (Rodrigue & Notteboom, 2011). Satellite terminals are located near the seaports and are used to accommodate additional traffic and functions such as warehousing that the seaport cannot handle, while load centres are intermodal facilities that have access to the regional markets and are usually located near (if not, in) logistics parks and free trade zones (Rodrigue & Notteboom, 2011). In addition to being intermodal facilities, load centres also provide warehousing, distribution, and logistics services (Rodrigue & Notteboom, 2011). Transshipment facilities on the other hand, are where freight gets transported through either the same mode (e.g. rail to rail) or different modes (e.g. rail to truck), and are becoming increasingly important (Rodrigue & Notteboom, 2011). They are typically directly connected to at least one seaport by high-capacity transport means such as rail (Henttu & Hilmola, 2011) or waterways (Witte et al., 2017), and therefore provide more efficient flows of cargo from seaports to inland (Roso et al., 2009). Roso et al., (2008) and Henttu and Hilmola (2011) also support the idea that the performance of inland ports is determined by the quality of intermodal transport interfaces and the performance of the seaports, with Roso et al., (2008) adding that it is therefore “necessary to have scheduled, reliable, transport by high capacity modes to and from the seaport” (p.4). Meanwhile, Wiegmans et al. (2015) identified factors and characteristics that affect the transshipment services of inland ports – the first of which is the presence of a container terminal, something that is critical in attracting transshipment capacity and sustaining growth. Secondly, having a larger variety of goods and have a relatively large portion of freight going to/from mid-range distances (Wiegmans et al., 2015). Thirdly, inland ports must be accessible by road for them to be successful (Wiegmans et al., 2015).

Meanwhile, Rodrigue and Notteboom (2012) offer five main functions they believe inland ports fulfil within supply chains – site and situation, repositioning, cargo rotation, trade facilitation, and governance. Site and situation refers to the need for an inland port to be located where there is good access to different modes of transport and a large population base, as well as available land for future development. The location is crucial as being close to a large population base will allow shippers to reduce transportation costs and improve their supply chain lead times. Repositioning occurs when the volumes imported does not match the volumes exported, thereby resulting in the necessity of empty container repositioning, which requires inland ports to have the physical and logistical capabilities to efficiently do so. Inland ports have to ensure that their inbound and outbound freight flows are reconciled as fast as possible as well, and one way to do so is to rotate the cargo from where import activities happen to where export activities, thus integrating the two flows to allow empty flows to move to where they need to be to improve the efficiency of distribution (Rodrigue & Notteboom, 2012; Rodrigue et al., 2016). This process is known as cargo rotation and ensures higher revenue for both inland port operators and container owners as it results in the rapid turnover of their assets. Inland ports can also offer trade facilitation to businesses – particularly smaller businesses that have difficulties achieving economies of scale on their own – by providing opportunities for lower transport costs and better accessibility to cheaper imports and exports. Lastly, there are a wide range of governance models for inland ports and their associated logistics zones, and these models are an indication of the inland port's "potential to identify new market opportunities and invest accordingly" (Rodrigue & Notteboom, 2012, p.7). For example, a combination of public and private ownership indicates that public interests are likely to be prioritized over private ones, so benefits such as job creation and the better utilization of regional transport infrastructures can be realized.

Depending on characteristics such as geographic locations, functions, and the relevant actors involved, there are several different ways of categorizing inland ports (Monios & Wang, 2013; Bask et al., 2014). For example, authors such as Henttu and Hilmola

(2011), and Monios and Wang (2013) classify inland ports based on their proximity to the seaports – either close, midrange, or distant. Close range inland ports are used as satellite terminals "to ease port congestion or facilitate fast-track customs clearance" (Monios & Wang, 2012, p.898), and are less than 50 kilometres from a seaport (Crainic et al., 2015). Freight between the seaport and the inland port can be moved via rail, thereby reducing congestion in the surrounding areas (Bask et al., 2014). Roso et al., (2009) identified close range inland ports as an alternative to other strategies such as operating smaller vehicles or changing to less polluting ones to reduce the environmental impacts of road transport. Midrange inland ports are located between 50 to 500 kilometres away from a seaport and are typically used as load centres (Crainic et al., 2015). While the distance is coverable by road, the high volumes and high frequencies of consolidated freight make rail a viable choice of transport (Bask et al., 2014). Due to the relatively shorter distances between the inland port to shippers compared to distant inland ports, midrange ports provide better truck transport savings than distant ports (Talley & Ng, 2017). These distant inland ports act as transshipment hubs and are located more than 500 kilometres away from a seaport where the ports and railway operators can maximise their economies of scale and have access to a wider geographical area (Roso et al., 2009; Crainic et al., 2015). They can increase the capacity of the seaports, which consequently increases productivity as well as allowing for bigger vessels to be handled at these seaports (Bask et al., 2014).

Beresford et al. (2012) offer another way of classifying the different kinds of inland ports, and is based on the combination of location, function, and the economic environment – seaport-based, city-based, and border-based. Seaport-based ports are located at the coast and provide relatively basic functions such as cargo loading and discharging and other low-value-added activities (Beresford et al., 2012). The main focus however, is on pre-customs clearance as their target is to "restructure their supply chain locally and shorten lead times" (Beresford et al, 2012, p.80). City-based inland ports are typically located within larger logistics clusters in metropolitan areas that are near access points to transportation nodes, and focus on providing day-to-day logistics services, usually to exporters (Beresford et al., 2012). They also provide a larger range of value-added services than seaport-based ports (Beresford et al., 2012). For inland ports that are located more than two thousand kilometres away from seaports in the border area, these are classified as border-based inland ports (Beresford et al., 2012). Such ports are typically used as transshipment and intermodal hubs, as well as for custom clearances, but they tend to relatively small due to the restricted development that is the result of their landlocked location and low levels of trade development (Beresford et al., 2012). Despite having many trade advantages such as comparatively lower labour costs and more resources, investments in border-based ports are scarce because of concerns such as limited central government funding, weak logistics infrastructure, and relatively longer supply chain lead times (Beresford et al., 2012). However, compared to seaport terminal users time is typically less of a concern for inland port users – relatively longer supply chain lead times are therefore considered an acceptable trade-off for the cost savings that can be obtained from value-added activities being carried out in peripheral locations (Bask et al., 2014).

Since many inland ports are developed with the needs of seaports in mind, the two kinds of ports are explicably linked. Roso et al. (2009) suggested that seaports and inland ports need to be considered when looking at problems that arise from increased container flows. Bask et al. (2014) concurred, adding that the two types of ports have a dyadic relationship where sea freight flow changes result in almost proportional changes in inland freight flows. Conversely, the capacity and services provided at inland ports play a part in the throughput levels into seaports (Bask et al., 2014). The better matched the services of the inland ports are with customer requirements, the higher the volume of freight throughput into the sea terminal (Bask et al., 2014). Roso et al. (2009) added that inland ports offer seaports increased throughput without any physical port expansions by allowing seaports the opportunity to secure a market in their hinterland. Research by Fabling et al. (2011) also indicated that the presence of an inland port had some influence on the usage of the seaport. Even inland transportation capacities can affect seaport capacities, and vice versa. Vessels are more likely to call into ports that provide high volume inland services, while inland transport efficiencies require high volumes of freight to be achieved (Frémont & Franc, 2010). Roso et al., (2009) had a differing opinion, writing that the progress of land transport generally has not mirrored that of sea transports. Regardless, inland ports and seaports need to establish close relationships to allow for more efficient and smoother transport processes and other value-added services such as customs clearance (Bask et al., 2014).

With the increasing need for inland freight transportation, inland ports are becoming a crucial player in the logistics chain (Dooms & Macharis, 2003). However, whereas seaports are of national significance, Dooms and Macharis (2003) argued that inland ports are considered of local importance only because most inland terminals are part of seaports. This distinction means that the existence and necessity of inland ports are more contested than that of seaports (Dooms & Macharis, 2003). Another important distinction to make is that while seaports are an obligatory node for moving freight from sea to inland, inland ports are not the only option for freight movements inland (Rodrigue et al., 2010). If there are changes to other factors such as decline in traffic or increased efficiency in seaports, there may be decreased usage in inland ports as they become the less desirable option (Rodrigue et al., 2010). In other words, not only do inland ports have to compete against each other, but they also have to outperform seaports and other transportation nodes.

3.1.2.2 Growing number of inland ports

As mentioned previously, with inland ports increasingly becoming a competitive advantage for seaports (Henttu & Hilmola, 2011) there is growing interest from seaports to establish their own inland ports in their jurisdictions, so they can have more control over a larger part of the inland freight transportation chain (Roso et al., 2009; Rodrigue et al., 2010). However, this trend is likely to contribute towards the over-supply of inland ports (Rodrigue et al., 2010). Studies have found that there is an asymptotic relationship between the number of inland ports and relative transportation costs – the costs decrease significantly as the number of inland ports increase, but only until a certain point before the costs will not decrease further (Rahimi et al., 2008; Henttu & Hilmola, 2011). Witte et al. (2017) agreed, writing that if inland ports are too close to each other there will be diseconomies of scale. Rodrigue et al. (2010) suggested that governments could be the key to resolving the problem of over-supply through two ways – the first is the development of a more stringent regulatory framework that includes inland ports to control the number established. The second is to not intervene at all and let the market reach equilibrium in terms of location, size, and functions (Rodrigue et al., 2010). Meanwhile, Rahimi et al. (2008) advocated that instead of having several inland ports, a variation of the hub and spoke model (similar to that of seaports) could be established instead as it is a “different, more efficient, and socially beneficial transportation system" (p.376). This model will allow truck operations to serve fewer sites, which reduces vehicle miles travelled (VMT), and once vehicles are changed to cleaner, more fuel efficient or even zero-emission ones the environmental impact of truck transport will also decrease significantly (Rahimi et al., 2008). Even rail and water transport will benefit from this hub and spoke model as economies of scale will be reached and the investment in infrastructure will be justified (Rahimi et al., 2008).

3.1.2.3 Inland port developers

Whilst inland ports predominantly exist to support seaports, they can be developed by more than just port authorities or port operators. Other developers can include public bodies and transport providers (Monios & Wang, 2013) or private investments (Rodrigue et al., 2010). Sometimes inland ports can be joint projects between intermodal operators and commercial real estate developers. In such cases the inland ports are typically part of bigger co-location projects (Witte et al., 2017). However, studies have shown that public-driven inland ports have increased risk of over-supply, as well as increased financial risks if the intermodal operation cannot compete with road transport (Monios & Wang, 2013). Inland ports can also be established by the government and depending on the level of contribution and responsibilities undertaken as well as their management structures, there are three types of models – landlord, tool, and service ports (Beresford et al., 2012). The landlord model is when the infrastructure is provided by the government, but everything else is the responsibility of the concessionaire that is usually a private company (Beresford et al., 2012). The tool model is when the infrastructure and operational superstructure are provided by the government, but the operations are carried out by the private sector, while the public service model is when everything is undertaken by the government (Beresford et al., 2012). However, authors such as Beresford et al., (2012) and Rodrigue et al. (2016) caution that even though government funding is an effective way to establish transport infrastructure such as inland ports, it is unlikely that the return on investment will be very high as such infrastructure projects are rarely profitable.

3.1.3 Impacts of inland ports

3.1.3.1 To shippers

Inland freight movements account for the majority of door-to-door shipping costs (Monios & Wang, 2013), but through the use of inland ports these costs can be reduced. These cost savings can be in the form of more than just monetary savings – for example, the resolving of cash flow issues, the reduction of unnecessary delays from the supply chain, or even using key nodes within the chain to perform value-added activities and other functions such as inventory management (Monios & Wang, 2013). There are several ways inland ports can achieve these cost savings. Firstly, inland ports offer similar services as seaports but are advantageous due to lower freight costs, higher flexibility, and closer distances to customers (Hentu & Hilmola, 2011). Fabling et al. (2011) agreed. After conducting research on the impact of MetroPort (one of the inland ports in New Zealand that is operated by the Port of Tauranga) on exporter behaviour, they found that there was "substantial usage" (p. 3) of the port and concluded that MetroPort likely benefitted exporters through reduced export costs and better access to shipping alternatives (Fabling et al., 2011). MetroPort reduces the distance between the port and its customer base in the industrial areas of Auckland as well, thereby also allowing firms to avoid the congestion of the central city (Fabling et al., 2011). However, their research has also shown that for existing exporters, the distance between the exporter and the inland port is not a significant factor that affects the inland port's uptake (Fabling et al., 2011). Meanwhile, factors that are "positively associated with uptake" of MetroPort include firm size and past export activities and volumes, with firms that export goods with a relatively low value-to-weight ratio being more likely to utilise the port (Fabling et al., 2011, p.3).

Secondly, inland ports reduce shipper costs by making supply chain operations more efficient. Several authors contribute on this idea, saying that inland ports help facilitate improved logistics solutions (Roso et al., 2009) and ensures "continuity within global supply chains" (Rodrigue & Notteboom, 2010, p.5) by providing more opportunities for shippers to connect with larger distribution locations that offer a variety of value-added services, as these inland ports are not limited by the size restrictions of the warehousing and distribution facilities (Rahimi et al., 2008). These inland ports can also act as buffers within the supply chain and become a temporary storage site when needed (Rodrigue & Notteboom, 2012). Henttu and Hilmola (2011) added that inland ports provide shippers with access to a wider range of logistics services, thereby creating greater convenience for them.

Inland ports also increase supply chain efficiencies by reducing the effects of trade imbalances. Trade imbalances arise from when there is a difference between imported and exported volumes as international trade is rarely balanced (Notteboom & Rodrigue, 2017). For example, as the United States is an import economy, shipping lines are reluctant to send shipping containers too far inland as there is no guarantee an export load for the journey back (Monios & Wang, 2013). Trade imbalances also incur repositioning costs when empty containers need to be moved because they do not have cargo for the return leg (Monios & Wang, 2013; Rodrigue et al., 2016). In fact, Rodrigue et al. (2016) found that containers spend much of their lives idle or being repositioned, which not only contributes to monetary costs but also unnecessary VMT when shifting empty containers from one location to another (Boile, Theofanis, Baveja, & Mittal, 2008). These reasons show that trade imbalances are a source of supply chain inefficiency. Inland ports are thus a solution to this inefficiency (Monios & Wang, 2013) as they can provide cargo consolidation services that reduce empty container movements. Boile et al. (2008) agreed, writing that the addition of inland ports into the supply chain significantly reduces the VMT and total costs of empty containers, and that inland ports have "great potential in optimizing regional empty moves" (p. 31). Some inland ports also provide storage space for empty containers, which reduces the need for cargo repositioning as well (Rodrigue et al., 2016).

Third, but not least, inland ports provide shippers with monetary cost savings through several ways. For example, inland ports help shippers with cash flow management. Bask et al., (2014) believe that inland ports help with the capacity issues at seaports and improve services for the overall transport chain as they allow for some of the functions traditionally conducted at seaports to be moved to inland ports. These delayed functions include the customs clearance process, which can be a cost saving as the delay in customs clearance allows for importers to pay for importer duties when the goods are taken from the inland ports, thereby benefiting cash flow management as the fee is paid for only when the goods are needed (Monios & Wang, 2013). Another major cost saving is achieved when inland transport is shifted from road to rail or water.

Whilst road transport is regarded as a flexible and fast form of freight movement that is less restricted by geographical constraints, the volume that is moved each time is lower compared with other modes of transport (Rodrigue et al., 2016). This low volume means that the cost per trip is higher than that of rail and/or water, which increases costs for shippers. By utilizing rail and/or waterway transport however, shippers will be able to reduce their freight movement costs, as these two transport modes offer much more carrying capacity than road and are effective ways to move large quantities of freight over long distances (Rodrigue et al., 2016). Using a combination of the three transportation modes will also result in cost savings. Frémont and Franc (2010) found that despite the increased complexity of organizing multiple types of transport within the inland leg, combined transport extend the economies of scale reached by sea transport and therefore reduces the costs of the inland leg of freight movement.

3.1.3.2 To freight transport operators

With rail accessibility being "at the heart of functioning and development of most dry ports around the world" (Rodrigue & Notteboom, 2012, p.3), rail operators thus benefit from the use of inland ports as the ports increase the scale of their operations (Roso et al., 2009). Woxenius, Roso, and Lumsden (2004) agree, adding that distant dry ports in particular are beneficial to rail operators in terms of the increase in scale to their business. The presence of inland ports have also encouraged seaport operators and shipping lines to integrate vertically to have more control over inland transport – for example, in Europe Maersk-Sealand and P&O Nedlloyd started the European Rail Shuttle (Woxenius, Roso, & Lumsden, 2004). This trend means that there may be increased competition between rail operators. However, there are obstacles that need to be overcome for shippers to be more willing to choose rail as the main means of inland transport. Roso (2008) identified the lack of sufficient infrastructure, lack of flexibility (in both time and space as shippers will be constrained the schedules and routes of the railway), and the potential for damaged goods as some of the main obstacles.

Road transport, on the other hand, do not benefit much from the change in freight transport modes since inland ports actually reduce the volume of freight moved by road (Roso et al., 2009; Talley & Ng, 2017). It is, however, impossible to completely eliminate the use of road transport (Roso et al., 2009), as road transport is still considered to be the faster and more flexible option compared with other transport modes (Woxenius et al., 2004). Thus road operators will still be able to benefit from the less congested seaport areas (Talley & Ng, 2017). Since road transport operators are not paid for waiting in the congestion around seaport areas, they will be able to provide their services with better total revenues (Woxenius et al., 2004).

For seaports there are also multiple benefits such as the expansion of the seaport's hinterland area and having more access to the freight movement aspect of the supply chain (Cullinane, Bergqvist, & Wilmsmeier, 2012). Inland ports can also help extend the life cycle of the port by "elongating the maturity phase and deferring a port's entry into a state of decline" by allowing seaports to remain competitive (Cullinane et al., 2012, p.3). Whilst there are several benefits that seaports can take advantage of, there are authors that have identified negative impacts of inland ports on seaports. Veenstra, Zuidwijk, and Asperen (2012) argue that the presence of inland ports will force seaports to change from being logistics nodes back to being locations for freight handling and transshipments only, and services such as customs and inspections will not be available at seaports as such agencies are moved into the hinterlands. The authors also write that the distribution parks within seaports will be replaced by other more directly related port activities (Veenstra et al., 2012). For inland ports that have not been established by seaports, this reversion could mean the loss of revenue as the number of services they provide will decrease.

There are several challenges that intermodal transport operators have to face to allow their operations to be economically feasible, such as short distances and the inability to double stack (Monios & Wang, 2013). As a result, many inland port operators are becoming more directly involved in container management by offering customers door-to-door services so that they can reach economies of scale in rail operations (Monios & Wang, 2013). However, this transition means that there is increased competition which "will dilute the potential consolidation of traffic" (Monios & Wang, 2013, p.906). Similarly, because the shift from road to rail extends the coverage areas of seaports (Talley & Ng, 2017), seaports have the opportunity to compete in more than just their traditional sea freight services (Fabling et al., 2011), which also encourages seaports to be more involved inland freight transport. As a consequence, inland freight handling providers will have less of a monopoly on the industry (Fabling et al., 2011).

3.1.3.3 To society

2.1.3.3a Environmental

Transportation activities account for one of the largest global sources of pollution, with road transport being “the most environmentally harmful transport mode” (Henttu & Hilmola, 2011, p.40). Santos, Behrendt, Maconi, Shirvani, and Teytelboym (2010) emphasized the harm that road transport brings – not only are the emissions, noises, and vibrations polluting the environment, but road transport also has negative impacts on biodiversity and the landscape, as well as the heritage of historic resources. Areas surrounding seaports are much more affected by the consequences of noise, congestion, and traffic accidents than areas not by seaports as well (Slack, 1999). With the increase in freight activities the use of inland ports is therefore becoming increasingly important. Plenty of literature support the idea that inland ports are vital in reducing negative environmental impacts by shifting inland transportation modes from road to others that are less environmentally harmful (Dooms & Macharis, 2003; Rodrigue et al., 2010; Hentu & Hilmola, 2011). Not only do inland ports allow for more freight to be moved via less environmentally harmful transport methods (Roso et al., 2009; Fabling et al., 2011; Talley & Ng 2017), research by Rahimi et al., (2008) found that when multiple modes of transportation are used, inland ports result in the reduction of VMT and the associated emissions. Fabling et al. (2011) also concurred, adding that the reduction is the result of bringing the port closet to its users.

Inland ports also reduce congestion by reducing the number of truck trips required, especially in areas surrounding the seaports and the freeways (Rahimi et al., 2008; Roso et al., 2009; Fabling et al., 2011; Talley & Ng, 2017). Congestion arises when high volumes of traffic occur and affects the quality of service that is provided by a transportation system (Sweet, 2011). Not only does congestion increase the chances of trucks missing their schedules as their travelling times are longer due to the delays, there are also several environmental impacts (Wan et al., 2013). Firstly, congestion increases the amount of carbon dioxide (CO_2) emissions, as does fluctuating vehicle speeds which occurs in congested areas – speeds below 45 miles per hour and above 65 miles per hour can cause CO_2 emissions to increase (Barth & Boriboonsomsin, 2008). Secondly, other greenhouse gas emissions such as carbon monoxide (CO) and ozone, both of which are crucial components of photochemical smog, also increase with congestion (Daniel & Bekka, 2000). Thirdly, fuel consumption increases as vehicles need to be driven longer (Barth & Boriboonsomsin, 2008), which not only is costly but also results in negative environmental effects. Hence the need to reduce congestion through the establishment of inland ports, as intermodal transportation can help achieve environmental benefits. For example, studies have shown that CO_2 emissions can be significantly reduced by using intermodal transport instead of just road transport (Lättilä, Henttu, & Hilmola, 2013). In another study conducted by Janic and Vleugel (2012) found that on any of the Trans-European transport corridors, the substitution of road with rail will reduce externalities such as greenhouse gas emissions and congestion by about 30 per cent. Noise levels, on the other hand, show no noticeable improvements with the substitution (Janic & Vleugel, 2012). Despite the many environmental benefits that inland ports seem to bring, Slack (1999) cautions that if inland ports are left to develop without careful planning, traffic congestion (amongst other problems) will still remain.

3.1.3.3b Economic

While the literature on port economics is extensive, research on the economic impact of inland port development is not (Witte et al., 2017). This difference is perhaps due to the difficulties in determining the exact economic benefits as there can be "spill-over effects that goes beyond the inland port" (Witte et al., 2017, p.82). That being said, several authors support the idea that inland ports provide job opportunities and therefore economic growth and development in the region. For example, Rahimi et al. (2008) wrote that not only do inland ports promote jobs and reduce port-area land values, but they modify existing freight networks, which allow regional economies to continue to compete in future years, a characteristic that is crucial in garnering community support. Similarly, Ng and Tongzon (2010) emphasized the importance of the role of inland ports in sustaining economic activities by facilitating import and export flows through a region, and thus also encouraging regional development. Dooms and Macharis (2003) meanwhile have stated that with the projected growth of road transport there could be serious consequences on the economy in the long term, so inland ports are needed to help the economy develop in a more sustainable way by shifting more freight through railway transport instead of road. Inland ports may also be a way to concentrate the infrastructure needed to support the growth of sea and inland transport (Dooms & Macharis, 2003). The implementation of an inland port may be the first and more economically desirable option before other approaches to seaport capacity expansion are considered (Cullinane & Wilmsmeier, 2011), which implies that inland ports are more relevant when the economy is booming than during a recession (Bergqvist & Woxensius, 2011).

Congestion has impacts on the economy as well – Sweet (2011) researched the economic impacts of congestion, and categorized congestion-caused impacts into first- and second-order impacts. First-order impacts include non-productive travel delay – which is measured using the average value per hour to compare actual and target travel times – and unreliable travel times – which considers the irregular delays such as weather or construction and is more difficult to measure (Sweet, 2011). Second-order impacts are less direct consequences compared with first-order ones, such as the impact of congestion on the economic growth of the region. With the reduction in congestion, road maintenance costs and accidents can both be reduced as well (Roso, 2008) and thus lower related costs on society. Therefore, there are positive consequences associated with the decreased levels of congestion on the economy with the establishment of inland ports (Ng & Tongzon 2010).

3.1.3.4 Inland port development constraints

Despite the numerous benefits, there are still constraints that prohibit the development of inland ports. For example, the difficulties in coordinating information exchanges and schedules which hinders the integration of seaports and inland ports, and the increasing competition between inland ports (Monios & Wang, 2013). Containerisation rates also affect integration as the lower the containerization rate, the lower the utilization rate of rail transport, which subsequently means that economies of scale are not reached (Monios & Wang, 2013). Dooms and Macharis (2003) identified stakeholder attitudes as another inland port development constraint. Unlike seaports where the activities (and therefore benefits to society) are clear and perceivable, stakeholders are less likely to understand the operations and contributions of inland ports. The lack of awareness "has a negative influence on the perceived legitimacy of port activities" (Dooms & Macharis, 2003, p.10) which makes inland port development more difficult. They have therefore suggested the following nine-step process for strategic inland port planning:

1. Categorise port zones according to their characteristics and define the stakeholders.
2. Thoroughly analyse the current situation.
3. Use information from the analysis in the previous step to conduct in-depth interviews with key stakeholders.
4. Perform a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis using the results from steps 2 and 3 as inputs.
5. Define long-term strategic alternatives for each port zone and specify the content and objectives.
6. Determine a set of criteria and weighs to evaluate the strategic alternatives.
7. Fill in the set of criteria from step 6 for each of the alternatives using information from steps 2 and 3.
8. Evaluate the strategic alternatives by performing multi-criteria analysis using the results from step 7.
9. Implement chosen strategic alternatives for each port zone.

It is important to note that the strategic alternatives of each zone should not hinder the development of each other's (Dooms & Macharis, 2003).

Meanwhile Roso et al. (2009) point out that instead of spending large sums of money on "immensely expensive infrastructure projects" (p.7), consideration should also be given to relieving the financial pressures on rail services if freight flows are large enough to warrant better rail operations. They argue that the costs and benefits that each of the actors incur and provide should be carefully analysed so that resources can be divided fairly between them (Roso et al., 2009). However, as mentioned before, government funding isn't the only way for inland ports to receive support for development. With less funds being available for inland port developments as the public is demanding more and more resources for social spending, Beresford et al. (2012) highlighted the importance of private sector participation as a way to reduce the government's financial burden.

3.1.4 Port study methods

As seen from the literature review, extensive research has been conducted in the field of freight logistics and port performances. A wide variety of research methods have been used – for example, Ogunsiji and Ogunsiji (2011) investigated the efficiency measurement techniques of ports in developing nations – in particular, Nigeria – using the Matching Framework Analysis approach to understand where the problem areas within the Nigerian seaports were, so that suitable recommendations could be made. The Matching Framework analysis is a qualitative method that is relatively easier to utilise as it does not involve complex computational processes. Case studies are another commonly used qualitative analysis method in freight logistics because they allow researchers to conduct in-depth interviews so that contextual insights into a phenomenon can be generated to aid in the development of new theories (Mangan, Lalwani, & Gardner, 2004). They are also generally focused on single organisations, which means that it is an unsuitable method to utilise when investigating an entire industry. Typically, however, quantitative methodologies are the chosen research method for the field of logistics research (Mangan et al, 2004). For instance, Song and Yeo (2004) conducted a quantitative analysis using data gathered from surveys administered either face-to-face or through the telephone to determine the competitiveness of container ports in China and Hong Kong, as well as identifying managerial and strategic implications.

Simulation modelling is also another method used in freight logistics studies, due to its ability to overcome the complex nature of problems where analytical models cannot (Pachakis & Kiremidjian, 2003; Alamz & Altiok, 2012). Merkuryev, Merkuryeva, Piera, and Guasch (2009) concurred, writing that simulations are a "critical technology" (p.127) to investigate complex logistics systems, especially when trade-off analyses are required. Simulations can imitate the behaviours of different actors and elements within systems and can predict the outcomes and performances of different scenarios, which is particularly useful in the evaluation of port performances (Kotachi, Rabadi, & Obeid, 2013) as port activities are dynamic and complex, and influenced by a variety of external and internal factors (Ho, Ho, & Hui, 2008). However, simulation models used for port operations and revenue analyses require much calibration and verification using available data, as often times the information required is proprietary and therefore not presented in great detail (Pachakis & Kiremidjian, 2003). If the port is still within the planning stage, the simulation model will have to use best estimates and assumptions due to the lack of data available (Pachakis & Kiremidjian, 2003).

3.1.4.1 Justification of method choice

Since the aim of this research is to investigate the entire freight system of the Golden Triangle, it involves several seaports and inland ports, as well as different modes of transportation and many stakeholders. The large number of components means that this system is more complex than just looking at an individual port and thus is too difficult to be calculated without the aid of computer software. Not only does the chosen investigation method have to be able to capture the complexities of the system so that predictions about the future behaviours of each of the elements could be made, it also needs to be able to allow for sensitivity analyses to be performed as this will indicate what the main barriers and enablers to the successful operation of the Ruakura Inland Port are. Therefore, a simulation using the system dynamics approach was selected as the method to conduct the research for this thesis as it satisfies all of the criteria above.

3.2 Systems thinking and system dynamics

3.2.1 Systems thinking

With the advancements in technology and globalization resulting in countries becoming increasingly interconnected, society is also becoming more complex (Arnold & Wade, 2015). The relationships between causes and effects may not be as apparent as they used to be and therefore are harder to be understood using methods such as intuition and traditional social and managerial sciences (Coyle, 1996). Sometimes there is a delay between an action or decision and the consequence, but because they are distant in time and space the causal relationships are not discovered easily (Sterman, 2001). Often actions also result in unintended consequences, which results in policy resistance where interventions to problems fail as they are defeated by the unforeseen responses to the interventions themselves (Sterman, 2001). Thus arises the need for a more comprehensive way of understanding the causes and effects of these complex situations to mitigate these negative impacts. Systems thinking (ST) was developed as a way to understand the world and the relationships within (Maani & Cavana, 2007; Ridwan & Noche, 2018). It is an area of growing interest, with researchers believing it to be extremely important to our future (Arnold & Wade, 2015). However, there is also criticism that ST is becoming more of a "management fad[s]" (p. 11) and does not provide enough understanding of systems (Forrester, 1994). Instead ST is much better suited as an introduction to systems to raise awareness about the existence and importance of the field (Forrester, 1994).

A system is “a collection of parts that interact with one another to function as a whole” (Maani & Cavana, 2007, p. 7). These parts interact to achieve a purpose, but sometimes the system may fail to do so (Coyle, 1996). Failure can be because of reasons such as the system being poorly designed or its attempts at adjusting to change are unsuccessful (Coyle, 1996). Another reason why systemic failures occur is because of how complex and fragile systems are becoming – this complexity means that are more chances of error and the cumulative effects of these errors can manifest to cause systemic failures (Venkatasubramanian, 2011). In fact, systematic failures are rarely due to a single error (Venkatasubramanian, 2011). The dynamic complexity of systems also means that any fixes to address system failures may be problematic due to reasons such as the constantly changing nature of systems and nonlinearity, hence the need for a way to understand and manage these complex systems (Sterman, 2001).

There has, however, been much debate about the definition of the term “systems thinking” (Arnold & Wade, 2015). Barry Richmond (1994), who coined the term in 1985, defined ST as being “the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure” (p. 140). He writes that ST will allow the user to understand both the generic and the specific, as well as the pattern and the event. In other words, systems thinkers will be able to see both the forest and the trees at the same time (Richmond, 1994). Arnold and Wade (2015) proposed that since systems thinking is composed of three types of things – elements, interconnections, and a function or purpose (the most crucial but least obvious part) – its definition should also contain the three things. Their study focused on the definitions available from existing literature and found that while most of them have described the elements of systems thinking thoroughly, explanations of what it actually is and what it can accomplish is lacking. Building on the existing definitions, they have in turn produced the following definition that they believe explains the elements, interconnections, and function (or purpose) of systems thinking:

“Systems thinking is a set of synergistic analytic skills used to improve the capabilities of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects. These skills work together as a team” (Arnold & Wade, 2015, p.675).

Regardless of how the term is defined, there are universal principles that set a framework for ST theories and practices (Anderson & Johnson, 1997; Maani & Cavana, 2007). These principles include: the big picture, short and long term, soft indicators, systems as a cause, time and space, cause versus symptom, and either-or-thinking (Maani & Cavana, 2007), and are explained in Table 1 below.

Principle	**Definition**
The big picture	To understand a problem the focus should be widened to include the bigger system (Anderson & Johnson, 1997) – i.e. being able to see both the trees and the forest (Richmond, 1994; Maani & Cavana, 2007; Venkatasubramanian, 2011)
Short and long term	Fixes can be either short term or long term. While habitual short-term solutions can threaten the survival of a system, its effectiveness in 'life threatening' situations should not be ignored (Maani & Cavana, 2007).
Soft indicators	Conventional performance indicators are not the only way to measure the performance of a system. Subjective indicators such as morale, burnout, and capacity for learning should also be used to understand the system (Yurtseven & Buchanan, 2016).
Systems as a cause	Many problems encountered in the system are created internally by the system itself due to organizational cultures and beliefs, etc. (Maani & Cavana, 2007), instead of being driven by just external forces (Adam & de Savigny, 2012).
Time and space	Often effects do not occur immediately after the cause – there are delays that result in actions/ decisions and their consequences to be apart in time and space (Maani & Cavama, 2007).
Cause versus symptom	The observable problems within systems are often only just symptoms and not the causes of the problems (Maani &

	Cavana, 2007). To fully solve a problem the causes must be addressed instead of just treating the symptoms.
Either-or-thinking	The idea that reality is not just simple cause and effects, but rather multiple causes that result in multiple effects, so problems may therefore have multiple solutions (Maani & Cavana, 2007).

Table 1: Principles for ST theories and practices

3.2.2 System dynamics

Developed by Jay W. Forrester in 1961, the term 'system dynamics' (SD) is sometimes used interchangeably with ST (Forrester, 1994). Forrester (1994) viewed ST as being a small area within the field of SD, while Richmond (1994) believed that SD is a major aspect of ST as the term ST is a more accurate description of the essence of SD. Generally, however, SD is the application of systems thinking to various disciplines and/or situations such as businesses and organisations (Maani & Cavana, 2007; Oztanriseven, Perez-Lespier, Long, & Nachtmann, 2014), and is seen as the "best hope" for dealing with complex systems that encompass multiple disciplines (Coyle, 1996, p. xi). It can "accept the complexity, nonlinearity, and feedback loop structures that are inherent in social and physical systems" (Forrester, 1994, p.3) by showing how each component within the system interacts with each other (Oztanriseven et al., 2014). The relationships and behaviours are represented by mathematical equations that are calculated with the aid of computer software (De Marco & Rafele, 2007) so that simulations of complex systems can be conducted, and behavioural changes and trends identified (Luan, Chen, & Wang, 2010; Oztanriseven et al., 2014). Another function of SD is that areas of improvement within the system can be identified through sensitivity analyses on the parameters and initial values of the model to see how the system responds to changes (Kleijnen, 1995; Maani & Cavana, 2007). This function is especially important when there are initial values and relationships that have been estimated using uncertain or partial information as it will help with user confidence of the model (Maani & Cavana, 2007). In other words, SD allows for predictions for future behaviours to be made with the assistance of the computational abilities of SD software such as Stella, Vensim, and Powersim. These simulations allow stakeholders to make better informed decisions that will eliminate undesirable effects, instead of being impacted by unintended consequences that could arise from trying to mitigate those effects themselves (Oztanriseven et al., 2014). Due to its ability to represent real world scenarios and behaviours, interest in the field is spreading at an exponential rate (Forrester, 1994; Sweeney & Sterman, 2000).

Behaviours in systems are composed of two fundamental elements – delays and feedback loops (Borshchev & Filippov, 2004; Ridwan & Noche, 2018). Delays refer to the time lapse between the causes and effects within the system as decisions may not have immediate impacts on systems, and add dynamic complexity to systems (Morecroft, 2015). Both information and material delays exist within reality and therefore are an important component within SD (Richmond, 2001). They are also a reason why unintended consequences occur – such impacts are usually hidden initially by the delays, which make it more difficult to attribute effects to causes (Jackson, 2003; Maani & Cavana, 2007). Delays create instabilities and oscillations within systems as decision makers often try to keep intervening with the processes to attempt to correct the undesirable consequences (Sterman, 2001). These continual interventions are likely to result in harmful consequences, particularly if the decision makers are not aware of the impact of system delays (Maani & Cavana, 2007). For example, delays in production, information exchanges, and shipments between suppliers and distributors may result in the severe fluctuation of stock levels due to under- or over-ordering of inventory, a phenomenon otherwise known as the bullwhip effect (Lee, Padmanabhan, & Whang, 1997).

Feedback loops (or causal loops) reflect the idea that systems are not linear, open-looped, or event-oriented (Morecroft, 2015). In other words, problems should not be treated as events that can be fixed by solutions that address the immediate issue and not the cause of the problem. Instead problem solving should be viewed as "a continual process of 'managing' the situation in order to achieve an agreed goal (or goals)" (Morecroft, 2015, p.38) where each of the relevant factors within the system are interlocked and contribute to the impacts of one another (Adam & de Savigny, 2012). There are two types of feedback loops – positive and negative. Positive (or self-reinforcing or growth-producing) loops are self-simulating and amplify the effect, whereas negative (or self-correcting or goal-seeking) loops counteract any changes by generating actions to eliminate any differences between the desired and actual states of the system (Coyle, 1996). Loops are constructed of labels (either words or phrases) that represent the variables, links (arrows) that show the direction of the connections, and the loops. Sometimes polarities are assigned to the links and loops to show the type of influence between the variables. The polarities of the links are typically denoted with "+" or "s" signs for movements in the same direction (i.e. positive correlation) and "-" or "o" signs for movements in the opposite direction (i.e. negative correlation), while positive loops are depicted with "R" and negative ones with "B" (Maani & Cavana, 2007). Any delays between variables are also depicted in these loops, often with "D" or "| |" on the arrows between the variables (Maani & Cavana, 2007).

The two types of feedback loops combine into causal loop diagrams (CLD) that describe and connect factors of influence in the system (Coyle, 1996). An example of a CLD is seen in Figure 1 below. Also known as 'influence diagrams', CLDs are visual tools used to help identify the key influencing factors and feedback loops of systems and are considered to be the most beneficial during the early stages of model conceptualization (Goodman, 1988). When the system being studied is highly complicated and has many comprehensive feedback loops, it may cause the loss of attention on the major elements and their interactions as there is too much detail, thereby potentially resulting in the important relationships within the system being overlooked (Richmond, 1994; Yuan & Wang, 2014). Therefore, only the "most pivotal elements that can represent the reality" should be included (Yuan & Wang, 2014, p.989). Forrester (1994), however, believes that CLDs over-simplify systems and cannot distinguish between stocks and flows, and neither can they identify which elements in the system result in the behaviour, so they should not be used in the model conceptualization stage. Instead CLDs can be used once the model has been created as they are a useful tool to help generate an overview of the subject and explain the model in simpler terms (Forrester, 1994). Interestingly, Richmond (1994) shares the same views as Forrester. He likened starting the ST process with CLDs before understanding the infrastructure of a system to studying the nerves while ignoring the surrounding organs. He then furthered his argument by saying that CLDs are the "antithesis of operational thinking" (p.145), one of the three thinking skills he views as being part of ST, and that it makes ST more difficult. And like Forrester, Richmond too believed that the appropriate place for CLDs are after the models have been constructed and the systems' structures and behaviours have been understood.

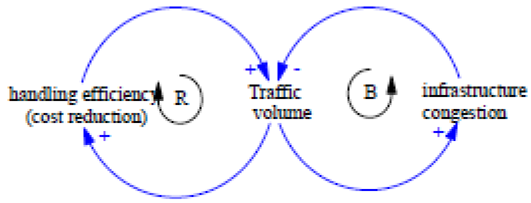


Figure 1: Example of a causal loop diagram
Sourced from: De Marco & Rafele (2007)

Despite opposing views on the usage of CLDs, they are typically used to construct stock flow diagrams (SFD) such as the one shown in Figure 2 below, which are in turn used to represent systems in SD (Sterman, 2001; Borshchev & Filippov, 2004). Stocks (or levels) refer to accumulations of quantities – for example, population or sales – within a system, and describe the condition of said system (Maani & Cavana, 2007), while flows (or rates) are activities that cause those conditions to change over a period of time (Richmond, 2001), such as number of births during the year or amount of revenue earned during the month. Flows can also be affected by converters (or auxiliary variables) that can be used in flow calculations to break down complex equations into simpler ones (Maani & Cavana, 2007). Converters can be constants, graphical or behavioural relationships (Maani & Cavana, 2007). Examples of converters include birth fraction, brand visibility, and such. Another way of viewing SFDs is to think about them in terms of a plumbing system that includes a series of pipes that connect tanks together (Richmond, 1994; Sterman, 2001; Ragni, Steffenhagen, & Klein, 2011).The pipes are the flows that result in inflows or outflows of water into and out of the stocks, which in this case are represented by the tanks or reservoirs where the water accumulates and disperses. The amount of water that flows through, on the other hand, are controlled by the valves on the pipes – i.e. the converters that influence the rate of the flows.

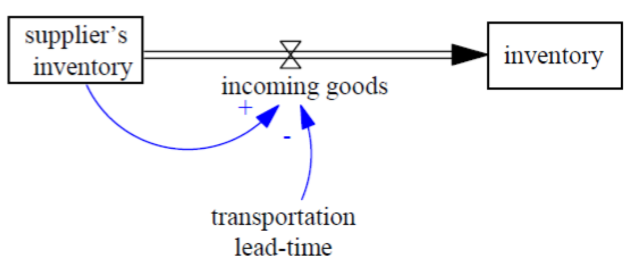


Figure 2: Example of a stock and flow diagram
Sourced from: De Marco & Rafele (2007)

While SFDs are a way of depicting metal models of systems (Richmond, 2001), there are problems that may be encountered during the construction and/or interpretation process. Like CLDs, there is also the risk of including too much detail in SFDs and hence resulting in cognitive overload (LeFèvre, 2002). This problem then leads to rejection from the reader/decision maker due to the difficulty in understanding, and the oversimplification or increased complexity of the modelling process for the modeler (LeFèvre, 2002). Another problem with SFDs is that the distinction between stocks and flows is not intuitive enough, which also results in the increased difficulty in understanding SFDs and consequently SD too (Sweeney & Sterman, 2000; Sterman, 2001; Ossimitz, 2002). Studies have been conducted to investigate the ability of university students to distinguish between stocks and flows, and the findings were "alarming" (Ossimitz, 2002, p.2), with many subjects not even being able to calculate the net flows into stocks (Sterman, 2001).

3.2.3 System dynamics approaches

There are several different approaches to SD. For example, Maani and Cavana (2007) propose a five-phase approach wherein the five phases are distinct but interrelated, and each involve a series of steps. The process starts with problem structuring where problems are identified with the aid of stakeholders and management. Once the first step is completed causal loop modelling occurs so that main variables are identified and behaviour over time graphs (or reference modes) can be drawn. A SFD is then constructed and its validity tested in phase three where dynamic modelling happens. Phase four is scenario planning and modelling – here policies and strategies are formed and evaluated by being simulated on the model. The fifth and final phases is the implementation and organizational learning where results of the simulations are communicated back to the management team and stakeholders. While each phase will help with system improvements, they are merely presented as guidelines so users can alter the phases to suit their needs (Maani & Cavana, 2007). Coyle's (1996) structure to SD is also similar to Maani and Cavana's, with the first two steps achieving the same goals. Coyle's stage three is a qualitative analysis of "bright ideas and pet theories" (p.10), in which an analysis is conducted on both past experiences and the views of experiences people within the system to produce insight into the problem (Coyle, 1996). If stage three does not result in enough insight, the construction of the simulation model will commence in stage four. Policies and strategies are then tested and evaluated on the model in stage five.

Unlike a lot of other studies, Forrester's (1994) six-step approach to how SD is used in system improvement does not begin with constructing CLDs. Instead it starts with describing the system and the undesirable behaviours within. In this stage a hyPoThesis of how the troubling behaviour occurs is generated. Step two is when the simulation model is formed and the descriptions from the previous step are translated into mathematical equations. This simulation is then run in step three, and repeated returns to steps one and two may be needed to make changes until the simulation provides an adequate representation of the behaviours in the system. Step four involves identifying the policy alternatives that would yield the greatest success in correcting undesirable behaviour. These policy alternatives then require consensus in step five before being implemented in step six.

3.2.4 System dynamics development

Whilst there is increasing interest in SD, there are several problems that hinder the development of the field. For example, for a beginner it may be difficult trying to figure out where to begin (in other words, where to place the first stock) once a mental model has been constructed. Their mental model will seem a lot more complex and therefore the transition from thoughts onto paper will be difficult (Richmond, 1994), thus resulting in reluctance to utilise SD. A study conducted by Sweeney and Sterman (2000) has even indicated that university students who "are highly educated and possess unusually strong background in mathematics and the sciences compared to the public at large" (p.3) had difficulty understanding the basic SD and ST concepts, such as delays and negative feedback. Another reason why uptake in the field of SD is slow is because of how little guidance exists to help with converting real-life scenarios into SD models, as well as how little understanding there is of SD in general (Forrester, 1994). Therefore, many SD projects fail to reach their full potential as it is difficult to find the support necessary for implementation (Forrester, 1994). These problems show that more education is needed in the field of SD and ST (Ossimitz, 2002).

3.2.5 System dynamics in the context of ports

SD is considered a powerful tool to handle complex relationships, particularly for port performance as port activities are "inherently dynamic" and complicated and involves processes and decisions that are under the influence of external factors (Ho et al., 2008, p. 9). External factors can be technological, economic, social and/ or political (Dooms & Macharis, 2003). These processes are also self-correcting or self-reinforcing (Ho et al., 2008), like causal loops. Despite the numerous benefits SD can bring, studies within the field of maritime transportation and ports have been limited (Oztanriseven et al., 2014). In particular, there is a lack of simulations on freight transportation in ports (Cortés, Muñuzuri, Ibáñez, & Guadix, 2007). For example, port-related SD studies can be used to investigate economic impacts of investments in port infrastructure and the ports themselves. One such study was conducted by Ho et al. (2008) where SD was used to determine the financial outcome of the expansion plans of Port of Hong Kong. The study investigated the effects of capacity expansion on freight throughput and congestion levels, concluding that there will be financial difficulties in the long term if projected freight throughput and revenue growth are not reached. Unintended side effects such as the overloading of other related infrastructure and the disruptions to the property values of nearby real estate were also identified through the use of SD (Ho et al., 2008).

Another study by De Marco and Rafele (2007) used SD to help determine a location (and therefore investment effort) for an inland port in Italy. Two locations were considered – Alessandria and Novara – and a simulation model of freight flow trends was developed. The trends are the result of variables such as investments in road and rail infrastructure, port capacity, and potential sea traffic. The simulation assumed unlimited financial resources and considered the distribution of total investment between the two locations, as well as the timing of the investments, and found that while priority should be given to the Novara site, investments should be shared equally with the Alessandria site in order to obtain the best overall results. SD can even be used to help with the improving of port performance and quality. Ridwan and Noche's (2018) study utilised SD (in conjunction with six sigma, a total quality management method to reduce defects and process variability) to design a port performance metrics to identify and reduce or eliminate waste from port operations so that performance can be improved.

4. Chapter Four: The New Zealand Situation

This section provides an overview and commentary of the current shipping patterns and volumes in New Zealand, as well as the different methods of inland freight movement and any trends that may affect them in the future. A closer inspection of the Upper North Island is conducted as it is where the Golden Triangle, the problem domain for this study, is located. The Golden Triangle is then explored further – an explanation is given as to why this area is of importance, and the significant freight infrastructure (i.e. the 'players') within are identified. Information about the two seaports in this area – Ports of Auckland and Port of Tauranga – and their inland ports are provided as they are important components in the simulation model. Finally, planned initiatives for New Zealand's freight infrastructure are mentioned as they will have impacts on the freight flow through the Golden Triangle region.

4.1 Current shipping patterns of New Zealand

New Zealand is a small, remote island nation in which trade plays a significant part in the economy – 30 per cent of the gross domestic product (GDP) is from exports, making the economy export-driven and "outward-looking, internationally competitive" (New Zealand Immigration, n.d., para. 4). With its abundance of natural resources and ideal growing conditions for the agricultural industry, New Zealand specialises in agricultural commodities and related value-added products. Top export products include products such as milk powder, butter, cheese, meat, wood articles, and fruit (New Zealand Trade & Enterprise, n.d.), with dairy products alone exceeding all other agriculture commodities (Deloitte, 2018). Imported items include vehicles, mechanical and electrical machinery equipment, textiles, plastics, and such (New Zealand Foreign Affairs & Trade, 2017). Almost of half of New Zealand's trade in the year ending September 2018 was conducted with the country's top three trade partners – China, Australia, and the European Union. Both imports and exports were at an incline from the previous year, with exports increasing $7.1 billion to $81.6 billion in 2018, while imports were at $79.1 billion, a $9.4 billion increase from 2017 (Statistics New Zealand, 2018). The increase in trade is due to multiple reasons – one of which being the strengthening of global economy following the period of "subdued growth" after the Global Financial Crisis and is expected to remain this way in the next few years

(Deloitte, 2018, p. 7). Shipping trends such as the increase in container ship sizes and the technological advances in ports to aide in operation efficiencies also contribute to the rise in trade activities (Deloitte, 2018). Other drivers include the shifting of lower skilled manufacturing to emerging countries such as China, and the removal of trade barriers, etc. (PricewaterhouseCoopers, 2012).

Approximately 99 per cent of all imports and exports travel through the country by sea (Deloitte, 2018), while the remaining is via air. Seaports therefore are integral to the country's economy, despite them being relatively small by world standards (Deloitte, 3024b). There are 15 ports in New Zealand and 10 of them are involved in international trade (Deloitte, 2014b), but the two dominant players in the market are Port of Tauranga (POT) and Ports of Auckland (PoAL) whose market share in 2017 combined to be 62 per cent of all containers handled (Deloitte, 2018). Not only are these ports responsible for being the gateway for imports and exports into and out of the country, they are also often a source of revenue for regional councils and can provide additional value in the form of other related economic activities (PricewaterhouseCoopers, 2012). The growth in trade meant that all ports in New Zealand saw an increase in container throughput in 2017, with PoT growing the most at 13.8 per cent from 2016, and Timaru the least but still an increase of 0.6 per cent (Deloitte, 2018). There is, however, an export/import imbalance as there are more exports than imports, which results in empty containers (Deloitte, 2014b; Fox, 2019). For example, 94 per cent of PoAL's import containers are full, compared to Port of Otago's 21 per cent (Deloitte, 2014b).

Airfreight, on the other hand, accounts for a very small fraction of goods imported and exported in terms of weight. In 2015 airfreight moved just under 0.3 per cent of the volume of international freight, but it was worth about 17 per cent of the value (King, M., Francis Small Consultancy Ltd, & Richard Paling Consulting Ltd, 2016). This difference is due to the nature of the goods that are airfreighted – they are typically just-in-time, perishable goods that have a higher return than sea-freighted goods and are also usually low in weight but high in value (Insight Economics, 2014). Auckland Airport, New Zealand's largest airport, has a dominant share of the international airfreight (Insight Economics, 2014). It also handled 85 per cent of the total airfreight traffic in New Zealand in 2015, making it the third largest port after PoAL and PoT (King et al., 2016). Like PoAL, import volumes through the airport outweigh exports

(Insight Economics, 2014). Main imports and exports include industrial parts and machinery, followed by other low volume high value goods such as pharmaceuticals, gems and precious stones, and medical parts and machinery (Insight Economics, 2014). Despite the expected increase in international freight task in the future, freight volumes through Auckland Airport are predicted to grow slower than passenger volumes (Market Economics, 2010).

A big portion of the freight movement within New Zealand is localised – in 2012/13 approximately 77 per cent of the freight tonnage is moved within the region it was sourced, while 14 per cent was moved to an adjacent region (Ministry of Transport, 2017b). Most of the freight is transported via road or rail within a relatively sparse network. In 2012, road transport moved 91 per cent of the total freight within the country, while rail moved seven per cent, and coastal shipping and air were two per cent and zero per cent respectively (Deloitte, 2014a).

4.1.1 Inland freight movement

4.1.1.1 The road network

The road network (shown in Figures 3 and 4) plays a vital role in the country's transport system, linking ports to markets and production facilities inland (Deloitte, 2014b). Common items transported include 91 per cent of the logs, 100 per cent of the aggregate, and 96 per cent of the liquid milk (Ministry of Transport, 2017b). Managed by the New Zealand Transport Agency, the state highway network consists of 5,981.3 kilometres of road in the North Island and 4,924.4 kilometres in the South Island (199 kilometres of which is the motorway), and links together approximately 83,000 kilometres of local roads (New Zealand Transport Agency, n.d.-a). The busiest section of road is State Highway 1 in central Auckland, which carries more than 200,000 vehicles a day (New Zealand Transport Agency, n.d.-a). This is consistent with the population and congestion problems the city experiences – Auckland has the largest population of 1.66 million as at 30 June 2017 in New Zealand (Auckland Council, 2018), and 700 additional vehicles are being registered each week (Congestion Question, 2018). Congestion problems are especially severe on the motorway and primary arterial road network where 27 per cent of the road network accounts for 63 per cent of the severe congestion that results in stop/start traffic and significant delays (Congestion Question, 2018). Congestion in Auckland is so severe that it has been described as "New

Zealand's single greatest challenge" (Castalia, 2012, p.18). A proposal to introduce congestion pricing in Auckland is therefore jointly developed by the Ministry of Transport, the NZ Transport Agency, Auckland Council, Auckland Transport, the Treasury, and the State Services Commission (Congestion Question, 2018). The goal of the project is to ease congestion by encouraging road users to choose different routes or transportation methods or times by charging them at different locations and/or times (Ministry of Transport, 2019c).

Figure 3: North Island state highway network

Figure 4: South Island state highway network

Both figures sourced from: New Zealand Transport Agency (n.d.-c).

4.1.1.2 The rail network

All rail operations (shown in Figure 5 below) in New Zealand are conducted by KiwiRail Holdings Limited, a State Owned Enterprise wholly owned by the Crown (Ministry of Transport, 2019b). Rail services are mostly focused on freight (in particular bulk, imports, and exports) which accounts for 57 per cent of their total operating revenue, but they also offer passenger services on some routes that are predominately tourism-focussed, as well as suburban passenger services in Wellington and Auckland (Ministry of Transport, 2019b). The company manages 4,000 kilometres of track that stretches through both islands of New Zealand, as well as 18,000 hectares of land and the assets on the network (KiwiRail, n.d.-a). With its 900 freight trains, 243 locomotives, and 4,605 wagons, KiwiRail takes pride in being able to deliver 91 per cent of all freight on time (KiwiRail, 2018). Common products transported by rail include 46 per cent of the manufactured dairy products and 29 per cent of meat products (Ministry of Transport, 2017b). Another commodity is logs. While the majority of logs are moved via road, rail is used to transport logs in the Bay of Plenty to PoT (Ministry of Transport, 2017b). The company also works with the ports to provide more rail efficiencies to cope with the increasing freight volumes. For example, its partnership with PoT saw it changing its train services to “enable efficient transfers of cargo and empty shipping containers to and from Tauranga” (Port of Tauranga, 2018a, p. 32). KiwiRail hafs spent $171 million on key freight lines to provide additional operational capacity (KiwiRail, 2018), and a further $15 million to increase the capacity of its container handling facilities in Auckland by 40 per cent (Port of Tauranga, 2018a).

Figure 5: Current rail network in New Zealand as of 2019
Sourced from: Ministry of Transport (2019)

4.1.1.3 The coastal shipping network

There are three types of coastal shipping – export transhipment, import transhipment, and domestic shipment that travel between the ports in New Zealand (as shown in Figure 6 below). Export transhipments are cargo that is loaded at one port in New Zealand, shipped to a second port where it is discharged and loaded again without leaving the port, before leaving the country for an overseas port. In New Zealand export transhipments are mostly from southern ports up to either PoAL or PoT (Deloitte, 2014b). Import transhipments are the opposite of export ones – the cargo comes into the country from an overseas port, is discharged and reloaded onto a second ship without leaving the port before it gets to its final port where it is discharged and leaves the port. This category of freight usually arrives in the country at PoAL or PoT before moving further south (Deloitte, 2014b). Domestic shipment refers to cargo that is shipped from one port to another via ship and will not leave the country. In 2013, 62.86 per cent of the coastal container movement was domestic, but 68 per cent of it was the movement of empty containers, which reflects the imbalance of trade between New Zealand ports (Deloitte, 2014b). Export transhipments and import transhipments on the other hand accounted for 26.25 per cent and 9.93 per cent respectively, while the remaining 0.96 per cent was unknown (Deloitte, 2014b). Products that are transported via coastal shipping can be bulk products such as oil, cement, and coal, or containerised freight (Ministry of Transport, 2008). However, for an island nation New Zealand's usage of coastal shipping is relatively low, compared to other countries like Japan where the geography is similar but domestic sea freight takes more than twice of New Zealand's market share (Ministry of Transport, 2008). To encourage the use of coastal shipping the Ministry of Transport proposed the *Sea Change* strategy. The strategy aims to help New Zealand take advantage of a more sustainable and cheaper shipping method, cope with the increase in freight movements in the future and ensuring that the country's spending on infrastructure is more efficient as shipping requires relatively little infrastructure compared to road or rail (Ministry or Transport, 2008). These benefits will in turn help New Zealand businesses remain competitive in markets overseas (Ministry of Transport, 2008).

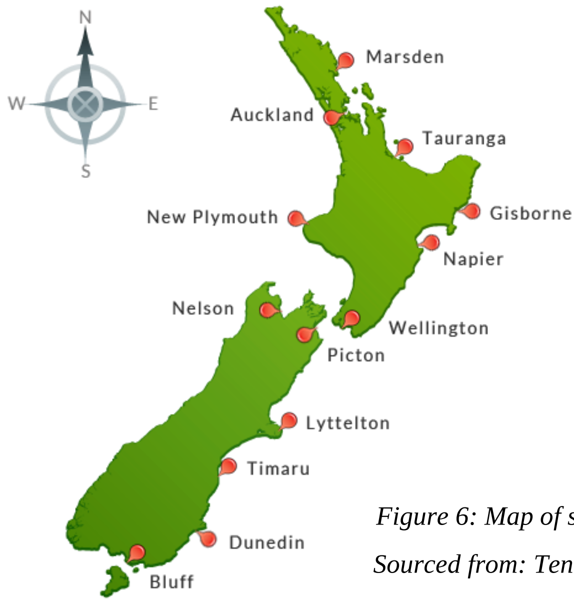


Figure 6: Map of seaport locations in New Zealand

Sourced from: Tenco (n.d.)

4.1.1.4 Inland freight movement trends

While a significant portion of freight is moved via road transport, this number has been decreasing in the recent years as recent trends have indicated there is an increase in both transshipments and the usage of rail. For example, PoT experienced an increase of 31 per cent of tranship containers in 2017 (Deloitte, 2018), while their truck trips were reduced by 504,139 trips due to their increased use of rail (Port of Tauranga, 2018a). KiwiRail reported that they moved 16 per cent of New Zealand's total freight task in 2018, equating to approximately 18 million tonnes, 25 per cent of which were exports (KiwiRail, 2018). There has also been an increase in coastal shipping due to the Kaikoura earthquake impacting the ability to utilise rail and road transport in the area (Deloitte, 2018). Other reasons for the increase in coastal shipping include changes in global shipping such as international shipping companies gradually reducing the number of ports they visit due to the increase in vessel sizes (Ministry of Transport, 2018). In terms of speed and convenience, road transport is indeed more superior to the other transport modes, which explains why land transport costs are a major part of total freight costs in New Zealand (PricewaterhouseCoopers, 2012). Road is also seen as the more reliable option, especially for companies that implement just-in-time practices (Ministry of Transport, 2008). However, coastal shipping and rail both result in lower emissions and lower costs per unit (Deloitte, 2018; KiwiRail, 2018) – for example, rail produces 66 per cent less emissions for each tonne of freight compared to road

(KiwiRail, 2018), while coastal shipping produces approximately 88 per cent less (Ministry of Transport, 2008). Meanwhile costs rank from road which is the most expensive, to rail, and then coastal shipping, the least expensive (Ministry of Transport, 2008). Hence, there is preference of rail and/or coastal shipping over road where possible (Port of Tauranga, 2018a), but road transport is projected to still move the greatest volume of all commodities in the future (Ministry of Transport, 2017b).

4.1.2 Commentary

While there has been criticism that the lack of cooperation amongst New Zealand's shipping companies is resulting in the waste of resources, there are also those that believe cooperation will hinder the progress that New Zealand ports are making. Port of Tauranga Chief Executive Officer Mark Cairns believes that "competition, rather than cooperation, is vital for New Zealand's ports" (para.1) and that competition was the key to transforming New Zealand's ports into world-class facilities (Fox, 2019). However, general consensus is that competition between ports is detrimental to New Zealand. In particular, the number of inland ports in the country is too high for a country that "is not a big enough market" (Hutching, 2016, para.6). While having inland ports can provide a multitude of benefits, being able to reach scale is a crucial target for the benefits to be capitalised. There are concerns over the duplication of ports and inland ports, and that these ports all serve the same functions (Ministry of Transport, 2019a). Within the Auckland region alone there are two inland ports, whereas most other countries keep the number of inland ports to a minimum. For example, Spain has only one – the Port of Seville – which is a river port (Arango, Cortés, Muñuzuri, & Onieva, 2011). PricewaterhouseCoopers' (2012) report points out that both Wiri and MetroPort struggled to reach capacity, with MetroPort reaching 55 per cent of utilisation more than a decade after opening while Wiri still was unable to gain significant volume as of 2011. The struggle was mainly the result of the benefits of utilising road transport being greater than that of rail transport. Road transport provides better convenience, speed, and cost benefits than the cost efficiencies that could be gained from using rail (PricewaterhouseCoopers, 2012). As a consequence, it is likely that New Zealand would not be able to see the benefits of inland ports on land usage and the freight network capacity in the short term (PricewaterhouseCoopers, 2012).

The same applies to the number of ports involved in international container trade. For a relatively small island nation, New Zealand has disproportionately large number of container ports (PricewaterhouseCoopers, 2012). Due to the large number of ports trying to compete for more and bigger vessels, investments in infrastructure are spread across too many projects. This competition makes it more difficult for New Zealand's ports to compete with their counterparts overseas, such as Sydney or Singapore (Hutching, 2016). The New Zealand Institute of Economic Research (NZIER) has therefore suggested that New Zealand should evolve from the current port configuration where each port continues to provide international services to a 'hub and spoke' configuration. The hub and spoke configuration will see one or two ports operating as international ports (i.e. the 'hub'), while the other ports act as the 'spokes' or feeder ports used for transhipments only (New Zealand Institute of Economic Research, 2015). However, research conducted by Deloitte (2014b) concluded that while the scenario of having two hubs on each island and the remaining ports being feeder ports "generated the best outcome on a PV cost basis" (p.13), the status quo scenario where everything remains the same will result in the lowest overall cost impact for New Zealand's supply chains. Other arguments against this hub and spoke configuration include the difficulty of choosing which ports to keep as the hubs. For example, in the North Island PoT seems like the logical choice to pick as the hub due to its ability to handle larger vessels and their arrangement with the Maersk shipping line that will last until August 2024 (New Zealand Institute of Economic Research, 2015). However, PoAL is still seen as the ideal location for an import hub and has the ability to handle larger import vessels at high tide (New Zealand Institute of Economic Research, 2015). Despite the arguments against the hub and spoke configuration, there are currently signs that shipping services are concentrating on fewer ports – in particular, Auckland, Tauranga, Napier, Lyttelton, and Otago – so it is unlikely that the current port configuration will continue (Deloitte, 2014b).

4.2 The Upper North Island

Home to 53 per cent of New Zealand's population, the Upper North Island area has been identified as being "critical to the success of New Zealand" (Waikato Regional Council, n.d.). The area which encompasses Northland, Auckland, Waikato, and Bay of Plenty, is responsible for generating 52 per cent of New Zealand's GDP, and has the fastest average GDP growth rate in the country (Upper North Island Strategic Alliance, 2017). However, fast growth across multiple regions give rise to challenges that need to be resolved in order to take advantage of the benefits. In 2011 the Upper North Island Strategic Alliance (UNISA) was established by three regional councils – Northland, Waikato, and Bay of Plenty – Auckland Council, Whangarei District Council, and two city councils – Hamilton and Tauranga – to manage these inter-regional challenges and issues (Waikato Regional Council, n.d.). The development of freight-related strategies is especially important as 64 per cent of New Zealand's goods in terms of value move through the three ports – Northport, PoAL, and PoT – in the Upper North Island and Auckland International Airport (AIA) as of 2013, and that freight task is expected to double by 2035 (Upper North Island Strategic Alliance, 2013). A document titled *The Upper North Island Freight Story* was therefore released in April 2013 (Upper North Island Strategic Alliance, n.d.) in anticipation of the future. The document, which was developed by UNISA in collaboration with New Zealand Transport Agency, KiwiRail, and Auckland Transport, outlines critical issues and opportunities within the freight sector in the area (Upper North Island Strategic Alliance, n.d.). Seven critical issues such as the road and rail network constraints, lack of information flow between each of the actors within the freight network, and the lack of strategic direction in the use of land and planning and investment of transport were discussed (Upper North Island Strategic Alliance, 2013). The purpose of the document was to provide a strategy in the form of a "shared approach" (p.8) for all of the key partners to work together to reduce the costs of trade through increased freight efficiencies, and increase the competitive advantages of New Zealand's importers and exporters (Upper North Island Strategic Alliance, 2013) as overseas merchandise trade accounts for the majority of the Upper North Island port task (PricewaterhouseCoopers, 2012).

4.3 The problem domain – the Golden Triangle

Within the Upper North Island another area is of especial importance – the 'Golden Triangle'. Shown in Figure 7 below, this term refers to the area comprised of Waikato, Auckland, and the Bay of Plenty (Castalia, 2012). With the rapidly growing population, there are signs that the Golden Triangle is extending south to Rotorua and Hawkes Bay as well (OneRoof, 2018). Currently this area is home to over 50 per cent of the population in New Zealand (Statistics New Zealand, n.d.), and accounts for 45 per cent of all freight tonnage produced (McRae, 2017; Deloitte, 2018). This freight tonnage currently equates to over 50 per cent of the value of exports from the country (Statistics New Zealand, n.d.; McRae, 2017), and has been forecasted to increase by 62 per cent by 2031 (Castalia, 2012). With over 50 per cent of New Zealand jobs located in the Golden Triangle (Workhere New Zealand, 2016), it is therefore integral to the economic development in New Zealand. Key outputs in the area include agriculture/horticulture (for example, dairy, meat, and kiwifruit), forestry (for example, wood and paper product manufacturing), business and property services, manufacturing (for example, fuel and agri-tech manufacturing), and finance and insurance services (Upper North Island Strategic Alliance, 2013). Users of the freight network in the Golden Triangle include exporters such as dairy co-operatives Fonterra and Westland Milk, and steel producers Bluescope Steel and Pacific Steel, while importers include (but are not limited to) companies such as Genesis that imports coal from Indonesia (Richard Paling Consulting, 2008).

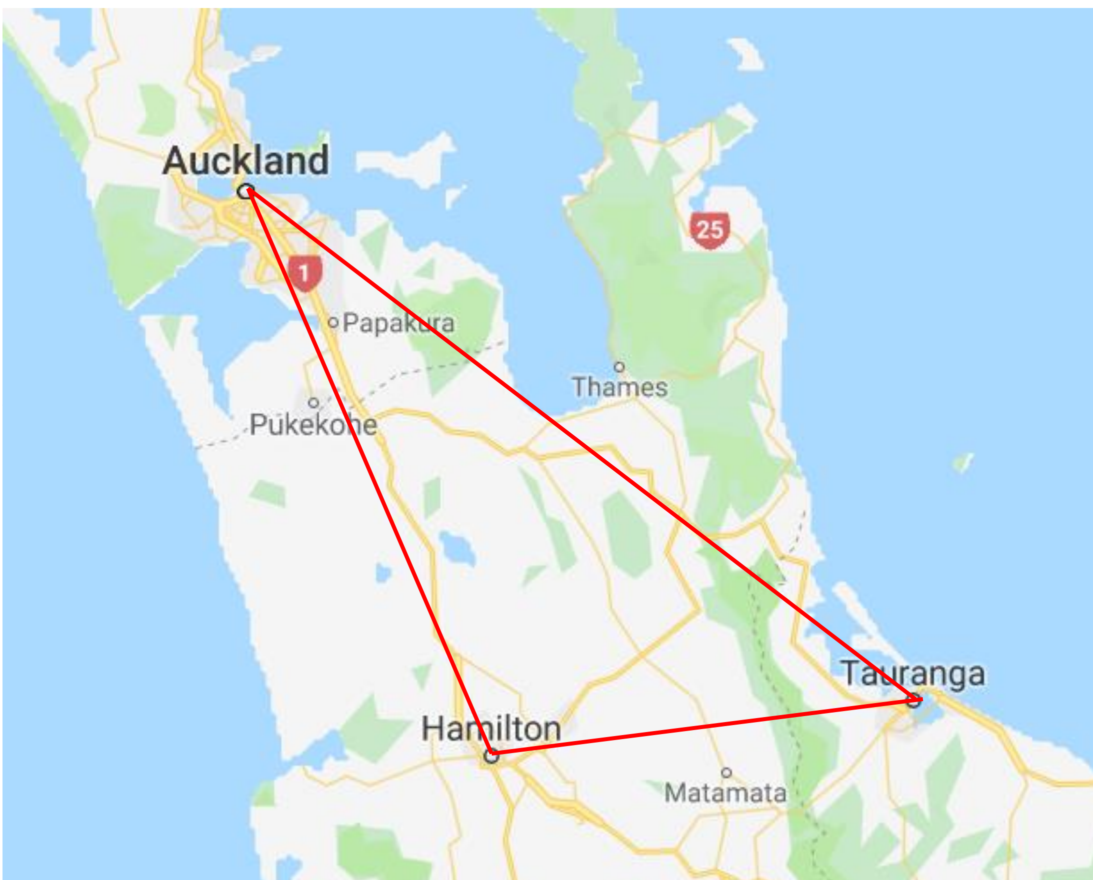


Figure 7: Map of Golden Triangle

Sourced from: Google (n.d.)

freight through AIA far outweighs the average value of international trade at approximately $1,700 per tonne (Deloitte, 2014a). Most importantly, however, the area encompasses the two seaports – Ports of Auckland and Port of Tauranga – that "continue to be the dominant players in the market with a combined market share of 62% of all containers handled in 2017" (Deloitte, 2018, p.42). Whilst importers and exporters that use PoAL and PoT have to incur higher port charges due to the higher land prices, the proximity to the markets and export producing regions means that any additional costs can be compensated by lower domestic freight costs (PricewaterhouseCoopers, 2012). These two ports compete for a significant proportion of the freight task in the Upper North Island and are considered close substitutes for containerised cargo (PricewaterhouseCoopers, 2012). The amount of capacity available at each port and the costs associated are therefore key in shippers' decision-making process and can affect where the freight moves through. Not only do the prices and costs affect shippers, they are also taken into consideration when ports determine whether additional physical infrastructure or operational efficiencies (such as automation and more cranes) are worth investing in (PricewaterhouseCoopers, 2012).

4.3.1 Significant freight infrastructure in the Golden Triangle

4.3.1.1 Ports of Auckland

The history of Ports of Auckland (PoAL) dates back almost a thousand years ago when the Auckland area became known as 'Tāmaki herenga waka', or the gathering place of many waka (Ports of Auckland, n.d.-a). Since then several wharfs have been built – the first of which was the Queen Street wharf in the 1850s, but it wasn't until 1988 when PoAL was formed after the purchase of the land assets from the previous owner Auckland Harbour Board (Ports of Auckland, n.d.-a). The company was originally listed on the New Zealand Stock Exchange, with the Auckland Regional Authority and Waikato Regional Council owning 80 per cent and 20 per cent each respectively, until its delisting in 2005 (Ports of Auckland, n.d.-a). It is now wholly owned by the Auckland Council (Ports of Auckland, n.d.). PoAL comprises of two seaports – the main port on the Waitematā Harbour, and a small regional port on the Manukau Harbour in Onehunga (Ports of Auckland, 2018). The main port is in turn made up of two terminals – Bledisloe Terminal and Fergusson Container Terminal – and six wharves – Princes Wharf, Queens Wharf, Captain Cook Wharf, Wynyard Wharf, Jellicoe Wharf, and Freyberg Wharf (Ports of Auckland, 2017). The company also operates one freight hub each in South Auckland (Wiri Inland Port), Mount Maunganui, and in Longburn (Ports of Auckland, 2018). A Waikato hub named Northgate Business Park was also officially opened in April 2019 in the 33 hectares of land the company purchased in Horotiu (Wilson, 2019).

Their annual revenue in 2018 reached $243.2 million while freight volumes were up 2.2 per cent to 973,722 TEU (Ports of Auckland, 2018), which accounted for more than 35 per cent of total domestic import volumes and approximately 19 per cent of total domestic export volumes, making it the second largest port in New Zealand in terms of total freight volumes (Deloitte, 2018). It is also the port with the highest import volumes and second highest export volumes, as well as the highest domestic volumes at 31 per cent of New Zealand's total domestic volume (Deloitte, 2018). Approximately 75 per cent of cargo tonnage at PoAL is containerized, with the remaining 25 per cent being bulk freight (Deloitte, 2018). Compared to PoT PoAL handles a more diverse range of exports, with dairy accounting for 21 per cent of the total exports, thereby accounting for the largest portion in 2012, followed by wood, iron and steel, and beverages (PricewaterhouseCoopers, 2012). Similarly, the variety of imports into PoAL is also greater than the other ports, and includes products such as paper pulp, sugars and sugar confectionery, and vehicles (PricewaterhouseCoopers, 2012).

However, at the current rate they are operating at the port is expected to reach their maximum container terminal capacity of 2 million TEUs per year by around 2035 assuming an annual growth of 3.2 per cent and productivity improvements (New Zealand Institute of Economic Research, 2015). Another capacity restriction is how the wharves were built. The wharves were built when loading and unloading times were much longer, so they were laid out in a 'finger wharves' configuration (New Zealand Institute of Economic Research, 2015). This layout limits the amount of space available for the temporary storage of freight and shortens the lengths of the berths, which in turn restricts the sizes of the vessels that can dock there and thereby affecting the port's berth occupancy rate (New Zealand Institute of Economic Research, 2015). Capacity constraints will limit economic growth for PoAL in the long term, as the port's ability to cater to future freight demands will be restricted (Consensus Working Group, 2016). Thus the company is aiming to turn the Fergusson Container Terminal into the first automated terminal in New Zealand, which will increase its capacity from 900,000 TEU per year to 1.6 million to 1.7 million TEU (Ports of Auckland, 2018). There are also plans to expand the capacity of the wharves through channel and berth deepening in the foreseeable future (Ports of Auckland, 2018).

In addition to the aforementioned expansion plans, PoAL is also considering relocating the port to a different location to provide for more capacity (Ports of Auckland, n.d.-b). However, this move will not happen in the near future due to the magnitude and complexity of the project. In the meantime, a 30 year Master Plan has been developed (with the input from stakeholders) to cope with the increasing capacity requirements and the changing demands of the people in Auckland (Ports of Auckland, n.d.-b). Endorsed by the Auckland Council in May 2018, the plan takes into consideration the economic, environmental, and social needs of the city, and "provides certainty and security for Auckland's supply lines" while decisions regarding the details of the move are made (Ports of Auckland, n.d.-b, para.3). The plan includes projects that are already in progress. For example, the automation of the Fergusson Container Terminal, as well as the expansion which will result in the wharf being extended by 50 meters and a new 300-meter berth along the north side of the terminal (Ports of Auckland, n.d.-b). Planned projects that still require consent – such as the building of new engineering workshops to house the new automated straddles for the terminals – and projects that are still ideas – such as rail grid automation – are also included in this plan as well (Ports of Auckland, n.d.-b).

4.3.1.1a Wiri Inland Port

Located on Wiri Station Road in "the heart of Auckland's major industrial and manufacturing area" (para.4), this inland port is managed by CONLINXX Limited, a company owned by Ports of Auckland Ltd (CONLINXX, n.d.). This port is mainly used for freight in which time is not the primary commercial concern, and processes and distributes import containers as well as consolidating export ones (New Zealand Institute of Economic Research, 2015). A dedicated rail line runs through the port alongside a fleet of trucks that can take advantage of the road connections the port has access to, including State Highway 20 which sits on its northern boundary (CONLINXX, n.d.). The inland port's proximity to both the market and accessibility to different transportation modes combined with facilities such as it being a NZ

Customs Controlled Area provides customers with convenience and speed (CONLINXX, n.d.), while its capacity of 100,000 TEU as at 2008 ("Inland Port Branches Out", 2008) allows Ports of Auckland to increase its container storage capacity.

4.3.1.2 Port of Tauranga

Officially established on 1 September 1873, the Port of Tauranga (POT) was initially managed by the Borough of Tauranga until the newly-constituted Tauranga Harbour Board acquired the port and all of the associated assets from them in 1912 (Port of Tauranga, n.d.-a). The board then changed its name to the Bay of Plenty Harbour Board in 1970 to better represent the entire district served by the port (Port of Tauranga, n.d.-a). Under the requirements of the Port Companies Act, the board set up Port of Tauranga Ltd on 25 July, 1988 to operate the port (Port of Tauranga, n.d.-a). The port is comprised of two wharves – Mount Maunganui and Sulphur Point – as well as a tanker berth for the transfer of dangerous goods (e.g. chemicals and oil products) in bulk (Port of Tauranga, n.d.-a). PoT underwent a six-year investment project to increase their capacity and become "big ship capable" (Port of Tauranga, 2018a, p. 9). The project was completed in 2016 and resulted in a 10.2 per cent increase in cargo volumes (Port of Tauranga, 2018a). However, PoT still continues to increase their container terminal capacity by rearranging the space available – for example, in 2017 they relocated Oji Fibre Solutions to another area, which resulted in an additional 820 container ground slots by the berths (Port of Tauranga, 2018a). A report from EY has shown that PoT has the capacity to handle up to three million TEUs per annum without any further land reclamation (EY, 2016).

With a revenue of $283.7 million in 2018, PoT is the largest port in New Zealand by container throughput (Deloitte, 2018). It has the highest export volumes, accounting for approximately 43 per cent of New Zealand's export volumes, as well as the highest transshipment volumes at over 47 per cent of total transshipment volume, and the second highest import volumes at 33 per cent of the total (Deloitte, 2018). Approximately 75% of the port's exports are forestry, kiwifruit, and dairy exports (Port of Tauranga, n.d.-a), with wood products accounting for 56 per cent alone (PricewaterhouseCoopers, 2012). Imports on the other hand consists of products such as animal feed and pet food, fuels, building materials, plastics, and cereals

(PricewaterhouseCoopers, 2012). Not only is it the first port in New Zealand to handle more than one million TEU in 2017, it is also the only port so far that can accommodate vessels sizes of 6,500 TEUs and above (Deloitte, 2018). In 2017 the Maersk Antares called into the port – at 11,294 TEU it was the largest container ship ever to visit New Zealand's waters (Port of Tauranga, n.d.-a). Nowadays vessels with capacities of between 7,500 and 11,500 TEU regularly visit the port on a weekly basis, compared with the maximum of 4,500 TEU prior to the dredging of the port (Port of Tauranga, 2017). The port also had the most container ship and bulk ship calls of 954 and 1,482 vessels respectively in 2017, compared to PoAL's 594 and 695 vessels (Deloitte, 2018). POT's container throughput has been predicted to increase by 2.5 per cent to 3.1 per cent per annum each year for the next 30 years (PricewaterhouseCoopers, 2012). With container vessels staying an average of 10 to 16 hours at the port (Port of Tauranga, n.d.-a) and 0.77 kilometres of container wharf length, the port has the highest TEU throughout per container wharf metre (Deloitte, 2018). It is also the only port in New Zealand that international shipping giant Maersk is working with for their Triple Star service, which links Tauranga to countries in Asia (e.g. Japan and Taiwan) and South America (e.g. Chile and Colombia) (Deloitte, 2018).

In addition to owning MetroPort Auckland, PoT also established MetroPort Christchurch, which is accessible by the Timaru Container Terminal and the rest of the South Island via rail (Port of Tauranga, 2018a). There are further plans to work with "partners to develop intermodal freight hubs in Hamilton and the central North Island" due to its location in the Golden Triangle (Port of Tauranga, 2018a, p. 34). Their partnership with KiwiRail saw PoT utilising the rail transport to increase their efficiency and lower carbon emissions, and once KiwiRail's container handling facilities in Auckland were upgraded, POT's capacity increased by about 40 per cent (Port of Tauranga, 2018a). Trains transfer imported containers from PoT to MetroPort, and then are loaded with empty containers that are destined for Hamilton for Fonterra and other exporters to fill with exports. These trains then move the containers back to PoT to be shipped out of the country. The result of this system has decreased the number of unnecessary empty container movements and inventory costs, thereby reducing wastage (Port of Tauranga, 2018a).

4.2.1.2a MetroPort Auckland

Located in the Auckland region, MetroPort was opened by Port of Tauranga in 1999 (Port of Tauranga, 2018a). It is bordered by the Northern, Southern, and South Western motorways, and is within proximity to the region's main industrial, warehousing, and distribution areas, which allows for improved supply chain efficiencies (Port of Tauranga, 2015). MetroPort "acts as a shorter-term consolidation point for exports and imports through the Port of Tauranga" (New Zealand Institute of Economic Research, 2015, p. 34). Thus AmZ Limited (2009) has argued that MetroPort should be classified as an intermodal terminal or even a rail head operation as it is where freight is changed from one transportation method to another. The port has the lowest truck turnaround time of an average of 18.5 minutes, which is the lowest in the Auckland market (Port of Tauranga, 2015). In the 7.67 hectares of land occupied by the port, there are 96 reefer points, 1,506 ground slots, and a siding length of 780 meters to allow for trains up to 110 TEU (Port of Tauranga, 2015). It is also fully Customs bonded and has produce quarantine inspection facilities and areas that are approved by the Ministry of Primary Industries, thereby providing added convenience for importers and exporters (Port of Tauranga, n.d.-a). MetroPort users are able to keep their cargo at the port for five free days until they start incurring the lowest demurrage rates in the region (Port of Tauranga, 2015). Importers can also utilise up to five additional free days of dwell time in Tauranga, which can help with the management of arrival container volumes as the containers can be delayed if necessary (Port of Tauranga, 2015). The hub handled an increase of 3.8 per cent in container volumes transported via rail between October and December 2018 (Port of Tauranga, 2019), while total container throughput increased by 15.2% to 287,238 TEUs (Deloitte, 2018).

4.4 Planned initiatives for New Zealand's infrastructure

Not only are ports trying to increase their capacities to cope with the increasing freight volumes, the government is also investing in projects that will increase the capacity of existing infrastructure. For example, in addition to being used by rail freight that travels between PoAL and Wiri Inland Port, and PoT and MetroPort, the rail lines between Southdown and Wiri are also being used by commuter traffic from both southern line branches (Upper North Island Strategic Alliance, 2013). The increase in freight volume in the future will mean that additional capacity will be needed to ease the pressure on this portion of the network. A third freight-dedicated rail line (also known as the Third

Main) is therefore currently being planned for this section as a potential solution to the emerging rail congestion issues (PricewaterhouseCoopers, 2012). KiwiRail is also focusing its investment in the Golden Triangle area to support the growing freight volumes there too (KiwiRail, 2018). Another investment of over $1 billion dollars from the Government was announced on 30th May 2019 as well (Walls, 2019). This substantial investment will go towards maintaining and replacing existing infrastructure and systems, as well as up to $300 million for regional rail projects (KiwiRail, 2019).

On the road infrastructure front, NZTA estimates that only 15 per cent of the capacity on main roads is consumed by vehicles used for freight-moving (Deloitte, 2014b). Similarly, UNISA's study found that the congestion on the roads will likely be the result of non-port traffic, and that the effects "may be a factor in the medium to longer term" for users of road infrastructure for freight-moving purposes (Upper North Island Strategic Alliance, 2013, p.38). However, as congestion is still a problem that needs to be resolved, NZTA has implemented the Roads of National Significance (RoNS) project. Commenced in 2009, the programme identifies the urgent priorities within the State highway system to allow for benefits such as improved safety, reduced congestion, and supporting economic growth (Ministry of Transport, 2017a). The Waikato Expressway (State Highway 1) was amongst one of the seven roads identified and is scheduled to be completed in late 2020 (New Zealand Transport Agency, n.d.-b). The upgrade will result in a 102 kilometre four-lane highway between Bombay Hills and the south of Cambridge and is expected to increase the efficiency of freight movement while also reducing congestion in Auckland (Castalia, 2012).

5. Chapter Five: Practitioner's Understanding Gap (i.e. Sponsor's Needs)

This section identifies the gap in understanding for industry professionals and explains how this study will fill that gap.

Being a relatively new concept in the industry, the literature on the impacts of inland ports are few, especially in the New Zealand context as New Zealand is small compared to other countries. With its export-driven economy, the effects of an inland port (or several) on the economy and existing freight patterns will provide valuable insight into the benefits of inland ports. While there are currently inland ports already established in the country, there is not much research on how they influence the freight flows in New Zealand. A study has been undertaken by Burgess (2012) to look at what the effects of the establishment of an inland port in Christchurch will be. However, as the Golden Triangle accounts for 45 per cent of all freight tonnage produced (Deloitte, 2018), more research needs to be conducted on the freight flows in this area specifically. This type of research will be especially beneficial with the introduction of the Ruakura Inland Port that will most likely alter the freight flow patterns that currently exist within the region. This study therefore aims to provide an evolvable simulation model that will become a decision support tool as it can be used to fill this gap by answering the following two questions:

Question One: How will the Ruakura Inland Port impact current freight flows in and around the North Island's Golden Triangle over the next 20 years?

Question Two: What are the main barriers and enablers to the successful operation of the Ruakura Inland Port?

Due to the time and data restrictions encountered during this study however, only the first question was answered at this stage. otential ways to utilise the simulation model to answer the second question are provided in section 11 – Study Limitations and potential Future Research Areas.

6. Chapter Six: Methodology

This section explains the research philosophy that drives the way this study is designed.

This study takes a pragmatist approach that is rigorous in method and relevant to organisations. It is value-driven, applied research that provides findings that are of practical value to practitioners and the industry. The aim of the study is to identify problems that may arise in the future of the freight movement industry within the Golden Triangle, so that appropriate measures can be put into place to either mitigate the problem completely or reduce the impacts. The use of simulation modelling as the method also reflects pragmatism as it is a mixed approach to research.

7. Chapter Seven: Method

This section provides an outline of the steps taken to construct the simulation model, as well as the assumptions involved and how the model is tested to ensure it is a fair representation of reality. Scenarios that are simulated using the model are then explained – these are events that are expected to have an impact on the current freight flows of the Golden Triangle.

7.1 Setting up model

Firstly, CLDs were constructed using information gathered from existing literature. These CLDs provided the foundation for the simulation in the later stages as they identified potential enablers and barriers to the successful operation to the Ruakura inland port. An example of one of the first CLDs constructed is shown below in Figure 8. These two balancing loops describe the behaviours that occur seaports. The one of the left shows that an increase of import tonnage arrival will result in the import tonnage at dockside to increase, but this increase will in turn limit the amount of import tonnage that can arrive. The right loop shows that as import tonnage increases, so does the amount of import tonnage departure, but as this increases the import tonnage at dockside will decrease.

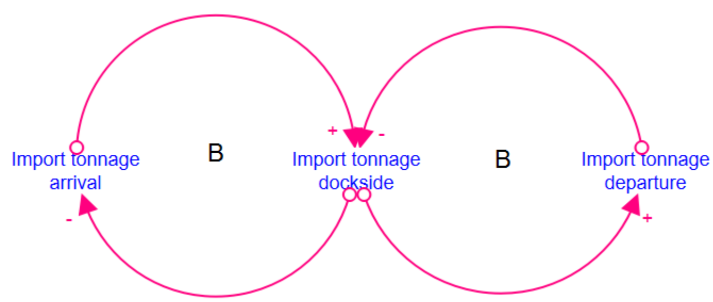


Figure 8: Example of CLD constructed

At the same time, information regarding future trends in the industry that could affect freight volumes was collected as well. Events that have been deemed as especially significant to the freight pattern of the Golden Triangle (i.e. events that would have big, observable impacts) were chosen to be influencing factors in the SD simulation in the later stages. Other variables that could also impact freight flow but are not currently planned for the near future were identified as well, as they could be things that Ruakura Inland Port, the government, and/or any of the players within the freight moving industry can investigate to see whether they are worth investing in. In addition, places where delays could occur within the system were noted for later use.

Next the key players within the freight moving industry in the Golden Triangle were identified, along with the routes of inland freight movement, and then a map of the physical flows showing was created as the foundation for the next steps. From there a basic SFD was constructed to illustrate how freight is moved to the seaports to the inland ports and end customers and back within the Golden Triangle. To avoid making the diagram too complex by including too many details, only the actors with the most significant impact were included. These actors include: PoAL, PoT, Wiri Inland Port, MetroPort, Ruakura Inland Port, KiwiRail (i.e. “rail”), and various road operators that have been denoted as “road” to simplify the diagram. The following players were not included due to various reasons:

- *AIA:* high in value but insignificant in terms of volume.
- *Hamilton Airport:* insufficient data on the volume of freight moved available. However, as AIA is the largest freight moving airport and only moves 0.3 per cent of the country’s freight, it is logical to assume that Hamilton Airport does not process enough freight to make a significant impact to the freight movements in the Golden Triangle.
- *Northgate Business Park:* new inland port being established by PoAL in Horotiu, but there is insufficient data available due to how new this inland port is.
- *Mount Maunganui freight hub:* insufficient information available.
- *Northport:* outside the scope as it is located in Whangarei, an area north of the Auckland region and thus outside of the Golden Triangle.

PoAL, PoT, Wiri Inland Port, MetroPort, and Ruakura Inland Port were all depicted in the diagram as the stocks as they are the places that accumulate freight within the system. The level of freight within each stock is changed over time by the trains and trucks that bring freight in and out of each location, so the train and truck capacities are represented in the SFD as flows. The SFD also showed the origins of the freight, the means by which it is transported (i.e. either rail or road), and the destination where it is going. This SFD was then translated into a SD diagram using the *iThink* software by isee systems. A base model was first constructed so that scenarios and sensitivity testing could be performed on it. Here converters were added to represent the variables that affect the amount of freight flowing into and out of the stocks. Such variables include the size of vessels and vehicles, the rate of the loading equipment, the amount of available space at each location, the tonnage of each TEU, and such. Delays were denoted in the diagram as delay converters and set to zero, which means that the model assumes all operations run without interruptions. The information and figures used for each of these stocks, flows, and converters are all averaged numbers and were collected from several different sources – for example, the New Zealand Transport Agency, annual reports, and regional council websites. The delta time of the simulation was set at 1/4, while the time period was day. Each of the seaports, inland ports, and end customers are connected by rail and road, but no freight is transported via road between MetroPort and POT.

Appendix 2 is the full model constructed for the simulation to be performed on. It is an aggregate of several sections similar to the one shown in Figure 9 below, which is the import freight flows from overseas into PoAL section of the model. The model shows how this import freight is then divided into road and rail freight that is moved through to the road and rail hubs to be transported to their respective destinations, as well as the amount of transhipment freight that needs to be reloaded onto vessels bound for other ports in New Zealand. The rectangles represent are the stocks 'PoAL import TEU dockside', 'PoAL import rail hub', 'PoAL import road hub', and 'PoAL import transhipment hub'. There are also two smaller rectangles with lines in them – these represent the amount of time it takes for a container to move from dockside towards the road or rail hubs where they are then moved onto vehicles ready to leave the port. The circles are the converters that control how much freight can flow through to each location. In this instance there are converters for variables such as train and truck capacity, space availability at the next location, and whether there is a backlog of freight. There are also circles with rectangles inside that represent the delays – for example, in here delays can occur in the train and truck schedules, which cause the train and truck frequencies to lower.

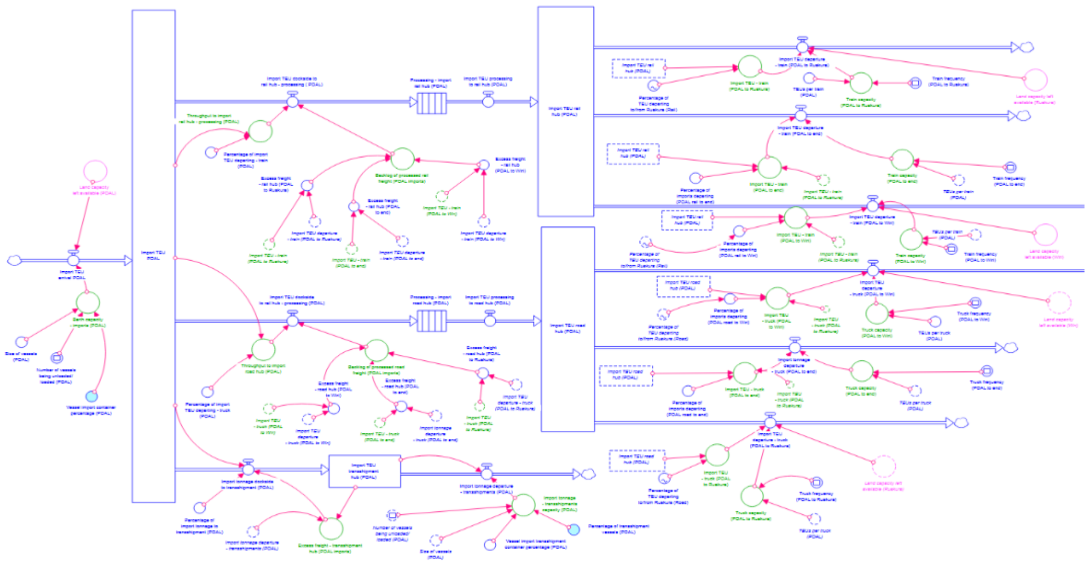


Figure 9: Screenshot of the import freight throughput into Ports of Auckland section of the simulation model for this study

Whilst SD is a good way of handling complex relationships such as port performances, the reality of the freight movement within the Golden Triangle was still too complex and contained too many details for it to be fully captured by SFDs and the SD diagram without being unnecessarily complicated. Since the system involved several hundred different elements, some of them were combined into bigger ones so that one figure was needed instead of several in order to simplify the simulation process. For example, the stock ‘import TEU road hub (PoAL)’ and converter ‘percentage of imports departing (PoAL road to end)’ both lead into a combined converter named ‘import TEU – truck (PoAL to end)’. These are shown in Figure 5 as green circles. Some of the variables are even accounted for in the model by a singular converter – factors such as train speed and loading speed of containers from inland ports or seaports onto trains do not appear in the model as converters. Instead they are condensed into the train frequency converter as they all result in impacts on the frequency of trains through a seaport or inland port. The pink circles in Figure 5 are for converters with calculations that are performed in the blank spaces of the model as there are too many components and will further complicate the model. In the import freight throughput into PoAL example, such converters are for amount of total capacity available left at PoAL, Wiri Inland Port, and Ruakura Inland Port.

7.2 Overall assumptions made

The following assumptions were also made to make the process easier to manage:

1. All stocks have a starting value of 0 – i.e. all the seaports and inland ports have no accumulated freight at the beginning of the model.
2. All of the freight that is captured in this model is containerised freight. Other types of freight such as roll-on/ roll-off (e.g. cars and trailers) and bulk cargo (e.g. oil and cement) are ignored.
3. Each container is one standard dry TEU and thus does not have special transportation or storage requirements.
4. Each vessel that comes into the seaport has import cargo to deliver and export cargo to pick up.
5. Empty containers are ignored – this study does not investigate the repositioning of empty containers.
6. Both Wiri Inland Port and MetroPort transport freight to and from Ruakura Inland Port, but do not do so with each other. Freight can also be transferred directly between PoAL and PoT and the end customers/ shippers.
7. Average length of stay of cargo and processing times for activities relating to cargo leaving the port such as customs, inspections, and paperwork processing at ports are combined as one variable and is assumed as the container dwell time.
8. When reaching full capacity at seaports and inland ports, cargo arriving by train takes precedence over cargo arriving by road (i.e. train freight is unloaded first before road freight in the event of there not being enough space left at the ports).
9. Competitors within the industry will not react to the opening of the Ruakura Inland Port. In other words, MetroPort and Wiri Inland Port capacities will remain at status quo.

Due to the time constraints and absence of data for several of the variables, other assumptions were also made for the missing variables and explained in Appendix 3.1.

7.3 Testing the model

To make sure SD models are a fair representation of reality, typically figures obtained in the previous step will be inputted into the simulation diagrams so that the results can be compared with real life numbers. However, as many assumptions about the missing variables were made, the outputs of this model were not going to be an exact reflection of reality. The model was also a simplification of the actual freight flows through the Golden Triangle, so there may have been missing variables. Caution was taken to ensure that everything is logical and within the known constraints – for example, no negative flows, stocks do not exceed maximum capacity and behave accordingly when inflow and outflow rates have changed. Once the base model was deemed to be a reasonable representation of reality, the various significant events were applied to it. A careful inspection of all of the stocks and flows was preformed after each event to inspect their effects.

7.4 Significant events chosen for the simulation

7.4.1 Opening of the Ruakura Inland Port

As mentioned previously, while the Ruakura Inland Port is expected to be completed in 2019, the port will not capture a large share of the market immediately. In fact, it has been estimated that it may take up to 40 to 50 years for the Ruakura Inland Port to reach its full potential of one million TEUs per annum (AmZ, 2009). Because there are too many variables that could change within such a large time frame, this simulation model will only take into account relatively low utilisation rates of the Ruakura Inland Port. Utilisation rates of 0.5 per cent, 10 per cent, and 25 per cent have been selected as the different utilisation rates for this study as they are likely to be achieved within the next 20 years.

This set of scenarios are simulated with the following parameters set out in Table 1. The additional assumptions applied to the base model for this scenario are located in Appendix 3.2.

Utilisation Rate	0.5 per cent	10 per cent	25 per cent
Throughput TEU per annum equivalent	5,000	100,000	250,000
Maximum capacity at inland port (TEU)	12,000	1,000,000	1,000,000
Availability of road and rail links	Road only	Both available	Both available

Table 2: Parameters used for the Ruakura Inland Port in operation scenarios

Sourced from: AmZ (2009)

7.4.2 Third Main

Expected to be completed in 2024, this train line between Wiri to Westfield (which also includes a line between Wiri and Quay Park) is expected to bring in a wide range of benefits to passengers, freight movements, and the community (KiwiRail, n.d.-b). Not only will this line create additional capacity to accommodate projected passenger demand in the foreseeable future, it will also improve the reliability and reduce the travel times for rail users across the country (Ross, 2017). There will be improved rail freight access between Wiri Inland Port and the rest of Auckland (KiwiRail, n.d.-b), which will allow for greater freight supply chain flexibility and resilience, and encourage road-rail integration (WSP Parsons Brinckerhoff, 2016). An estimated 400 less heavy vehicles will be able to be replaced with the trains, which will result in less congestion and increased road safety on a route that is also a "well-known bottleneck in the national rail network" (WSP Parsons Brinckerhoff, 2016, p.12). In addition to the many benefits, this line is of significance because it is a major component in the freight movements across New Zealand and is crucial in connecting South Auckland with the CBD and the wider region (WSP Parsons Brinckerhoff, 2016).

Once the Third Main is fully established and operational, the increase in train capacities will be the following in Table 2:

Route	**Capacity prior to Third Main**	**Capacity after Third Main**
PoAL and Wiri Inland Port	2.28 trips/ day	8 trips/ day
PoT and MetroPort	6.14 trips/ day	7.14+ trips/ day (will assume 7.14 trips/ day in simulation)

Table 3: Capacity prior and after the Third Mean

Sourced from: WSP Parsons Brickerhoff (2016), Port of Tauranga (2018), and KiwiRail (2014).

7.4.3 Waikato Expressway

Made up of seven separate projects – Longswamp, Rangiri, Huntly, Ngāruawāhia, Te Rapa, Hamilton, and Cambridge – the four-lane Waikato Expressway is expected to be a crucial transport corridor that connects the three regions within the Golden Triangle (New Zealand Transport Agency, n.d.-b). It will increase the capacity of the highways and reduce travel times between Auckland and Waikato, thus making the movement of freight and people more efficient and consequently result in improved economic growth and productivity (New Zealand Transport Agency, n.d.-b). The Expressway is also expected to support the growth strategy of the Waikato region and increase transport network reliability by making it more robust and safer (New Zealand Transport Agency, 2014). With its numerous benefits, the Waikato Regional Council (2014) named the completion of the Waikato Expressway project as a key short-term priority to be accomplished within the next 10 years in their Waikato Regional Land Transport Plan 2015-2045. As of July 2019 four of the seven projects have been completed and opened, leaving only Longswamp, Huntly, and Hamilton still under construction, but the final section is scheduled to be opened in late 2020 (New Zealand Transport Agency, n.d.-b).

Once the Expressway is fully operational, travel times between Auckland and Hamilton will be reduced by approximately 20 per cent (New Zealand Transport Agency, 2010). For simulation purposes this figure was translated as a conservative 15 per cent increase in truck volumes in all of the routes.

7.4.4 Maximum capacity Ruakura Inland Port Should be able to Operate at Under Current Conditions

In addition to the three utilisation rates above, simulations were also run at higher percentages to find out what the maximum utilisation rate of the Ruakura Inland Port could be under the current freight scenario before there is insufficient import freight throughput into the Golden Triangle freight system. The stocks were carefully observed at each utilisation rate to see if any of them were near empty, which was an indication that the utilisation rate was approximately near the maximum rate.

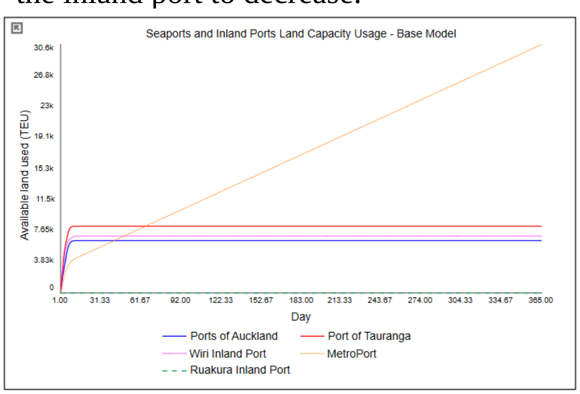
Assumptions made for this set of scenarios are in Appendix 3.3.

8. Chapter Eight: Results

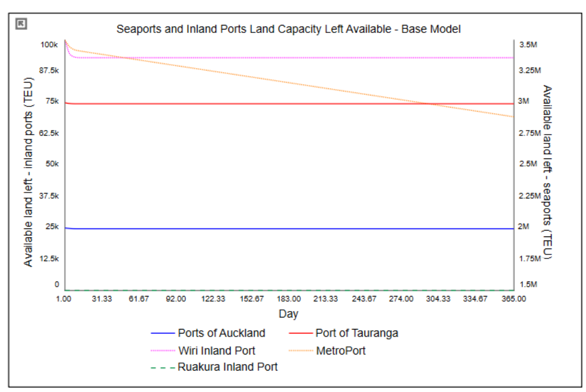
This section presents the findings from the simulation results for each of the different scenarios identified.

8.1 Current Golden Triangle freight situation – i.e. the base model

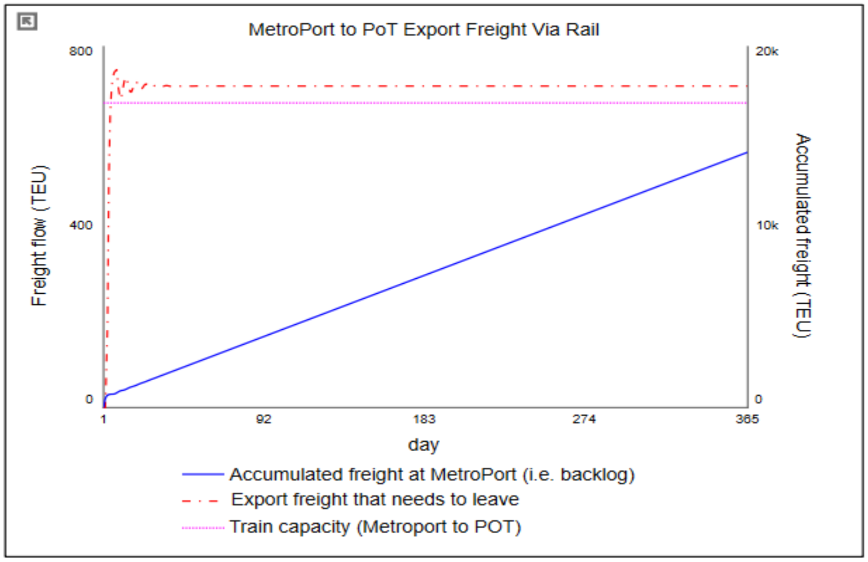
The model shown in Appendix 2 demonstrates the current freight situation within the Golden Triangle as of 2019, with the Ruakura Inland Port still under construction and therefore not in operation. Graph 1 above shows that the inflow and outflow of freight at three of the four seaports and inland ports have stabilized (i.e. the inflows and outflows have reached equilibrium so the net flows remain the same each day), as there is a plateau in each of their trends. However, MetroPort's capacity usage is at a consistent incline, which is also echoed in Graph 2 where the amount of available capacity is decreasing while the other ports and inland ports' available capacities remain the same. Upon closer attention to the model, it was found that there are two bottlenecks that occur in the rail transportation option within the current freight situation, both of which are also export freight flows. The first bottleneck is the freight flow from end customers to PoT and the second is from MetroPort to PoT. The rail capacities at these sections are too low, thus causing a backlog of freight to occur as there is a delay in transport. While the backlog of freight from the end customers do not affect the capacities of any of the seaports or inland ports, the section between MetroPort and PoT does. The stock for MetroPort export capacity accumulates more freight (as shown in Graph 3 below), thus causing the amount of available capacity at the inland port to decrease.



Graph 1: Land capacity usage of each of the seaports and inland ports currently

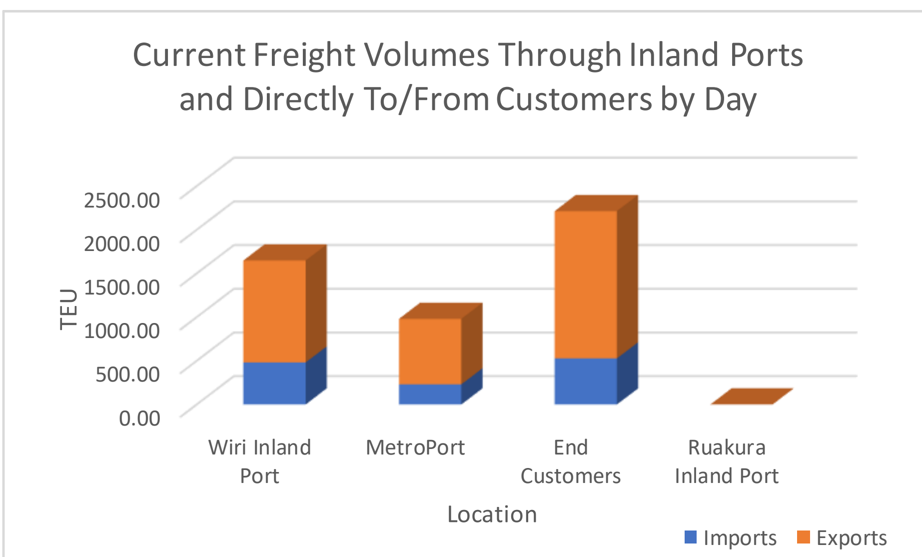


Graph 2: Land capacities left of each of the seaports and inland ports currently



Graph 3: Export freight via rail from MetroPort to PoT under current freight conditions and accumulated freight levels at MetroPort

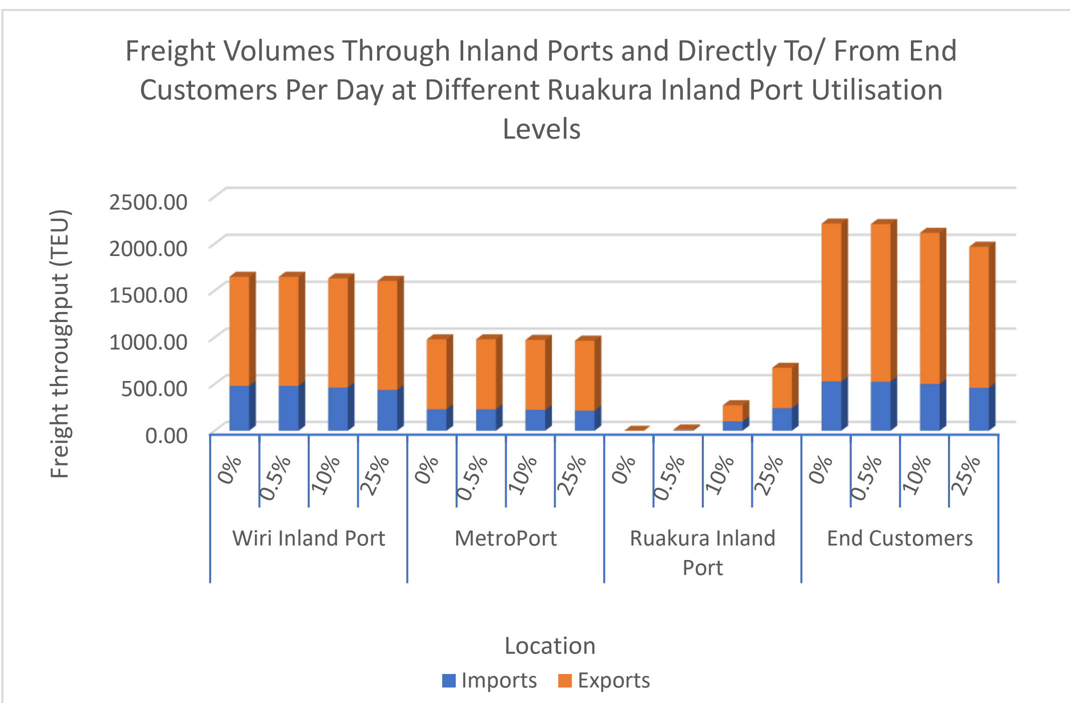
Graph 2 also shows that all four locations are still operating within their capacities. The amount of import and export freight that flows through between the seaports and inland ports, as well as directly to and from end customers (i.e. the contestable freight) are summarized in Graph 4 below. It shows that the most amount of freight travels directly between end customers and PoAL and PoT, and that Wiri Inland Port is handling more freight each day than MetroPort.



Graph 4: Current freight volumes between PoAL and PoT and the inland ports, as well as directly between end customers

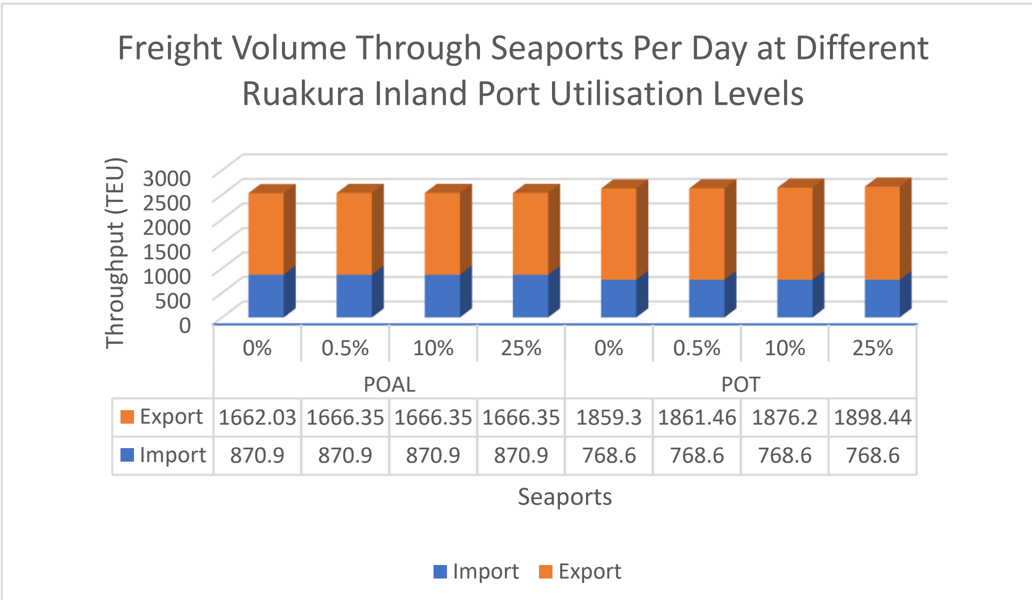
8.2 Opening of the Ruakura Inland Port

Graph 5 above shows how the current freight throughput volumes (presented in here as 0 per cent utilisation rate) will change once the Ruakura Inland Port is operational. The simulation results indicate that even at an uptake of 25 per cent of Ruakura Inland Port's total capacity, there is not much change in the total freight throughputs of Wiri Inland Port and MetroPort. Both inland ports show minor decreases to their import freight throughput across each level of Ruakura Inland Port utilisation. Surprisngly, however, their export freight throughput volumes both show an increase between the current situation and 5 per cent utilisation of Ruakura Inland Port, but no further increases occur in each of the other ustilisation rates. In contrast with the relatively unobservable impacts on Wiri Inland Port and MetroPort, the Ruakura site will cause greater effects to the freight volumes that flow directly between end customers and the seaports, which show visible changes across the four utilization levels. The changes that occur at 0.5 per cent utilization are almost negligible, but at 10 per cent and 25 per cent the effects become more pronounced as the utilization rate increases. Another point of difference is that both import and export volumes are negatively impacted by the change in utilization rates – not just imports.



Graph 5: Daily freight throughput through the inland ports, as well as freight flows directly between end customers and seaports under different rates of Ruakura Inland Port utilisation

While import volumes through PoAL and PoT remain constant across the different levels of Ruakura Inland Port utilisation, Graph 6 below shows that there are slight changes to the export volumes. Both PoAL and PoT experience increases as the level of Ruakura Inland Port utilisation increases, but in different ways. PoAL's increase only happens once when the utilisation rate increases from 0.5 per cent to 0 per cent, while PoT's increases each time the utilisation rate increases.

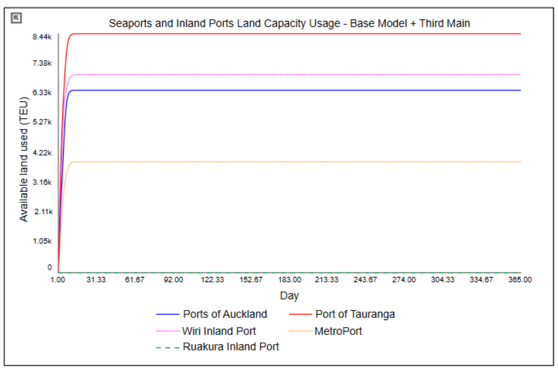


Graph 6: Import and export freight volume through PoAL and PoT per day under different Ruakura Inland Port utilisation levels

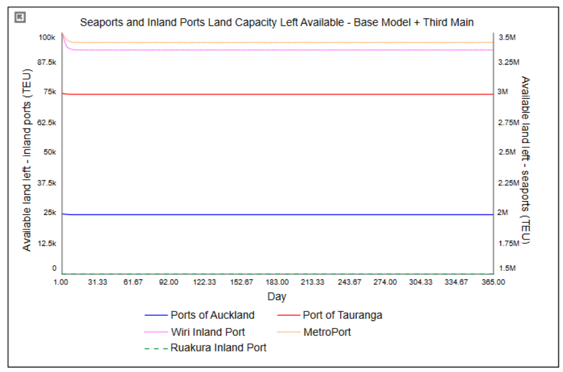
Other observations from the model also reveal that the bottlenecks that exist in the current freight situation are still present despite the different Ruakura Inland Port utilization rates. Since the effects on inland port freight flows are minute, there will still be an accumulation of excess rail freight at MetroPort due to the insufficient rail capacities between MetroPort and PoT. In fact, the level of accumulation at each utilisation rate will still be the same as the current freight situation. The remaining flows on the other hand show no bottlenecks and can all handle larger freight volumes.

8.3 Third Main

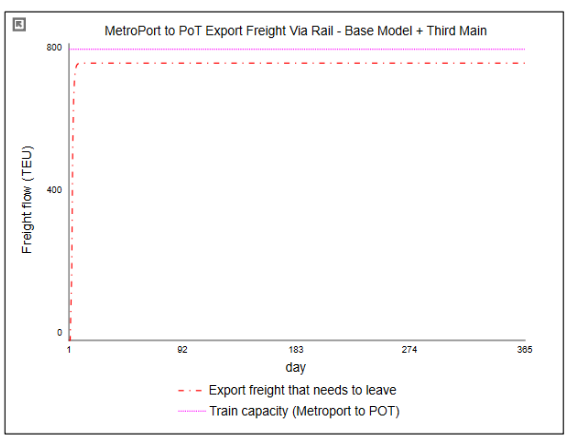
From Graph 7 and Graph 8 it is evident that once the Third Main is open the bottleneck that was located at the rail link between MetroPort and PoT for export freight will be removed. The line for MetroPort land capacity usage now mimics the lines of other establishments – it shows a plateau after a brief period of incline as the system adjusted to the flows. This change was confirmed in Graph 9 below, which shows that the train capacity in this section is now higher than the throughput of export freight. Since the constraint has been removed, the volume of exports leaving PoT has increased by approximately 3.8 per cent as well. As evident from Graph 10, the additional capacity resulting from adding the Third Main will also be enough to cope with the changes that the Ruakura Inland Port will bring, even at 25 per cent utilisation.



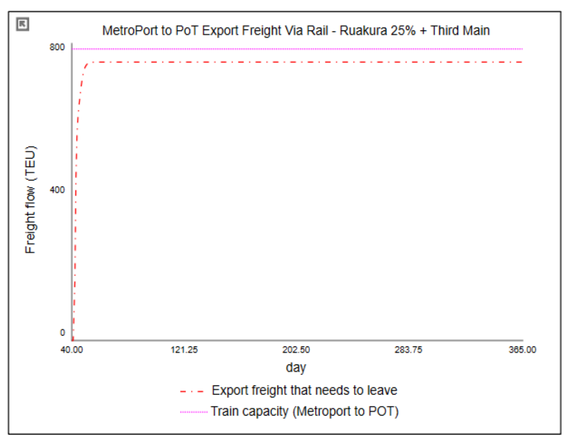
Graph 8: Land capacity usage of each of the seaports and inland ports under current conditions once the Third Main is open



Graph 7: Land capacities left available of each of the seaports and inland ports under the current conditions once the Third Main is open



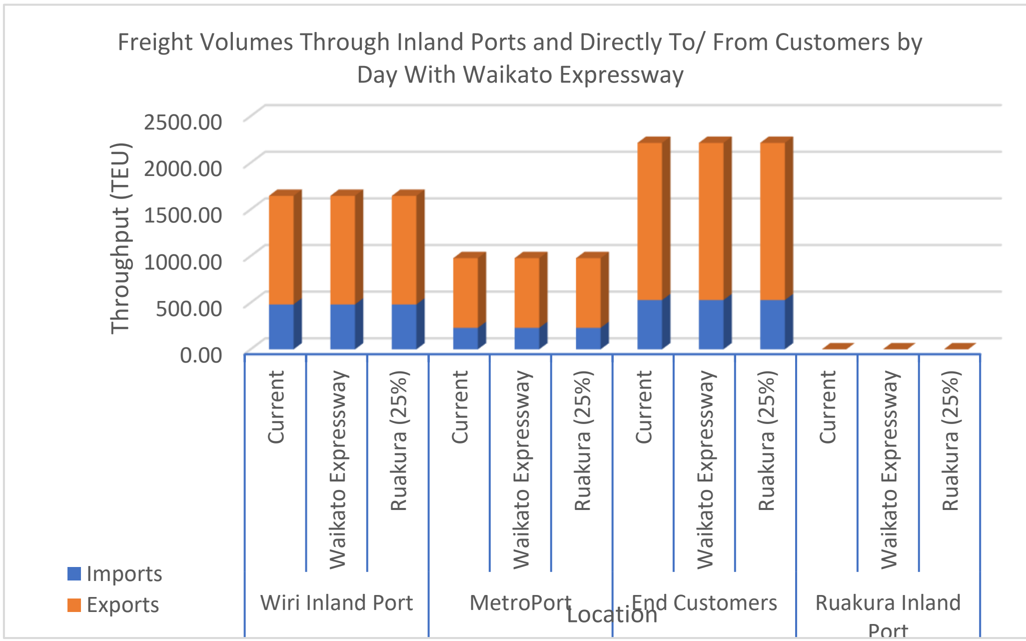
Graph 10: Export freight via rail from MetroPort to PoT and accumulated freight levels at MetroPort under current conditions once the Third Main is open



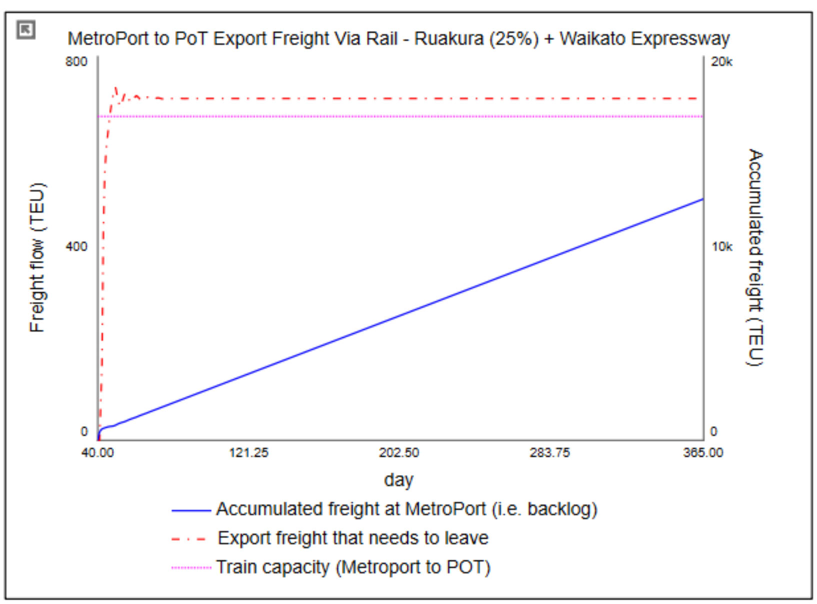
Graph 10: Export freight via rail from MetroPort to PoT and accumulated freight levels at MetroPort once the Third Main is open and the Ruakura Inland Port is operating at 25 per cent utilisation

8.4 Waikato Expressway

As shown in Graph 11, the inclusion of the increased capacity that the Waikato Expressway will bring will not impact the current freight flows or when the Ruakura Inland Port capacity utilization is at 25 per cent. The bottlenecks that exist within the current flow patterns are also still present, as evident from the capacity utilisation of MetroPort shown in Graph 12 below, which is identical to the one from the current freight situation scenario.



Graph 11: Comparison of freight volumes through the inland ports and to/ from end customers directly when the Waikato Expressway is open versus freight flows currently



Graph 12: Export freight via rail from MetroPort to PoT and accumulated freight levels at MetroPort when Ruakura is at 25 per cent utilisation

8.5 Maximum capacity Ruakura Inland Port Should be able to Operate at Under Current Conditions

Observations from the simulation model reveal that the 'PoAL import TEU rail hub' stock holds the least capacity out of all the other ones, so it was used as a signal of the maximum utilization rate of Ruakura Inland Port before the available freight runs out. Table 3 below shows the stock levels at each utilization rate:

Utilisation rate	*50 per cent*	*75 per cent*	*87 per cent*
Freight volume at PoAL import rail hub (TEU)	61	9.1	0

Table 3 – Utilisation rates of the Ruakura Inland Port and corresponding changes in the import freight volume at the PoAL rail hub.

This table shows that at as the utilization rate increases, there is a corresponding decrease in the import freight volumes at rail hub of PoAL, until at 87 per cent of utilisation the volume reaches zero.

9. Chapter Nine: Discussion

This section presents an analysis of the findings from the previous section and discusses the potential reasons behind certain behaviours that were observed in the simulations. Implications for Ruakura Inland Port, other players within the Golden Triangle freight system, and other stakeholders are also identified.

From the simulation it can be seen that most components within the current freight system are operating within capacity, with the exception of the rail line capacity at the MetroPort/ PoT and end customer/ PoT sections. These two bottlenecks are causing the export volumes through PoT to not reach its full potential, thereby resulting in the loss of benefits such as revenue and economies of scale for the seaport that could have been gained if the freight is not delayed at the departure location. The impacts of the bottlenecks extend to the exporters as well – for them the delay could mean the loss of business opportunities and revenues, which may cause them to use PoAL instead of PoT to transport their freight. In addition, the bottleneck at the MetroPort/ PoT rail section is also causing an accumulation of backlogged freight at MetroPort, which is a concern as this means that the inland port is not performing its duties of providing logistics services as efficiently as possible. Like seaports in which cargo storage capacities are considered to be a critical success factor (Roso et al., 2008; Min et al., 2017), MetroPort's ability to be successful will further be limited by the decreasing amount of available capacity. While the storage space issue is not a concern now as MetroPort is still operating within capacity, it will become a problem in the future if it reaches full capacity as predicted by Castalia (2013).

Once Ruakura Inland Port is operating, the freight flows through the Golden Triangle will inevitably be altered, despite it being developed with the intention to assist with the increase of freight volumes in the future and not to compete with the existing inland ports. However, as the Castalia report pointed out, the effects of the Ruakura Inland port on the freight flows in the Golden Triangle region will not be immediately apparent, especially since the inland port is expected to be a road-only terminal with low handling capacities in its first stage. Additionally, if the history of Wiri Inland Port and MetroPort are of any indication, there is also the possibility that the Ruakura Inland

Port will struggle to gain capacity within the first stages, especially considering how much larger it is compared to the other two sites. The infrastructure constraints coupled with the slow uptake from users due to factors such as contractual agreements are most likely the main reasons why the impact of the Ruakura Inland Port will be very minimal in the first few stages, which is consistent with the results from the simulation. The relatively low levels of impact mean that most of the current infrastructure capacities will not be not be a constraining factor for freight flows through the region. Once significant utilisation has been achieved, the effects on the freight flows will be much more apparent as the volume of freight moved will be much larger.

Another interesting finding from the simulation is that the impact of the new inland port will not be equal on the import and export freight flows. Import freight flows through inland ports – as well as the direct flows between seaports and end customers – will be affected more than export ones as they show a greater level of change. This difference is most likely because a portion (which is 50 per cent for the purposes of this study) of the export flows that will be directed towards Ruakura Inland Port from other routes will still go through the two inland ports as there are freight movements between the three. In other words, a portion of the export tonnage that used to be shipped directly to the seaports and Wiri Inland Port and MetroPort from exporters prior to the opening of the new inland port will now be shipped to Ruakura Inland Port first, before being transferred to the other locations. This cooperation between the three ports is most likely the explanation as to why both Wiri Inland Port and MetroPort show an increase in export freight throughput once the Ruakura site is operational. Not only does this mean that the existing inland ports will gain some more freight flow from exporters who used to ship directly to the seaports but now use Ruakura Inland Port, but also that the overall impact of the Ruakura Inland Port on current freight patterns may not be as great as expected.

Consistent with what authors such as Bask et al. (2014) found, the freight throughput levels into seaports also show changes as the utilisation rate of Rukura Inland Port increases. However, in this case the reason for the increase is likely due to the existing bottleneck at the rail line between end customers and PoT. With Ruakura Inland Port being in operation some of the pressure at that section will be relieved as the backlogged freight can be redirected to the inland port instead. Even at 0.5 per cent of utilisation the simulation results indicate that the addition of this third inland port will be beneficial to the current freight situation as the export throughput through the two seaports will increase. However, there still needs to be a solution to either increase the capacity of the rail lines at both bottlenecks or reduce the volume of flow that enters those two sections as at 25 per cent utilisation there still will not be enough freight redirected to remove the delays. Thus this problem emphasizes the need for the Ruakura Inland Port – if the utilisation rate increases further there will be reduced delays within the system which will ultimately result in the increase of export flows through the seaports. Further investigation is required to determine why there is a difference between the patterns of increase in export levels in PoAL and PoT.

Interestingly, the simulation results also somewhat support Rahimi et al.'s (2008) hub and spoke configuration argument for when there are multiple inland ports. As with the hub and spoke configuration where each of the inland ports interact with each other, there will be freight flows between Ruakura Inland Port and the other two inland ports within the Golden Triangle. Since the results show that there would be benefits to the freight flows through PoAL and PoT with the inclusion of the new inland port that will connect all three of the inland ports together, it stands to reason that the hub and spoke configuration may be of merit to seaport freight throughput as well. If there are bottlenecks at one location the freight can then be redirected to the other ports to mitigate the negative impacts, just like in the simulation when some of MetroPort's backlogged freight is rerouted to Ruakura Inland Port and Wiri Inland Port instead.

Since it is unlikely that the Ruakura Inland Port will be able to have a significant effect on the export freight flows within the near future, the capacity issues between MetroPort and POT, and end customers and PoT have to be resolved as soon as possible, or else it is likely that MetroPort will reach maximum capacity. This problem will not only cause inefficiencies as the amount of exports that can leave the country through PoT will be reduced, but it will also become another factor that alters the freight flow patterns in the Golden Triangle because exporters will turn towards other alternatives. Hence the government's decision to construct the Third Main will have a significant impact on current freight flows. As shown from the simulation results, not only will the Third Main remove the bottleneck that is at the MetroPort/ PoT rail freight section, the increase in rail capacity there will be enough to cope with the predicted increase of freight flow following the opening of the Ruakura Inland Port. However, as the seaports and inland ports are aiming to transport more freight via rail lines instead of by road, there is the possibility that this increase in rail capacity will not be enough as the simulation results indicate that the Third Main will be operating at almost full capacity due to the amount of freight that needs to be moved.

The Waikato Expressway, on the other hand, appears to have no effect on the freight flows – both current and at 25 per cent Ruakura Inland Port utilisation – at all. This is most likely due to the fact that the current train capacities in all areas are enough to handle the existing and future freight throughput. As a result, it may take until the utilisation rate of the Ruakura Inland Port is much higher before the impact of this new expressway to manifest in the form of increased freight flow. In other words, the effect of it may not be observable until more than 20 years from its opening. However, with the amount of backlog freight at the end customer/ PoT export rail freight section shown in the simulation that cannot be resolved by the Ruakura Inland Port in the short term or the Third Main, this may benefit from the Waikato Expressway. The backlogged freight will still need to be transported – instead of waiting for available capacity from the rail lines, exporters may choose to utilise the road option instead, and with the Waikato Expressway travel times between locations within the Golden Triangle will be reduced, thus benefitting exporters. This phenomenon implies that while the Waikato Expressway will reduce total travel distances and times for all traffic, it will have less impacts on freight-moving road usage (i.e. port traffic) and more on non-freight-moving road usage (i.e. non-port traffic), especially in the short term. Therefore, it is consistent with the findings from UNISA’s study – the reduction of congestion may not result in benefits to users of road infrastructure for freight-moving purposes until the medium to long term.

Finally, the last set of scenarios testing for the highest rate of utilisation of the Ruakura Inland Port shows what the maximum utilization rate is before the inland port moves more freight than there is available. In other words, under the current conditions the Ruakura Inland Port can operate at 87 per cent capacity without being restricted by the amount of freight available within the Golden Triangle. Any rate above 87 per cent will result in inefficiencies as the port will have idle capacity as it waits for more freight to be made available. Therefore, this rate provides an indication as to the maximum capacity that the first stage of the Ruakura Inland Port should be able to handle.

10. Chapter Ten: Conclusion

This section presents a summary of the study.

Following the predictions of the increase in future trade volumes, there has been much interest in the field of inland ports in anticipation of the problems associated with the increased flow of freight. Studies have shown that inland ports can reduce the harmful environmental impacts while bringing economic benefits into surrounding areas. More importantly however, inland ports will allow the freight infrastructure within a country to better cope with increase freight volumes. In New Zealand's case, the increase in freight flow will significantly impact the Golden Triangle area that is composed of Auckland, Tauranga, and Hamilton. This area is responsible for almost half of all of the freight tonnage produced, and the current infrastructure is expected to reach maximum capacity in the future as a result of the increased trade volumes. Therefore Tainui Group Holdings (together with Chedworth Properties and Hamiton City Council) proposed a structure plan for the Ruakura area that involved an inland port as a solution to the future freight flow problems.

From the literature available it can be concluded that the introduction of another inland port into the Golden Triangle region will impact current freight patterns. However, there is no information that estimates how big an impact that will be. If this knowledge can be obtained prior to the opening of the Ruakura Inland Port, this will allow the members within the industry to make informed decisions about how to 'futureproof' their operations. They will be able to identify any future problems that may be a threat to them so that strategies can be put into place to either reduce or mitigate completely the negative impacts. Opportunities will also be identified to allow them to take advantage of as much as possible. There is therefore the need for a way to allow for future predictions to be made for the freight system within the Golden Triangle.

Due to the complicated and dynamic nature of logistics systems, traditional quantitative and qualitative methods were judged to be unsuitable methods for this study as they did not have the ability to overcome this complexity. Simulation modelling on the other hand, could take into account the numerous interdependent relationships within the system and provide insight into the behaviour patterns of each of the elements. A system dynamics approach to simulation modelling was chosen as it is a way of thinking that looks at both the big picture and the individual components, which is crucial in studying large complex systems like the freight system for this thesis. Because the system contains more than just one port, the computations involved were also too difficult to perform without the aid of system dynamics software.

A simulation model that was deemed a reasonable reflection of the current freight situation in the Golden Triangle region was thus constructed as a decision support tool so that simulations of future scenarios and events could be conducted. This will allow users to understand how the freight system will behave under different changes, and whether there would be any bottlenecks that would cause delays in the system. The future scenarios tested for this study were the opening of the Ruakura Inland Port, the impacts of the Waikato Expressway, and the addition of the Third Main rail line in Auckland. The Ruakura Inland Port scenario was then separated into 3 other ones, assuming that the utilization of the port will be able to reach 0.5 per cent, 10 per cent, and 25 per cent of its full capacity of one million TEUs. A base model showing the current freight situation was first created so that the results from the different scenarios can be compared, thereby answering the question of how the Ruakura Inland Port will affect current freight flows.

The base model which showed the current situation indicated that while all ports and inland ports are currently operating within capacity, there are two bottlenecks within the system that will hinder the efficiency of the entire freight moving industry. The two bottlenecks both occur at the rail sections of export freight movement – one from end customers to PoT, and the other from MetroPort to PoT – resulting in the accumulation of freight at both locations, which will in turn affect the overall freight moving efficiency. Simulation results from the Ruakura Inland Port scenarios suggest that while there will be an impact on the bottlenecks as some of the freight will be redirected elsewhere, the effects are unlikely going to make a significant impact until many years later when the utilisation of the Ruakura Inland Port is at a much higher rate than the ones simulated in this study.

The same holds for the introduction of the Third Main and Waikato Expressway – the impacts for both will be small in the short term and may increase in the long term.

Surprisingly, however, the simulation results also revealed that the impacts on the freight flow through Wiri Inland Port and MetroPort may not be as great as expected. While there will be less import freight flow through the two existing inland ports, there will be a small increase in the export freight volume. This increase is most likely due to Ruakura Inland Port redirecting a portion of the accumulated freight at bottlenecks towards Wiri Inland Port and MetroPort. The overall increase in export volumes from the seaports also suggest that there is merit in a hub and spoke configuration for inland ports as because of the cooperation between the ports, the overall negative impact of a new player within the industry will be less severe. Another major finding from the simulation suggests that the maximum capacity that should be made available by the Ruakura Inland Port at the first stage of construction is approximately 87 per cent.

The scenarios tested in this study demonstrated the potential of simulation modelling in the logistics industry. Not only can the model constructed be used on those scenarios, but it can also be used for any other ones in the future, which means that it will provide practical value to practitioners. As the availability of figures and information used in the model increases so that the number of assumptions made can be reduced, the reliability and accuracy of the model will also increase, thus providing even more value to users.

11. Chapter Eleven: Study Limitations and Potential Future Research Areas

This section outlines the limitations of the study that have an impact on the quality of the findings of this research, as well as opportunities (i.e. gaps in practitioners' understanding) for further research where the findings will likely to be of value to the freight moving industry in New Zealand.

Due to the time constraints, the data used in this study was gathered from existing sources from the internet, thus limiting the amount of information available as a lot of what was required does not exist on publicly accessible forums. Therefore, the simulation model was constructed relying largely on assumptions that were made using the resources available, which also included two reports[1] that were kindly supplied by Mr. Blair Morris (General Manager Ruakura) at Tainui Group Holdings. As a result, the accuracy of the results is limited by how close the estimates and assumptions made are to reality. Through the use of system dynamics however, the model can show how each of the variables are related to each other and how they will react when conditions are changed, which is important in answering how Ruakura Inland Port will impact current freight flows as the comparison figures are all obtained using the same set of assumptions. The consistency of any potential deviations from reality means that the accuracy of the figures used in this model has relatively less impacts on the final results. Nonetheless, it will still be beneficial to use figures that are as accurate as possible to increase the reliability of the simulation results. If this model were to be used in practice, more information will be required to ensure that it is the fairest representation of reality possible. Industry professionals such as those in logistics companies or the seaports, or exporters and importers could be consulted to help with the data collection and identification of any potential trends that may impact the industry in the future, as well as uncover any relationships within the system that may have been missed when this pilot model was constructed.

[1] These two reports were written by consulting agencies that were engaged by Ruakura Inland Port to evaluate the commercial viability of the Ruakura Inland Port project.

In the future a sensitivity analysis should also be conducted to investigate how reactive the system will be to changes in the variables. Such an analysis will allow industry professionals to identify drivers and inhibitors within the system to assist them in making the appropriate decisions so that the least amount of resources can provide the maximum amount of impact. For example, if a change in the capacity of rail will result in much larger impacts than that of road, it would be the logical choice for decision makers to concentrate their efforts on ensuring rail capacities are changed instead of road capacities. Another example is if a delay in the form of a truck driver strike will cause freight flows to be significantly altered, importers and exporters may have to have contingencies in place to mitigate the effects.

There are several other research opportunities that should be taken advantage of to provide practitioners with more information to aid in their decision-making processes. For example, the same simulation should be updated in the future to better match the freight landscape then. More accurate predictions about the freight flows will be able to be made closer to the time as the model will rely on less assumptions. The study should also be replicated for the entire country to look at how the Ruakura Inland Port will change freight movements within both islands as there is freight flow between the Golden Triangle region and the rest of the country. Potential bottlenecks within New Zealand's freight system should also be identified so that resolutions can be made for the country to take full advantage of the new inland port. Another avenue to pursue would be to include the reactions of competitors in the simulation. While the impact of the Ruakura Inland Port is unlikely to be immediately apparent on the freight throughput into Wiri Inland Port and MetroPort within the foreseeable future, the two existing inland ports will still lose some freight volume (and therefore revenue) as the three inland ports will more or less be competing for the same freight. Wiri Inland Port and MetroPort will more than likely adjust their operations accordingly to attempt to prevent the loss of business. Such adjustments will impact the system as a whole and provide different outcomes than the ones from this study. Last but not least, further research can be done on how the annual increases in trade volumes will impact the Golden Triangle's freight system as well, as the model for this research did not include the predicted annual growth of trade.

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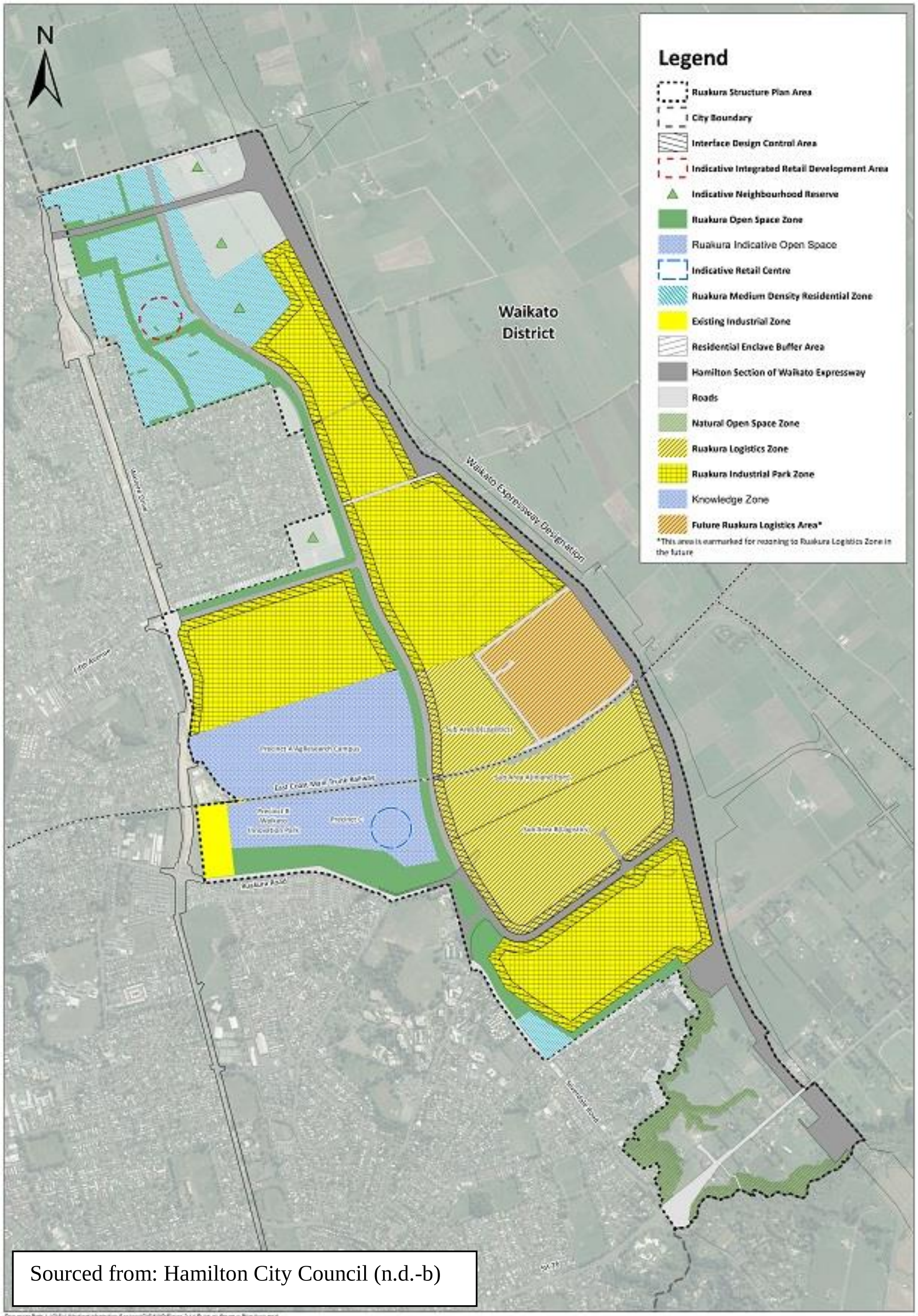
Appendices

Appendix 1 – Map of the Ruakura structure plan



Sourced from: Hamilton City Council (n.d.-b)

Appendix 2 – Simulation model

Appendix 3.1 – Assumptions made in base simulation model

Missing variable	Assumption based from	Result
Truck frequency from Wiri Inland Port to end customers and back	Same as truck frequency from PoAL to end customers	377.5 trucks per day each way
Train frequency from Wiri Inland Port to end customers and back	Same as train frequency from PoAL to end customers	1.28 trains per day each way
Percentage of import and export TEU departing via train and road from Wiri Inland Port	Same ratio as the import tonnage from PoAL dockside to road and rail hubs, less the transshipments	Train: road = 8.86:91.14
Percentage of import TEU departing from PoT to end customers and MetroPort via rail	Same ratio as percentage of imports departing from PoAL to end customers and MetroPort via rail and road	30 per cent: 70 per cent
MetroPort capacity	Same as Wiri Inland Port	100,000 TEU
Percentage of import TEU departing via train and road from MetroPort	Same ratio as the import tonnage from PoT dockside to road and rail hubs, less the transshipments	Train: road = 59.59: 40.41
Percentage of imports departing from PoT to MetroPort via road	Evidence suggests that freight flow between PoT and MetroPort are all via train (Port of Tauranga, n.d.-b)	0 per cent
Train frequency from PoT to end customers and back	Same ratio as PoAL to Wiri and end customers, with PoAL to Wiri being 6.14	2.63 trains per day
Truck frequency from end customers to PoT	Same as truck frequency from PoT to end customers	532.72 trucks per day

Train frequency from MetroPort to end customers and back	Same as train frequency from PoT to end customers	2.63 trains per day
Truck frequency from MetroPort to end customers and back	Same as truck frequency from PoT to end customers	532.72 trucks per day
Export TEU from end customers to Wiri Inland Port via train	PoAL's import: export ratio is 1:1.98	103.35 TEU per day
Export TEU from end customers to Wiri Inland Port via truck	PoAL's import: export ratio is 1:1.98	1063.26 TEU per day
Export TEU from end customers to PoAL via train	PoAL's import: export ratio is 1:1.98	44.35 TEU per day
Export TEU from end customers to PoAL via truck	PoAL's import: export ratio is 1:1.98	455.4 TEU per day
Export TEU from end customers to MetroPort via train	POT's import: export ratio is 1:2.82	552.74 TEU per day
Export TEU from end customers to MetroPort via truck	POT's import: export ratio is 1:2.82	375.06 TEU per day
Export TEU from end customers to PoT via train	POT's import: export ratio is 1:2.82	397.62 TEU per day
Export TEU from end customers to PoT via truck	POT's import: export ratio is 1:2.82	896.76 TEU per day
Container dwell time at PoT and MetroPort	POT's container dwell time is 2 days	2 days
Size of vessels docked at PoAL	As of 2015, approximately 40 per cent of vessels that called	4,000 TEU per vessel

	into PoAL were 4,000 TEU or larger.	
Import and export containers loaded onto each vessel at PoAL	1. Total container throughput in 2018 was 952,300 2. PoAL's import: export ratio is 1:1.98 3. Total number of container vessels to visit in 2018 was 594	537.98 and 1065.21 containers per vessel
Size of vessels docked at POT	Vessels between 7,500 and 11,500 regularly visit the port, so assuming average vessel size would be the average of those two values	9,500 TEU per vessel
Import and export containers loaded onto each vessel at POT	1. Total container throughput in 2018 was 1,086,000 2. POT's import: export ratio is 1:2.82 3. Total number of container vessels to visit in 2018 was 954	298 and 840.34 containers per vessel

Appendix 3.2 – Assumptions made for the Ruakura Inland Port in operation scenarios

		Results Used in Scenarios		
Missing variable	**Assumption based from**	**0.5% (5,000 TEU/ annum)** ***(13.70 TEU/ day)***	**10% (100,000 TEU/ annum)** ***(273.97 TEU/ day)***	**25% (250,000 TEU/ annum)** ***(684.93 TEU/ day)***
Percentage of import TEU: export TEU at Ruakura	Import: export ratio of 1:1.71 of New Zealand's freight movements via sea transport	36.90: 63.10	36.90: 63.10	36.90: 63.10
Train frequencies to and from Ruakura	Approximately 22 trains arriving and leaving Ruakura each day, evenly divided between PoAL, POT, Wiri, MetroPort, and end customers	2.2 trains per day	2.2 trains per day	2.2 trains per day
Truck frequencies to and from Ruakura	Same as truck frequencies to and from Wiri Inland Port	PoAL and PoT to Ruakura and back: 788 trucks/day. Wiri and MetorPort to Ruakura and back: 388 trucks/day.	PoAL and PoT to Ruakura and back: 788 trucks/day. Wiri and MetorPort to Ruakura and back: 388 trucks/day.	PoAL and PoT to Ruakura and back: 788 trucks/day. Wiri and MetorPort to Ruakura and back: 388 trucks/day.

Container dwell time	Same as POT's container dwell time	2 days	2 days	2 days
Amount of imports to exports	Assuming import: export of 36.90: 63.10	Imports= 5.06/ day Exports= 8.64/ day	Imports= 101.09/ day Exports= 172.88/ day	Imports= 252.74/ day Exports= 432.19/ day
Amount of import freight transported via rail and road	Assuming rail: road ratio of 34.22: 65.78	Rail: 0/ day Road: 5.06/ day	Rail: 34.59/ day Road: 66.50/ day	Rail: 86.49/ day Road: 166.25/ day
Amount of import freight arriving from each location via rail and road	Assuming total imports equally distributed between PoAL, POT, Wiri Inland Port, and MetroPort	Rail: 0/ day Road: 1.265/ day	Rail: 8.6475/ day Road: 16.625/ day	Rail: 21.6225/ day Road: 41.5625/ day
Amount of export freight transported via rail and road	Assuming rail: road ratio of 34.22: 65.78	Rail: 0/ day Road: 8.64/ day	Rail: 59.16/ day Road: 113.72/ day	Rail: 147.90/ day Road: 284.29/ day
Amount of export freight arriving from each location via rail and road	Assuming total exports equally distributed between PoAL, POT, Wiri Inland Port, and MetroPort	Rail: 0/ day Road: 2.16/ day	Rail: 14.79/ day Road: 28.43/ day	Rail: 36.975/ day Road: 71.0725/ day

Appendix 3.3 – Assumptions made for the maximum capacity Ruakura Inland Port should be able to operate at under current conditions scenario

		Results Used in Scenarios		
Missing variable	**Assumption based from**	**50% (500,000 TEU/ annum) *(1369.86 TEU/ day)***	**75% (750,000 TEU/ annum) *(2054.79 TEU/ day)***	**87% (870,000 TEU/ annum) *(2383.56 TEU/ day)***
Percentage of import TEU: export TEU at Ruakura	Import: export ratio of 1:1.71 of New Zealand's freight movements via sea transport	36.90: 63.10	36.90: 63.10	36.90: 63.10
Train frequencies to and from Ruakura	Approximately 22 trains arriving and leaving Ruakura each day, evenly divided between PoAL, POT, Wiri, MetroPort, and end customers	2.2 trains per day	2.2 trains per day	2.2 trains per day
Truck frequencies to and from Ruakura	Same as truck frequencies to and from Wiri Inland Port	PoAL and PoT to Ruakura and back: 788 trucks/day. Wiri and MetorPort to Ruakura and back: 388 trucks/day.	PoAL and PoT to Ruakura and back: 788 trucks/day. Wiri and MetorPort to Ruakura and back: 388 trucks/day.	PoAL and PoT to Ruakura and back: 788 trucks/day. Wiri and MetorPort to Ruakura and back: 388 trucks/day.

Container dwell time	Same as POT's container dwell time	2 days	2 days	2 days
Amount of imports to exports	Assuming import: export of 36.90: 63.10	Imports= 505.48/ day Exports= 864.38/ day	Imports= 758.22/ day Exports= 1296.57/ day	Imports= 879.53/ day Exports= 1504.03/ day
Amount of import freight transported via rail and road	Assuming rail: road ratio of 34.22: 65.78	Rail: 172.98/ day Road: 332.50/ day	Rail: 259.47/ day Road: 498.75/ day	Rail: 300.98/ day Road: 578.55/ day
Amount of import freight arriving from each location via rail and road	Assuming total imports equally distributed between PoAL, POT, Wiri Inland Port, and MetroPort	Rail: 43.245/ day Road: 83.125/ day	Rail: 64.8675/ day Road: 124.6875/ day	Rail: 75.245/ day Road: 144.6375/ day
Amount of export freight transported via rail and road	Assuming rail: road ratio of 34.22: 65.78	Rail: 295.80/ day Road: 8.64/ day	Rail: 443.70/ day Road: 852.87/ day	Rail: 514.68/ day Road: 989.35/ day
Amount of export freight arriving from each location via rail and road	Assuming total exports equally distributed between PoAL, POT, Wiri Inland Port, and MetroPort	Rail: 73.95/ day Road: 142.145/ day	Rail: 110.925/ day Road: 213.2175/ day	Rail: 128.67/ day Road: 247.3375/ day

Reflection

To say this journey was an uphill battle would be an understatement. I decided to pursue a Masters degree before I had even considered what kind of topic I would do my thesis on. All I knew was that I wanted it to be more than just academic literature and theory – it had to have practical value and relevance to the real world. It took a long time before I settled on the topic of the impacts of the Ruakura Inland Port. With Eric's help I was able to put together a preliminary proposal of the aim, methodology, and potential value of my thesis before we contacted Blair Morris at Tainui Group Holdings. Blair was more than happy to help, having sent through two reports the afternoon after our meeting, but he too was constrained by time as he was a very busy person. While I started to gather as much information as I could about the current freight landscape in the Golden Triangle, I was also trying to learn how to navigate my way through a methodology and way of thinking that I had never encountered before. Even the software that I was using was unfamiliar to me, and it took me a lot of time to understand how the pieces worked together as the amount of technical support available was limited. To this date there are probably still several hundred functions that I do not know exist or how they work. I also had trouble trying to figure out how the relationships in the system could be represented by a series of calculations in the model, so a lot of trial and error was experienced before I started to feel confident enough in my model to run tests on it.

However, about 5 weeks before my thesis was due my sister went through a life-threatening surgery for an incredibly rare condition that had the family shaken up. I flew back to Taiwan a few days before the surgery and spent almost a month there, during which most of the time was at the hospital. This unexpected event meant that I needed to apply for an extension as I was not able to do anything while overseas. When I got back it was then another mad sprint to try to get my simulation model to work and figure out how to present my data. Changes were still being made to the model right until the last few days as new problems were discovered each time a new scenario was run. These changes meant that each time there was a new iteration of the model all of the previous scenarios had to be run again to ensure the results were as accurate as possible.

In hindsight my time management skills definitely could be improved, because regardless of the interruption close to the due date, I should have been further ahead in my research than I was at that point. Had I been on time, the results of this study would have been more comprehensive as both of the research questions would have been answered.