THE APPLICATION OF SEMI-AUTOMATED GANTRY CRANES IN EMPTY CONTAINER DEPOTS

BY

CORINNE L. ANKENBRUCK

A thesis

Submitted to the Victoria University of Wellington

In fulfilment of the requirements for the degree of

Masters of Commerce

Victoria University of Wellington

2019

TABLE OF CONTENTS

List of Figures and Tables

Fig 32 – stakeholder management capability of the OCP crane project (modified from Elias et al., 2002, p.308)

Fig 33 – Stakeholder typology (from Mitchell et al., 1997, Fig 2, p.874)

Table 5: Key stakeholder typology for the crane at OCP

ABSTRACT

Purpose– The storage and supply of empty containers is a bottleneck in the global supply chain. In the wake of increasing containerisation and globalisation, improving efficiencies of processing within empty container depots can realise efficiencies. The overall objective of this research project is to propose an efficient and effective solution for reducing waste in an empty container depot using a crane. The issue of applying gantry cranes to empty container depots will cover both an operational and a strategic evaluation of the following research questions: 1) What are the potential solutions for a specific yard based on lean thinking, and which solution should be used within the constraints and contexts of this yard? 2) Who are the key stakeholders, and what are their stakes while implementing the solution in the yard to reduce waste?

Design/methodology/approach - A review of the literature around empty container depots revealed that while lean operations have been applied to manufacturing, warehousing, and ports, it has not yet been applied to empty container depots. Whereas warehouses primarily deal with stock-holding and ports deal with quayside operations, empty container depots act as a conduit between consignors and consignees. In the vein of American Pragmatism, Design Science Research, and Strategy-as-Practice, this thesis shows that in the context of empty container depots a gantry crane is an artefact that can create efficiencies, reduce costs, as well as explore further effects on the organisation and its wider geo-political *habitus.*

Case Study - A New Zealand company that handles roughly half a million TEUs per annum cooperated with this study. The study was conducted by analysing data from four working depots (Auckland, Tauranga, Napier) selected to illustrate variations in container volumes, types of flows (imports, exports, seasonality), and depot layouts. The current operations of these depots were analysed using lean operations, value stream mapping, and operations interwork centre flow graphs. Of the four sites identified, one (the Auckland OCP site) was shown to achieve the greatest results from a gantry crane. The results of the analysis were then used to develop a potential solution in which waste was identified and eliminated, primarily around excess handling and land utilisation.

Findings – A key finding was that efficiency gains differ from site to site based on their unique demands and overall layouts. Furthermore, changes towards the current yard using gantry cranes need to be implemented incrementally based on continuous improvement. This is due to practical constraints around operations, culture change, cashflow management, the acquisition of capital, and broader market/stakeholder influences.

Originality/value - The practical applications of this research case are scalable on a vast level. The effects of this research are explored in how the introduction of an artefact affects the organisation, its vision of itself, its strategies, and the broader supply chain in which this organisation operates. The results are further re-contextualised in order to offer a holistic view of an artefact in its situated environment.

CHAPTER 1: INTRODUCTION

1.1 SUMMARY

This chapter introduces the research area and subsequent research question. It briefly reviews the practices of empty container depots and identifies the problem that the thesis hopes to address by eliminating waste in one of the niche areas of the global supply chain. The company, ContainerCo (NZL) Ltd, is briefly outlined for use in the case study. This chapter also outlines the structure and scope of the overall work.

Chapter two is a literature review. It explores the concept of continuous improvement and lean. It goes into more depth in lean by exploring other areas of continuous improvement such as: just-in-time, total quality management, total preventative maintenance, and human resource management. From there, it identifies a gap in the literature between just-in-timee and human-resource-management, and restates the research question in the context of this gap.

Chapter three is a review of the methodology. A brief section is set aside to explain who the researcher is and how this may affect the research. The research paradigm is established to be post-positivist. A mixed methodology is identified for use throughout the thesis, and supporting theory established around Design Science Research, American Pragmatism, and Strategy-as-Practice.

Chapter four explores the current process of empty container depots that are generally replicated all over the world. This is explored at both a macro (regional) level, and a micro (depot) level. The specific New Zealand context for the flow of empty containers and empty container depots is also explained. The stakeholders are identified in this context. The processes are then mapped using interwork flow charts and value stream mapping, at which point waste in the system is identified.

Chapter five identifies four empty container depot sites in New Zealand that might be suitable for the implementation of a semi-automatic gantry crane. Only one of these sites (Auckland OCP) is found to be suitable under the constraints of operations, flow of containers throughout the region, and the flow of imports and exports. That site is then explored in more depth. Possible scenarios for a crane are posited, and one suggested for future implementation.

Chapter six explores the human resources factor in the form of a stakeholder analysis to answer: How a crane affects key stakeholders involved in the business. This includes: employees, customers, carriers and suppliers, competitors, and the wider New Zealand market. A stakeholder analysis is undertaken and analysed. The human factor is further explored in the context of the theory of strategy-as-practice.

Chapter seven explores some of the limitations of research, and future areas for research are also outlined. The thesis is then concluded with some closing remarks and summaries of the work.

1.2 INTRODUCTION

Empty container depots store, repair, and upgrade empty shipping containers for shipping companies. These services allow shipping companies to reuse shipping containers at the destination where the previous cargo was unloaded. At a micro-level, this allows shipping companies to comply with local laws (especially in cleaning), identify and produce containers suitable for transporting different type of cargo, and to hold stock against future demand. At a macro level, such services allow shipping companies to distribute containers across their network and maintain their fleet to a uniform standard, reducing the need for repositioning. These services are provided at scale; the United Nations Conference on Trade and Development report that global container traffic through ports had risen from 135 million TEUs in 1995 to 752 million TEUs in 2017, an annual compound growth of 8%. (UNCTAD, p.67, 2018). With the global fleet of containers continuing to expand, so also has the demands of shipping companies for empty container services - with an expectation that increased volumes will also lead to improved efficiencies and a lower cost per-unit.

The challenge therefore to empty shipping container depots is in reducing unnecessary internal processes in order to reduce costs not to just the shipping companies, but to the global market as a whole. One ideal solution for this problem would be lean supply chains, which specifically focuses on eliminating as much waste as possible from a series of processes. Examples of waste in the context of empty container repositioning can be immediately identified; excess motion, transportation, and waiting time. In other words, this approach would remove as many "moves that are not needed, unnecessary processing steps, and excess inventory in the supply chain" as possible (Jacobs & Chase, p.347, 2014).

A traditional way that operations managers in empty container depots try to eliminate waste is by finding new and improved methods of yard planning. However, these methods tend to employ the same equipment and technology that empty container depots have used in the past, but in more efficient ways. In this thesis, the questions around reducing waste in the system were interrogated in conjunction with the impacts of implementing new plant and technology in empty container depots in the form of a semi-automatic gantry crane. The overall objective of this research project is to propose an efficient and effective solution for reducing waste in an empty container depot using a crane. The issue of applying gantry cranes to empty container depots will cover both an operational and a strategic evaluation of the following research questions:

1) What are the potential solutions for a specific yard based on lean thinking, and which solution should be used within the constraints and contexts of this yard?

2) Who are the key stakeholders, and what are their stakes while implementing the solution in the yard to reduce waste?

1.3 STRUCTURE

A case study was conducted using a New Zealand based company, ContainerCo (NZL) Ltd. ContainerCo employs around 300 staff and has 13 empty container depot sites across New Zealand and Fiji. They handle around 450,000 Twenty-Foot-Equivalent-Units (TEUs) *per annum* across all their sites. To put this number of units handled into perspective: the Ports of Auckland, which is New Zealand's second largest port, handled roughly 973,000 TEUs in the 2018 year, and the Port of Napier, which is New Zealand's fourth largest port, handled around 266,000 TEUs in the 2018 year (Deloitte, p.55-58, 2019). ContainerCo therefore represents a significant portion of containerised throughput in the New Zealand sector. The organisation and its competitors are often regarded as occupying a similar space to inland ports.[1]

In order to complete these evaluations: the current operational processes within ContainerCo's empty container yards were first mapped; a value stream map for these processes were produced; and a comparative analysis of the needs of an empty container depot versus seaports was completed, especially identifying the unique position that empty container depots occupy on a global scale. This was done in order to contextualise the environment in which these operations occur. Finally, four of ContainerCo (NZL) Ltd's empty container yards in New Zealand were used as case studies to discuss rapid containerisation levels, trade route imbalances, and the need for greater efficiencies in empty container depots.

The conclusion this thesis reached was that semi-automated gantry cranes did improve efficiencies across some but not all yards. While a crane was found to smooth overall operations, the real value of a crane remains in: increasing the density of stacking and maximising volume. Because of this, only yards that had significant and sustained volumes found the maximum benefits of a crane. Other yards with more seasonal volumes did not maximise this value, since they would see far more significant downtime of the crane.

A literature review of lean was undertaken in the second chapter. In it, lean was broken down into its main bundles: just-in-time, total quality management, total preventative maintenance, and human resource management. From there a gap in the literature was identified between just-in-time and human resource management. In particular, there is a gap in change management and stakeholder management when an organisation attempts to implement a just-in-time philosophy.

[1] For reasons that will be explained later on, empty container depots are not exactly ports or even inland ports. However, they still represent a conduit between the quayside and the hinterland operations of the supply chain value stream. Ergo, they are often bundled into the same logic as ports, even though they are not technically ports.

These case studies will also serve as examples for how lean operations can reduce waste with regards to excess moves, unnecessary processing steps, waiting times, land utilisation, and turnover as well as the greater ramifications of these real-life applications. Specifically with regards to the gap in the literature, how the implementation of lean systems through an artefact interacts with change management and stakeholder management, and in turn how the stakeholders affect the artefact.

While research has been done on container volume imbalances, marine terminal congestion, and advanced planning and coordination in order to mitigate these factors, there has been very little focus on empty container segments of the global supply chain (Pérez-Rodríguez, N., & Holguín-Veras, p.380, 2014; Kim & Günther, p.vi, 2005). This leaves another significant gap in the study of empty container depots as a whole. However, this thesis will concern itself only with the efficiencies a semi-automated gantry cranes could produce inside empty container depots, its impact in terms of leaner operations, and how this in turn would change the overall shape of standard facility layouts. It also identifies how an empty container handling organisation could move its production philosophy from bespoke handling to a more rigid automation structure.

The methodology used in this thesis is mixed. It applies a more quantitative and pragmatic design science research approach by attempting to find a practical solution to a problem through the implementation of an artefact. However, it also employs a qualitative aspect through the lens of strategy-as-practice. This focuses on how the implementation of an artefact affects the organisation's stakeholders, and how these people affect the artefact in turn through their various practices. In the vein of American Pragmatism, Design Science Research, and Strategy-as-Practice, this thesis shows that in the context of empty container depots a gantry crane is an artefact that can create efficiencies, as well as explore further effects on the organisation and its wider geo-political *habitus.*

The practical applications of this research case are scalable on a vast level. Empty container depots all across the globe replicate many of the same techniques and methods in their operations. By exploring an affordable way to implement lean in this space, there is the opportunity to see these efficiencies realised in many other places outside of New Zealand. The effects of this research are explored in how the introduction of an artefact affects the organisation, its vision of itself, its strategies, and the broader supply chain in which this organisation operates. The results are further re-contextualisted with regards to human factor in order to offer a holistic view of an artefact in its situated environment.

CHAPTER 2: LITERATURE

2.1 SUMMARY

This chapter provides a synopsis of the literature of continuous improvement and lean. From there, it identifies four bundles within the lean literature, namely: just-in-time, total quality management, total preventative maintenance, and human resource management. A gap in the literature is analysed between just-in-time and human resource management. The research question is then restated in the context of this research gap, and the goals of this thesis are identified as: delivering possible scenarios for the implementation of a semi-automated gantry crane, as well as exploring the human factor ramifications of such a change.

2.2 CONTINUOUS IMPROVEMENT

Continuous Improvement (“CI”) is a translation often used for the Japanese concept of *kaizen*, which represents the philosophical branch to which concepts like lean, total quality management, total preventative maintenance, etc. belong (Singh and Singh, p.75, 2015). It is the “philosophy that Deming described as improvement initiatives that increase successes and reduce failures” (Elias and Davis, p.3, 2017). In other words, it is about making constant incremental changes within an organisation.

On the other hand however, *kaizen* itself is a far more amorphous term than the directly translation of CI might lead us to believe. It has all of these three factors, but it is also a series of “pervasive and continual activities, outside the contributor’s explicit contractual roles, to identify and achieve outcomes he believes contribute to the orgnisational goals” (Brunet and New, p.1428, 2003). An important aspect of CI therefore is not just the known strategic goals of incremental change within in an organisation, but the unintended strategic consequences of one’s actions, be they in the board room or on the front lines. As such, there is a very real human factor to how CI is implemented across an organisation. Indeed Watson (1986) described “that kaizen strategy depends mainly on human efforts to improve results” (Singh and Singh, p.11, 2019).

At its heart, CI is comprised of three fundamental parts: that it is continuous; that it is incremental; and that it is participative (Singh and Singh, p.76, 2015). CI does not have an endpoint; that would defeat the purpose. It also is not generally signified by the rapid changes that one might find in research and development, though one need not preclude the other. And lastly, it requires an embeddedness in the culture of its workforce, as they are the ones who will be generating improvements, and who should be experiencing the gains of said improvements.

One of the major concepts, which this literature review will explore, and that exists beneath the umbrella of CI is: lean.

2.3 LEAN

The concept of lean has been present in the supply chain industry since the 1970s (or as early as the 1940s) when it was first developed by Toyota in Japan to achieve maximum efficiency at minimum cost with minimal waste (Melton, p.662, 2005; Schonberger, p.403, 2006; Womack et al., 1990; Jacobs and Chase, p.347, 2014). While originally it was applied solely to manufacturing, it has since been applied to various other business processes including service operations (Arlbjorn et al., 2010; Melton, 2005; Slack & Lewis, p.94, 2015). This paper seeks to apply lean concepts to a very specific section of the global supply chain - handling empty containers within New Zealand depots. Using lean, an organisation can focus on eliminating waste by reducing the amount of unnecessary handling within a depot yard when a container is received from importation, prepared, washed, maintained, modified, stored, and then eventually reused for exportation.

Lean can come to mean a variety of different processes that exist throughout an organisation. In other words, lean does not exist purely in the realm of manufacturing, but also in development, procurement, and distribution (Karlsson and Ahlstrom, p.26, 1996; Cudney and Elrod, p.20, 2011). Shah and Ward also identify other “bundles” that exist between context and implementation of lean systems, these being: just-in-time, total quality management, total preventative maintenance, and human resource management (Shah and Ward, p.130, 2003). This paper will specifically be focusing on the implementation of just-in-time and human resource management lean operations in the context of empty container depots within New Zealand.

Cherrafi et al. identify seven forms of waste: transport, inventory, motion, waiting, over processing, overproduction, and defects, all of which have "a direct impact on performance, quality and costs, and...are all non-value-adding operations for which customers do not want to pay" (Cherrafi et al., p.829, 2016). Here, value is defined as "a capability provided to a customer at the right time, at an appropriate price, as defined in each case by the customer" (Stone, p.114, 2012). The waste that will be addressed in this thesis is in unnecessary handling and delays in flow caused by traditional push-type manufacturing practices (Slack & Lewis, p.94, 2015). The immediate value that is achieved by the company as well as by the stakeholders further along the value stream can be seen in: cost reduction, greater storage capacity in areas with high storage demand, and faster stock turnover.

The many variations within the concept of lean and continuous improvement are vast. A more comprehensive review has been undertaken of the four bundles within lean as identified by Shah and Ward, as below:

2.3.1 JUST-IN-TIME

Just-In-Time ("JIT") as a concept is attributed to Taiichi Ohno in Japan during the 1950s (Garcia-Alcaraz and Macias, p.7, 2016; Pinto et al., p. 2, 2018). It was applied to Toyota car manufacturing with the primary objective to continuous improve processes by eliminating waste, improving quality, and reducing costs. At its core, JIT is the concept of reducing inventory and tangible benefits. It aims at producing the requisite product, at the right time, in right quantities and should take away the unnecessary stocks (Jasti and Kodali, p.868, 2014; Jacobs and Chase, p.11, 2014; Garcia-Alcaraz and Macias, p.4, 2016; Furlan et al., p.836, 2011). However, JIT does not only focus on delivery times as its name might suggest. While a primary tenet of JIT is the delivery of a finished product in a timely manner, JIT is itself a part of the broader lean philosophy, and as such it exists in tandem with other techniques within that philosophy.

There exist a variety of definitions for JIT logistics. Some focus on equipment and production lines to “help create efficient equipment layouts and encourage processing of smaller lot sizes, which increase the speed by which a product is made” (Prajogo et al., p.226, 2016). Others still believe that the JIT philosophy should be applied to an entire production system and not just machines (Garcia-Alcaraz and Macias, p.7, 2016). The difference between lean and JIT is minor. Lean focuses on seeking efficiencies to add value for the customer, whereas JIT can be practiced on its own without the express purpose to add value for the customer (Pinto et al., p. 3, 2018). In a sense, JIT is a tool that exists inside the overall toolbox of lean. It is an essential philosophy in lean manufacturing for eliminating waste, seeking continuous improvement, and respecting workers within a business, but it does not have the driving purpose of creating value for customers that lean has (Garcia-Alcaraz and Macias, p.11, 2016).

2.3.2 TOTAL QUALITY MANAGEMENT

The origins of Total Quality Management (“TQM”) are more muddied than JIT. While there is evidence of it appearing in some respects in Japan in the late 1940s or even in Henry Ford’s work in the mid 1920s, the term and philosophy of TQM were not fully developed as they are understood today until the 1980s (Martinez-Lorente et al., p.380, 1998).

As a philosophy, TQM “aggressively seeks to eliminate causes of production defects” and is often used in tandem with just-in-time as a cornerstone of many manufacturer’s production practices (Jacobs and Chase, p.11, 2014). This is not its only role within an organisation, however. It also affects other functions within an organisation such as research and development, supplier management, and customer management, all of which play important parts in the quality of a finished product (Friedli et al., p.182, 2010; Yang and Yang, p.452, 2011). The International Organisation for Standardisation plays a major role in setting the quality standards that are widely recognised and accepted by the global community, and which inevitably become the backbone of TQM's standards (Jacobs and Chase, p.12, 2014).[2]

As a bundle within lean, TQM is quite customer focused, since it aims to deliver the exact product without error. The ways in which TQM strives to achieve or even exceed customer expectations with a finished product is through a variety of practices within the manufacturing process. These include: standard operation procedure and problem solving teamwork, statistical process control, proprietary design of equipment, visual display, cleanliness and order (Furlan et al., p.837, 2011).

2.3.3 TOTAL PREVENTATIVE MAINTENANCE

The origins of Total Preventative Maintenance ("TPM") as it is understood today can be attributed to Seiichi Nakajima and his seminal work on the topic "Introduction to TPM" (Nakajima, 1988). It was developed as the Japanese response to American style manufacturing in order to support the overall lean philosophy (Ahuja and Khamba, p.716, 2008). Unlike TQM, which focuses upon the end product, TPM focuses on the equipment that produces, handles, or otherwise interacts with that product. The purpose of TPM is to ensure that equipment is as effective as possible throughout its lifespan by creating checks or triggers which prompt autonomous maintenance, preventative maintenance, and workplace safety (Galeazzo and Furlan, p.515, 2018; Friedli et al., p.182, 2010).

To limit the philosophy of TPM purely to the role of fixing broken items however, would be incorrect. TPM incorporates a variety of phases including: traditional breakdown management (when equipment breaks, it needs fixing), preventative maintenance (estimating the probability of a future breakdown and acting to prevent this), predictive maintenance (similar to preventative maintenance, but only performed when the need for maintenance is imminent), corrective maintenance (improving equipment reliability, maintainability, and safety), maintenance prevention (designing equipment so that it is as maintenance free as

[2] ISO's standards are also applied to shipping containers all across the world, and play a large part in any empty container depot's work bringing containers up to a certain standard for a customer.

possible), reliability centred maintenance (increasing the reliability of equipment by identifying its function, and cause/effect of failures), productive maintenance (increasing the productivity by reducing total cost of equipment over its life), and computerised maintenance management systems (automating as many maintenance processes as possible) (Ahuja and Khamba, p712-715, 2008).

2.3.4 HUMAN RESOURCE MANAGEMENT

Unlike the other bundles within the lean family, Human Resource Management ("HRM") arrives far later in the scene. From very early on, lean has acknowledged the importance of the worker within an organisation, but the specific emergence of HRM's role in lean practices did not occur until the 90s (Hiltrop, 1992; MacDuffie, 1995; Shadur et al., 1995). HRM relies upon the commitment and involvement of its employees in order to achieve lean practices; and it does this by "streamlining the organisational structure with decentralised authority, multi-functional training programs, and collaboration/communication between the whole workforce" (Furlan et al., p.837, 2011). In other words, HRM within the realm of lean focuses on how human practices within the organisation affect the implementation of lean practices, and how to best steer those practices so that they meet the desired lean goals. It places an emphasis on the human contribution to outcomes and productivity (Galeazzo and Furlan, p.515, 2018).

There is a cleavage within the research about whether lean is simply a series of neutral management tools, or whether lean is "an attempt to increase management control over labour" (Bamber et al., p.2883, 2014). The adoption of lean practices within an organisation requires a great deal of change that must be made sustainable in order to be effective in the long term. Managing the implementation of lean practices in an organisation requires a strong focus on: training, communication, rewards, job design, and work organisation; and even then the entire process is dynamic (Martinez-Jurado et al., p.757, 2013). As a whole, there is a "paucity of coherent theory that links *Lean Thinking* with HRM" (Thirkell and Ashman, p.2958, 2014). HRM represents an under-researched aspect of lean practices that fundamentally applies to all the other relevant bundles within the lean family.

2.4 GAP ANALYSIS

Culture and practices have consequences whenever any change is implemented within an organisation, be that change be lean or otherwise. “The organisation culture is the base for all involvement activities. Culture is a result as well as an enabler for sustainable and successful lean operations” (Bhamu & Sangwan, p.918, 2013). This does not merely apply to people working on the front lines of the company however. The culture shift must also take place at a governance and shareholder level. In order for the lean model to be a viable solution for any company, it must take into account a broad remit of stakeholders, including: the customer (who must be satisfied with the value-adding exercises lean seeks to achieve), the employees (who must feel empowered and appreciated instead of made redundant), and the investors (who must feel that they are receiving a good return on their investment) (Ruttimann, p.2, 2018). As Ruttiman points out, the latter is especially true of Western-centric companies, where a premium emphasis is placed on short-term investment returns over long-term stability with fewer returns (Ruttimann, p.2, 2018).

The introduction of a new artefact or new technology is not itself a change, it is a catalyst for change (Leopold & Kaltenecker, p.92, 2015). Too much change however can result in a fatigue across the whole organisation. Lean focuses on continuous improvement, which is a form of change. This change however is not expected to be a fast shock to the system, and needs to be carefully managed lest fatigue for change take root. Instead, the main form of change for lean systems should be small steps in day to day improvements carried out mainly by frontline staff and middle managers (Ruttimann, p.135, 2018).

The case study with ContainerCo will focus on reducing waste in the organisation’s empty container park operations in lieu with lean practices. This exercise in particular will use the JIT philosophy, but also how this will affect and be affected by the human resource management facet of the organisation. There has been research which concludes that the failure to consider the impact of supply chain management on other lean bundles such as total quality management explains the inadequacies of those models (Prajogo et al., p.225, 2016;

Baird et al., p.790, 2015; Galeazzo and Furlan, p.513, 2017). These failures can also extend to a failure to address the impacts of human resource management or change management on lean approaches.

While empty container depots are only a small segment of the supply chain, there has been research done around lean operations in warehousing that take into account very similar scenarios, such as Demeter and Matyusz's 2009 study on "the impact of lean practices on inventory turnover." Both an empty container yard and a warehouse must operate under similar constraints of continuous flow of goods, minimising handling, and maximising the use of limited space (Baker and Canessa, p.426, 2007; Dotoli et al., p.1, 2013; Pérez-Rodríguez, N., & Holguín-Veras, p.381, 2014). Unlike warehouses however, empty container depots do not usually handle packing processes, as they are not true cross-dock[3] or warehousing operations in the traditional sense. Their only goods are empty shipping containers, not full ones.

Due to the industry in which they operate, empty container depots are often thought of as being more similar to port faculties rather than packing and warehousing, and therefore their operations have been conflated together. However quayside ports operate under different constraints (Kemme, p.2-3, 2013). Therefore, applying lean practices to empty container depots is effectively applying theory to an area of the supply chain that has not yet been looked at in any depth.

Similarly, a semi-automated gantry crane is an artefact that is often used in quayside ports, but which has not yet been applied to the area of empty container depots. Current practice in empty container depots across the globe is to use top-loader forkhoists to lift, move, and stack empty containers in depots. There are other technologies and artefacts that can be applied to this space, such as: reach-stackers and straddle carriers. The problem that these artefacts encounter however, are the same as those encountered by forkhoists, which is that they cannot achieve a greater density or speed of operations than what is currently used. If they cannot reduce waste in the system, then the purpose of a lean exercise is immediately lost. Alternative solutions might be bespoke handling units. However, there are a variety of

[3] Cross-docking operations can be defined as any process which removes loads from an incoming mode of transportation, breaks those load down, then re-groups the pieces directly into their outbound mode of transportation for final delivery.

crane options – be they rail-mounted, rubber-tyre, etc. – that can be made to order and modified more cheaply to meet the requirements of reducing waste in empty container depots.

This review identified a gap in the literature around the crossover between just-in-time and the human resource management factor of change management when implementing lean practices. This gap is what the case study in this thesis will explore with the elimination of waste through the implementation of an artefact, and how that artefact is interacted with by the company's various stakeholders. It will use the lens of design science research and strategy-as-practice in order to interrogate the concepts of lean.

CHAPTER 3: METHODOLOGY

3.1 SUMMARY

Whereas chapter 2 was a review of the relevant literature, chapter 3 will explore the methodology and theory that this thesis employs. This chapter gives an overview of the mix of methodologies and how the data was both collected and interrogated. Overall this thesis is post-positivist in the research gap it explores between just-in-time and human resource management. However, it also uses an embedded explanatory design and design science research, in which quantitative data is interrogated in a qualitative manner.

3.2 ABOUT THE RESEARCHER

The role of the researcher in this thesis is important in some instances to the research itself. I am an insider who works, not directly for ContainerCo, but for one of its major shareholders, Petroview NZ Ltd, a private equity and holdings company which owns 50% of the operational business. I have worked in the supply chain and logistics industry for 6 years now. However, my background before that was not in operations.

Originally, I was a student of Classical Civilisations. I specialised in Latin language, literature, and Late Antique history. While I am a permanent resident of New Zealand, I am also a citizen of the United States of America, and have lived in Wellington for many years now. My introduction to supply chain and logistics did not begin until I moved to New Zealand. At that point, I began to work for Petroview as an Executive Assistant and Office Manager. From there, I worked my way up into Businesss Research Analysis, Project Management, and eventually to my current role in Strategy Management.

I have never worked on the front-lines of the operational company, ContainerCo. As such, my approach to the business has always been a very top-down view, and is somewhat unusual in that respect. Ergo, I have attempted to work closely with the Managing Director and

National Operations Manager in order to ensure that the analyses offered by this thesis are actionable as well as relevant to the academic research.

3.3 RESEARCH PARADIGM

Between the choice of positivism (a systematic, scientific, deductive, or quantitative approach) and social-constructivism (ethnographic, ecological, naturalistic, inductive, qualitative, or interpretivist approach), this work does not fall neatly into either one category (Alvesson and Skoldberg, p.15, 2009; Ibn-Mohammed, p.703, 2017). The research question of improving efficiencies involves a strong positivist approach because it is has an actionable quantitative goal in operations, however a single-mode research paradigm is not wholly applicable here. Because this research also seeks to explore the views of relevant stakeholders and those people affected by the implementation of an artefact, a mixed approach is necessary. If a purely positivist approach were to be taken, then the research would fail to explore these human factors (Ibn-Mohammed, p.693, 2017).

The midpoint of this thesis with chapter 5 is positivist in its approach to data and creating potential applicable solutions to an empty container depot. However, chapters 4 and 6 take a social-constructivist approach by first exploring the environment in which an empty container depot operates, and then interrogating the artefact that is proposed to be implemented in a qualitative fashion. This work was undertaken with the philosophical approach that no artefact exists in a vacuum, and that human factors have a very real impact on strategy and operations. Ergo, this thesis takes a mixed-mode approach to both its research paradigm and its methodology, the latter of which will be discussed further below.

3.4 DATA COLLECTION AND ETHICS

This thesis addresses a specific artefact-based issue of empty container depots, including its implementation, and its efficacy. Immediately, this sets the research as a bricoleur, requiring a mixed research paradigm and methodology. One half is a positivist approach with quantitative reproducible data, which is pulled directly from ContainerCo's operating systems to reflect real time movements on the ground. This data includes volumes through the parks and all work done on the containers that move through the yard. Employee information is not visible at this level, and all customer information will be redacted to retain anonymity. The other half is post-positivist in that it explores the human repercussions from implementing an artefact such as a crane.

Approval was gained from the Managing Director of ContainerCo (NZL) Ltd. to collect information on the company's operations from the four identified keystone sites. The data was collected using the company's Terminal Operating System, which handles and stores all information regarding the company's: customers, internal processes, and third party carriers and suppliers. All information regarding customers and third parties was aggregated for the purposes of maintaining confidentiality. No observations or interviews were conducted whatsoever. As this does not require human participants for information there was no need for ethics approval. Ergo, all information has been acquired without disrupting operations.

This thesis acknowledges that an artefact -- and indeed an organisation as a whole -- does not exist in a vacuum. It has more qualitative foundations and contexts that act upon it and alter its ultimate efficacy. In essence, these contexts are the people who operate the artefact, who implement the artefact, and who engage with it at a strategic governance level, as well as the broader industry which affects the artefact's strategic uses. Ergo, this thesis takes a mixed methods approach. This thesis has four stages: 1) a contextualisation of the organisation and the artefact, 2) the collection and presentation of quantitative data, 3) the exploration of future situations, 4) a re-contextualisation of these findings back into their environment.

This kind of research is identified by Gregor & Hevner as exaptation, *id est:* known solutions extended to new problems (Gregor & Hevner, 2013, p.347). The solution of semi-automated gantry cranes is a known solution for ports and other industrial spaces, but has yet to be applied to the area of empty container depots. As such, the contributions of this work are theoretical in that they are based in strategic planning, but not yet in actual practice.

3.4.1 MIXING METHODOLOGIES

As with any mixed methods approach, one of the main issues encountered was centred around the sequence of quantitative *versus* qualitative (Ivankova et al, p.9, 2006). It is a question of timing, explanation, exploration, and triangulation, as well as which framework this work falls under (Campbell et al, p.378, 2011). The main methodologies in business research are descriptive, exploratory and causal research (Sreejesh *et al.*, p.29, 2014). For this thesis, the closest approach was the Explanatory Sequential Design, which traditionally advocates the sequence of quantitative data collection followed by qualitative analysis, and then an elaboration on the quantitative findings (Bryman & Bell, p.646, 2015). An alternative approach might have been the Concurrent Triangulation Design, in which the data collection is broken up into levels of concurrent quantitative and qualitative information and then then merged together for an overall interpretation - but this did not fully address the embeddedness of this thesis' approach (Creswell & Plano Clark, p.64, 2006). While the qualitative interpretation takes a more supplemental role to the quantitative data collected in this thesis, ultimately the approach here is still more firmly rooted in Explanatory Design than in Embedded Design.

In this instance, the differences between Embedded and Explanatory designs are not so clear cut. This thesis uses a design that understands that the quantitative data is situated; the organisation and the artefact do not exist outside of their *habitus*. It acknowledges the quantitative information's embeddedness, while also using a sequence of phases to describe the situation, and then offer a single interpretation based on the interaction of these results. Rather than having a single chain of sequential events, as might be found in the Explanatory Design, this approach can be visualised as so:

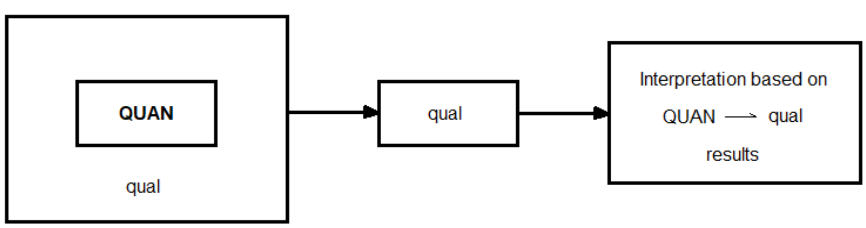


Figure 1 – A visual representation of Embedded Explanatory Design
(modified from Creswell & Plano Clark, p.73, 2006)

Using mixed methods has its strengths and weaknesses. Neither approach alone can capture the whole picture, but together both qualitative and quantitative methods give a more holistic vision of the organisation and the artefact of the crane. Its strengths lie in the ability to explore quantitative data in more detail, to flesh out the data *in situ*, rather than removing it completely from its environment (Ivankova et al, p.5, 2006). However, the weaknesses lie in how best to explain the relationships between methods, between variables, as well as in what sequence and priority (Bryman & Bell, p.643-4, 2015). Here, priority is given to the quantitative data being drawn from the organisation's operations, but the sequencing brackets this quantitative data with qualitative analysis so as to firmly embed it in its environment.

Wong and Cooper clearly identify four stances for the paradigms behind mixed methodologies, these being: pragmatism, transformative paradigm, multiple paradigms in mixed methods, and the paradigm depending on the designs of the mixed methods (Wong & Cooper, p.48, 2016). The mixed methods approach taken in this thesis is rooted in the pragmatist paradigm. As such, both deductive and inductive approaches are mixed (Wong & Cooper, p.48, 2016). The weighting of qualitative and quantitative in a pragmatic worldview depends upon the research question itself (Creswell & Plano Clark, p.82, 2006).

In this instance, quantitative data is drawn from its environment, analysed, then resituated in a way that sets out to find a potential solution to the problem identified. This re-contextualisation is ultimately practical in nature. It is meant to identify a real world problem, and provide an immediate purpose for the artefact through pragmatic means. More in the spirit of action research, this thesis generates knowledge through the creation of an artefact, and enacts change by creating a plan to incorporate the artefact into a working environment (O'Leary, p.139, 2004).

As such, this pragmatic approach is not concerned with the finer complexities of epistemology.[4] The goal here is not to search for objective truths. While Haack reminds us that truth need not be an active goal to be an important aspect of inquiry, it should be said that the purpose of this inquiry is to hopefully create something useful in and of itself (Haack, p. 199,

[4] I am sure many epistemologists would say that is the case of all pragmatists.

1995). As pointed out by Menand's example of Dewey's thoughts on belief being instruments for coping: "When your fork proves inadequate to the task of eating soup, it makes little sense to argue about whether there is something inherent in the nature of forks or something inherent in the nature of soup that accounts for the failure. You just reach for the spoon" (Menand, p.361, 2001).

To be clear, embedding the organisation and the artefact in order to better understand the contexts in which they operate is not an endless search for truths about global trade and politics. It is not even a search for individualised phenomena about the interactions of people with the organisation and its artefact. It is simply understood that in order for an artefact to be of as much use as possible, a pragmatic worldview would demand a mixed approach to how that artefact operates in its environment.

3.4.2 DESIGN SCIENCE RESEARCH

Action research was mentioned previously, but the primary methodology is based in Design Science Research (DSR) and further explored using the theory of Strategy-as-Practice (SAP). It is understood that in order for a model to be useful, it must be used in practice. Moreover, to achieve this, the model must not exist in a vacuum. Rather, it must be properly integrated by exploring the context in which it will operate at both an industry and organisational level. By marrying the two together, this also gives materiality to strategy-as-practice by linking it to an artefact with immediate real-world applications.

Strategies in supply chain – in both academic theory and real-life application – all tend to approach strategy as something that is done, as an action, as practice. Strategy in this field is about agility, about responsiveness, about ambidexterity, about performance, integration, and resilience. Design and information science research focuses on "bridging theory and practice," in other words giving theory materiality (Bednar and Sadok, p.51, 2016). That language in and of itself is telling. It strongly indicates the relationship between the effectiveness of an organisation, its information units, the people who interact with the organisation both internally and externally, and finally the artefact itself (Bednar and Sadok, p.54, 2016). This thesis hopes to achieve bridging theory with practice through the application of an artefact and the generation of knowledge.

In essence, DSR is pragmatic in nature; it focuses on relevance and creating contributions to its environment (Gregor & Hevner, 2013, p.342; Hevner, 2007, p. 91). As Hevner points out however, "...practical utility alone does not define good design science research. It is the synergy between relevance and rigor and the contributions along both the relevance cycle and the rigor cycle that define good design science research" (Hevner, 2007, p. 91). Design science is fundamentally concerned with improvement through the implementation of artefacts, which are human-machine systems whose purpose is to support operations, management, analysis, and decision-making functions in an organisation (Hevner, 2007, p.88; Hevner et al., p.1). However "the new artefact may have deficiencies in functionality or in its inherent qualities (e.g., performance, usability) that may limit its utility in practice" (Hevner, 2007, p.89).

This link to practice is key in defining the productivity or usefulness of the artefact that will be put in place. Both the artefact and practice influence one another. While DSR "should make clear contributions to the real-world application environment from which the research problem or opportunity is drawn...we would be remiss not to mention the important contributions that DSR projects make to *praxis*" (Gregor & Hevner, 2013, p.342). In essence, the installation of an artefact initiates a sequence of events in which the artefact is embedded in its environment and reacted upon until it inevitably becomes part of the "structured structures predisposed to function as structuring structures" (Bourdieu, 1977, p.72).

It is this overarching concept of *habitus* which ties the methodology and analysis together. "It (Habitus) is not a structure [*per se]* but a durable set of dispositions that are formed, stored, recorded, and exert influences to mould forms of human behaviour" (Navarro, 2006, p.16). These social practices are neither mechanically imposed, nor even intentionally pursued; moreover, they can change over periods of time as people's experiences produce additional patterns (Navarro, 2006, p.16).

This interaction between artefact, people, and environment creates a tension in social practices which can determine how useful an artefact is post-implementation. Ultimately this is what leads us to delve further into the gap identified around the relationship between design science research and strategy-as-practice.

3.4.3 STRATEGY AS PRACTICE

The main focus of the strategy-as-practice framework is that strategy isn't something an individual or organisation "has," it is something an individual or organisation "does" (Jarzabkowski & Seidl, 2008, p.1391). It is a situated, socially accomplished action, an activity that is both formal and informal, intended and unintended (Jarzabkowski & Seidl, 2008, p.1392). Moreover, it is comprised of three parts: *praxis* (an action *eo ipso*), practice (an intended action), and practitioner (an agent). By breaking the act of strategising into these three parts, strategy-as-practice does not focus on any one aspect of strategy, whether at a micro or macro level, without taking into account the other parts, and introduces the challenge of explaining outcomes that are consequential to a firm at all levels.

In the framework of strategy-as-practice, the difference between *praxis* and practice can quickly become entangled. Looking deeper into the origins of *praxis* however, can clearly differentiate the two. In his Nicomachean Ethics, Aristotle categorises all human action into three types: *theoria* (thinking), *praxis* (doing), and *poiesis* (making). While *praxis* can only be done by a rational creature, it is only linked to *prohaeresis* (rational choice), and is not necessarily deliberate in and of itself (Adkins, 1978, p.301). "The term *praxis* never means a morally (or ethically) qualified action, that is, an action for which one may appropriately be praised or blamed" (Belfiore, 1983, p.110).

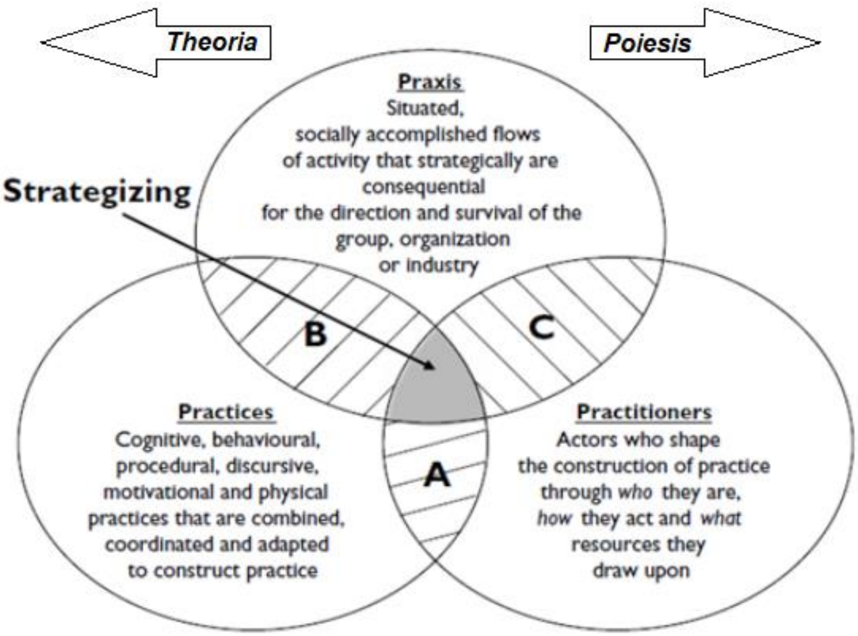


Figure 2 – A conceptual framework for analysing strategy-as-practice
(modified from Jarzabkowsky et al., 2007, p.11)

By understanding then how *praxis* is situated between *theoria* and *poiesis* in its original form, we can quickly differentiate between the three aspects of practice-as-strategy. Practices are actions that occur with *theoria* through rational choice. They are, in brief, intended, formal, and often ritualised. *Praxes* however, are actions that have strategic consequence but which are made without explicit intention to have those strategic outcomes. They are mere actions in and of themselves, separate from moralising.

Much of the literature around strategy is still dominated by a top-down approach, which blocks out myriad experiences of individuals who are actual strategy practitioners. Even if their influence on strategy is unintended, it is still consequential. By using this framework and clearly identifying the focus of future research, strategy-as-practice may explain outcomes that are consequential to the firm at all levels: from the individual, to the broader institution. Strategy-as-practice ties in very neatly to the concepts of Continuous Improvement and Lean, which – as previously discussed in the literature review – rely upon the practices of workers within the organisation to implement effective improvements.

3.4.4 THE MIXING POT

This approach of strategy-as-practice does not preclude artefacts and technologies. The scope of strategy-as-practice is such that it includes the range of symbolic interactions that people undertake with material objects such as an artefact, or even things of less substance such as knowledge. This is especially apparent through the lens of something like information systems in particular, in which knowledge, software, and hardware are all inherently interdependent. "When information systems researchers talk about technologies," Whittington notes, "they are always describing practices as well…Practices are not merely discursive or symbolic, but material and technological" (Whittington, 2014, p.89). This interaction between artefacts and practices is key in exploring the strategies and risks associated with the installation of a new artefact into an organisation. Indeed, strategic outcomes are affected by all of the activities, contexts, processes and content that occur within and around an organisation (Peppard et al., 2014, p.5).

At first glance, pragmatism and strategy-as-practice should not play well together. The history of practice, especially in the hands of Plato, exists in a world of pure forms and eternal principles (Nicolini, 2012, p.24). In the hands of Aristotle, *praxis* is similarly used to describe moral conduct and how to be a good citizen within the constraints of these pure forms (Nicolini, 2012, p.26). However, Aristotle also releases practice from these constraints through *phronesis*, meaning 'wisdom' or 'intelligence'. "*Praxis* cannot even in principle be adequately captured in a system of universal rules -- and hence cannot be the subject of *episteme* (knowledge), because it has to do with mutability, indeterminancy, and particulars" (Nicolini, 2012, p.27). While Aristotle does not include materiality and performativity in the space of *episteme*, his more nuanced approach allowed later Western philosophers to do so.

It is from these later interpretations of practice that pragmatism comes into view. Rather than drive them apart, serendipity is actually what ties the two together. Practice is itself "a dynamic, temporal process that both converges and diverges" whereas the "essence of a pragmatist ontology is actions and change; humans acting in a world that is in a constant state of becoming" (Simpson, 2014, p.1332; Goldkuhl, 2012, p.139). Strategy itself is in many ways an emergent process, depending on which school one applies to (Peppard et al., 2014, p.3).

On the other hand, design science marries very well to pragmatism and lean, since design science itself is "inherently an iterative and incremental activity with no well-defined stopping rules" (Hevner et al., p.13). And yet it is this same definition that means design science also marries well to strategy-as-practice, since it is an activity, and strategy-as-practice's main tenant is that strategy is not something people *have* but rather something people *do.* As Whittington so succinctly puts it: "In practice theory, it is a central assumption that practitioners are agents whose ordinary activity can make a difference. In their *praxis,* practitioners enact practices in ways that affect outcomes – that is why their activity is worth studying" (Whittington, 2014, p.89).

From here, we must now delve into the current operations of the organisation and its environment. Then, we can drill deeper into the underpinning structures which require a crane as an artefact, before modelling the artefact itself, and then finally recontextualising the artefact in its environment using qualitative analysis.

CHAPTER 4: EMPTY CONTAINER DEPOTS IN NEW ZEALAND AND ABROAD

4.1 SUMMARY

Whereas chapter three explained how the research will be conducted, chapter four is an overview of the current processes within an empty container depot. It first identifies what an empty container depot is, and what an empty container depot is not, by comparing a depot to ports and warehouses. The constraints of empty container depots are explored, after which the macro (regional) flow of empty containers is identified followed by the micro (depot) flow of empty containers. The internal operational processes are mapped on a micro level using value stream mapping and interwork flow graphs. Four ContainerCo depots are identified as possible locations for the implementation of a crane, and one is chosen as a case study for a more in-depth analysis in chapter 5.

4.2 CURRENT OPERATIONS AND CONSTRAINTS

To define what constraints a container depot operates under, we must first identify what a container depot is and what it is not. Empty container depots provide container-related services to companies that own shipping containers (Mittal et al., 2013). Examples of these customers are typically large shipping companies, or container leasing companies. [5] The depot receives the containers, repairs them, and then stores them for their next use; these are then released by the shipping company, who deals with its customers directly. Empty container depots are therefore the central hub of containers. Containers (sometimes referred to as simply “boxes”) are received from importers and serviced to the shipping company’s specifications. They are then released, on shipping company instructions, to exporters.

The industry that empty container depots are most often compared to is the port industry. A port is traditionally defined as “a geographical area where ships are brought

[5] Empty container depots often have a hire and sales division as a subsidiary; this is, however, a separate kind of business and should be considered separate from the Depot business.

alongside land to load and discharge cargo -- usually a sheltered deep-water area such as a bay or river mouth" (Stopford, p.29, 1997). Ports can specialise in different kinds of freight, such as break-bulk,[6] while others again accept all types of freight -- such as dry bulk[7] or liquid bulk. Some even offer significant other services depending on the level of equipment, capital and infrastructure that is available to them (Mangan et al., p.30, 2018). More than that however, ports act as central hubs or links that offer a complex bundle of services in the larger supply chain of global shipping (Mangan et al., p35, 2018). Ports have also been described as "generations" (Casaca, p.263,2005) or "conduits for facilitating intermodal transfers at the interface of sea and inland transportation systems" (Cullinane and Song, p.86, 2006). Ports are primarily concerned with efficiency of cargo and ship turnover, competing amongst themselves "for ocean carrier patronage and short sea operators (feeders) as well as for land-based truck and railroad services" (Steenken et al., p.5, 2005). As a hub or conduit between land and sea operations, port constraints are naturally positioned between their quayside operations and their hinterland operations, as below:

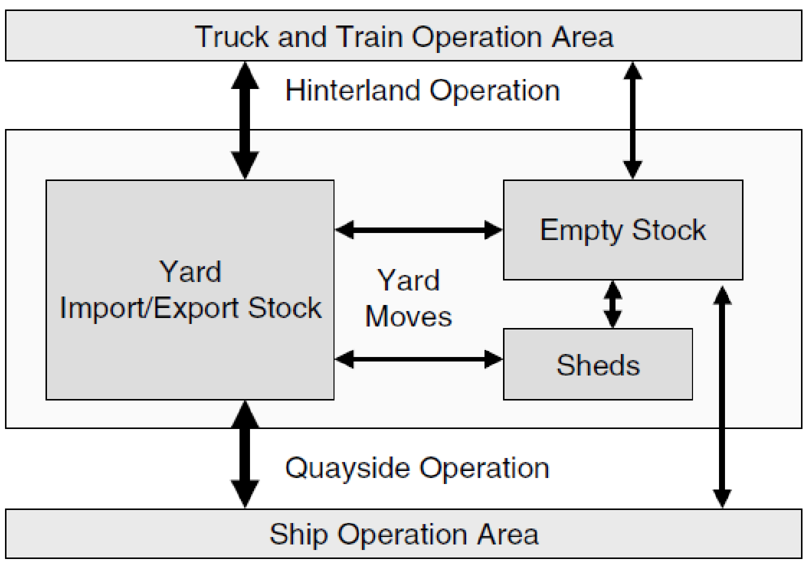


Figure 3 - Operation areas of seaport container terminals and flow of transports (Steenken et al., p.6, 2005)

[6] Break-bulk freight is any freight that has been broken up into separate pieces; for example pallets
[7] Dry bulk is a commodity cargo transported in large quantities – for instance salt.

This description however, does not wholly apply to empty container depots. While empty container depots often operate near ports, they do not have to take all quayside operations into account. Ports that manage container terminals are focused on “gateway activities” – full containers - in which export cargoes are loaded into containers, and import containers packed with goods are discharged when a container vessel arrives at the port (Chew and Lee, p.4, 2015). Empty container depots by definition do not handle full containers, and therefore do not engage in many of these gateway activities. Rather than concerning themselves with quayside operations, managing import and export stock, as well as packing and unpacking in cross-dock operations, an empty container depot is focused on the washing, repairing, maintaining, and storing of empty containers for re-use.

The temptation might then be to categorise empty container depots as warehouses with large-scale products (*id est* the containers themselves). In some sense this would be true, especially in recent years where warehouses have evolved from “their traditional inventory holding roles...to act as cross-docking points, value added service centres, production postponement points, returned good centres, and many other miscellaneous activities, such as service and repair centres” (Baker and Canessa, p.425, 2007). Empty container depots fundamentally differ from warehouses in that stock-holding is not their primary function. However, they do act as service and repair centres, and can in some cases vertically diversify their services to include cross-docking, if they’re close enough to a port.

While empty container depots are neither ports nor warehouses, they are still concerned with some of the same issues around value creation and waste elimination in their operations. They must manage inflows and outflows of containers, and attempt to predict demands from multiple large shipping company customers, whose movements shift according to broader trends in global trade. Specifically, this paper will focus on eliminating waste in the following:

- excess handling -- how to reduce over-handling of containers by putting in place a semi-automated crane to replace current handling machinery, as well as changing the yard layout to decrease excess handling;

- space requirements/limitations -- land in central hub locations is often very expensive but necessary to either rent or own in order to provide essential services to a region, ergo land utilisation must be maximised in order to be cost-effective; and,
- flow of goods -- how to ensure that containers move as smoothly through a yard as possible to eliminate waiting time and increase the rate of turnover.

By using a semi-automated gantry crane and creating standard set layouts for an empty container yard, the aim is to apply lean to the overall operations by tackling each of these four issues. In order to begin, we must first give examples of the current operations of an empty container depot in New Zealand.

4.3 CURRENT FLOW OF EMPTY CONTAINERS AT A MACRO (REGIONAL) LEVEL

There are several ways we can visualise the movement of containers within a region. In their study of "determining optimal inland-empty-container depot locations under stochastic demand" Mittal et al. gave us one simplified example of where empty container depots sit in the larger chain of region container transportation as below:

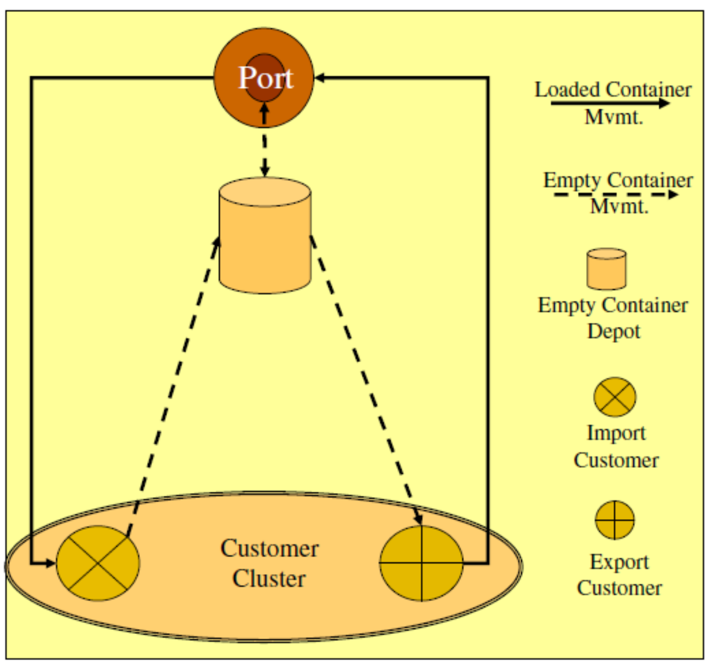


Figure 4 - A typical regional empty container repositioning system.

(taken from Mittal et al., 2013)

While this is an excellent representation of the flow of empty containers within a region, it leaves out an important stakeholder in the process, which is the shipping company. As stated previously, shipping companies are the major customer base for empty container depots. The importers and exporters arrange their containers through shipping companies, as the containers themselves represent the purchase of space on ships from the shipping companies. In many cases, the importers and exporters do not even deal with the shipping companies directly and instead liaise through a freight forwarder, who deals with the shipping companies on their behalf.

As it is the shipping companies which usually own the boxes, to them falls the onus to upgrade, store, repair and maintain these boxes. This means that shipping companies should also be a part of the customer cluster in the bottom section of this visual, and remain the core customer for the ports at the very top of this structure.

This graphic has therefore been amended to include the shipping companies. The graphic was turned on its side and the shipping companies placed over the top of the entire exchange, to more clearly show the relationship between all parties involved. Another layer was also added between the ports and the exporters/importers - the freight stations and distribution centres. Full containers can flow directly from ports to importers and vice versa, but often they move through a freight station and distribution centre before that point. This would of course depend upon the port in question, and what services they might offer. The amended graphic below gives a more complete picture of the flow of empty and full containers within a region:

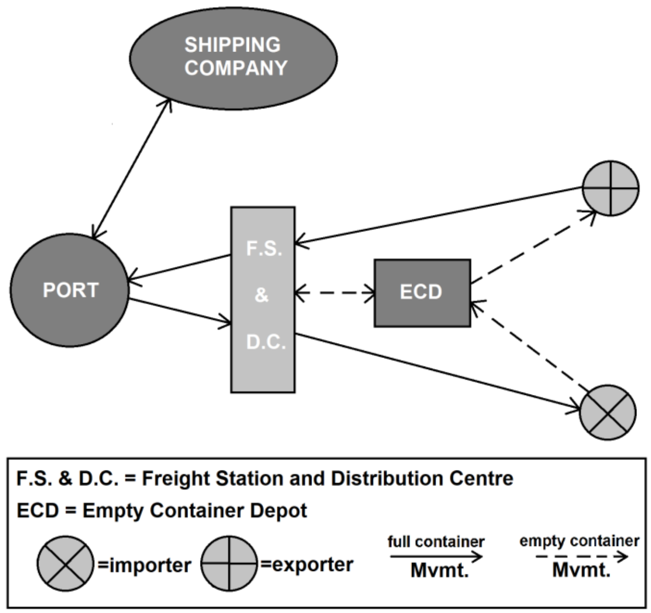


Figure 5 - Regional empty container repositioning system (modified by the researcher from Mittal et al., 2013)

An additional view of the stakeholders at a regional level can be seen in Theofanis and Boile's 2008 publication on "Empty Marine Container Logistics." Here, they identify the interchange of empty containers between consignees and consignors, in order to eliminate any confusion between the shippers and the shipping companies. This highlights the relationship between empty container depots, marine terminals (be these ports or freight and distribution centres) and the consignees and consignors who retain ownership of the goods.

For the purposes of this paper, the importance of the shipping companies should not be understated. They are the parties involved who retain ownership of the majority of empty containers flowing through New Zealand. Ergo, they are the primary customers for New Zealand empty container depots.[8]

4.4 THE NEW ZEALAND CONTEXT

There is a notable imbalance in the flow of containers within New Zealand. The majority of containers entering New Zealand are bringing in finished goods such as vehicles, machinery,

[8] Further analysis of stakeholders and HRM will take place in Chapter 6.

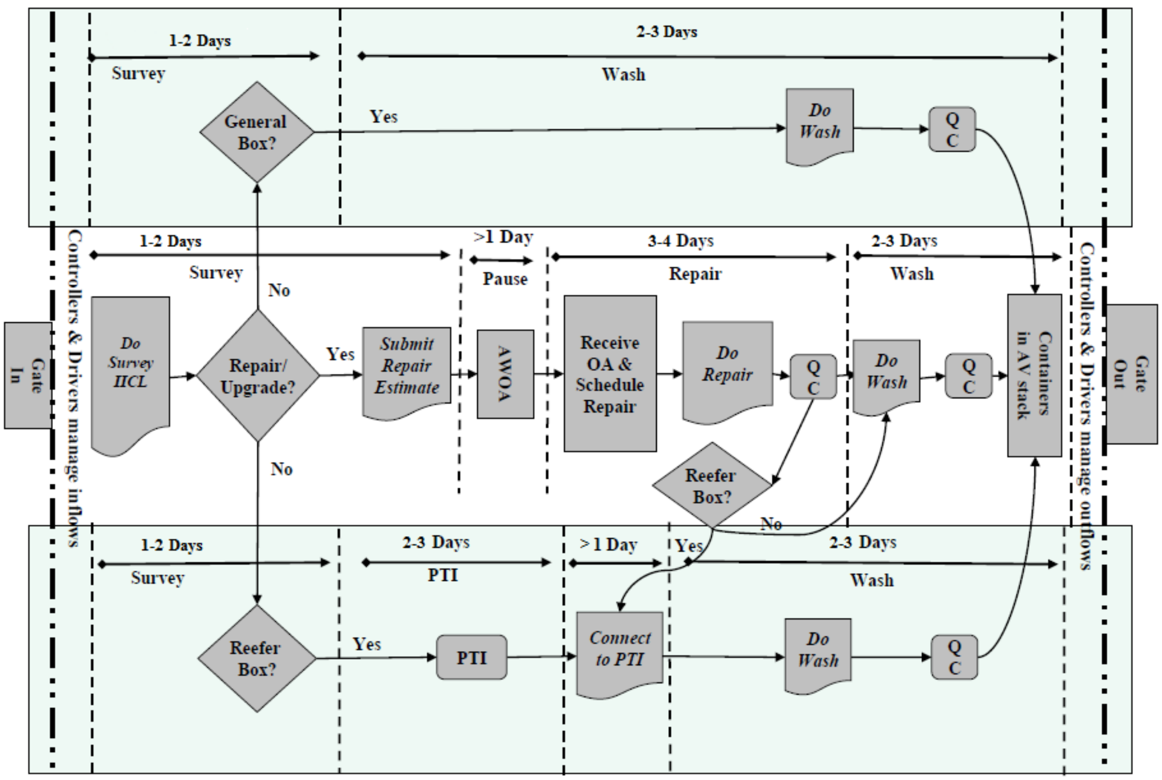
and textiles, whereas the majority of containers exiting New Zealand are carrying food grade products such as milk powder and meat, or wood products such as pulp, and paper (Imports and Exports, StatsNZ, 2018). Containers carrying finished goods, however, do not require the high standard of container that is necessary to carry food. This means that most empty containers within New Zealand must be repaired and upgraded from a low, to a high standard; without this step, the container cannot be packed with food grade products for exportation. In the New Zealand supply chain, this therefore creates a larger demand for empty container repairs and upgrades (henceforth referred to simply as “repairs”) than might be found in other regions, with as many as 60% of all containers that enter New Zealand requiring repairs. This represents the primary source of for empty container depots, as their sites are one of the only places where such repairs can reliably take place.

Additionally, there are seasonal trends in containers flowing through New Zealand. New Zealand exports – such as meat and kiwifruit – are largely seasonal in their very production. This seasonality creates a serious “mismatch for each container type” across the country (Deloitte, p. 15, 2016). There is a further mismatch of imports and exports between the various ports, as the Port of Auckland is the largest import port - handling more than 35% of all imports - and the Port of Tauranga is the largest export port - handling 43% of all exports. This creates regional inefficiencies; shortages of containers in one location, and excesses in others, which cannot necessarily be resolved in efficient ways (Deloitte, p.44, 2018). Empty container depots are forced to cope with these seasonal, regional, and global trade trends, which materially affect: how many containers will be flowing through the yards at various locations, what grade of containers will be received, fluctuations in the arrival and departure of trucks and containers, and the level of services and repairs required by the shipping companies for their export customers.

4.5 CURRENT FLOW OF CONTAINERS AT A MICRO (DEPOT) LEVEL

This paper is concerned with identifying and eliminating waste at a micro (depot) level rather than a macro (regional) level. However understanding how empty and full containers move around a region makes understanding the of empty container depots more apparent, and what forces are at play in terms of suppliers, buyers, and rivalries (Porter, 1989). Containers are processed inside a container depot to meet ISO standards, which are designed to ensure correct containers can then be provided in a timely manner to meet the needs of these outside processes.

Below is an ‘ideal’ process flow chart of an empty container depot at a micro-level, including general grade boxes and reefers (refrigerated containers):



IICL = Institute of International Container Lessors Qualification Level
QC = Quality Control
PTI = Pre-Trip Inspection
OA = Owner Approval
AWOA = Awaiting Owner Approval
AV stack = Available Containers Stack
Reefer Box = Refrigerated Container

Figure 6 - Process flow of empty containers in a depot (taken from an independent contractor’s analysis of the ContainerCo internal processes)

This flow chart is 'ideal' in that it assumes that every box will travel through every service in a production-line like way. This is not always the case. A number of assumptions were therefore made for the purposes of this analysis. The first is that only 20' and 40' containers would be stored inside the yard. The next assumption is that the crane will "remember" where it placed specific containers; yard management by container allows refrigerated units, AV, EVAC, and storage units to be geographically stacked together.

The critical process in an empty container depot is "survey." The survey acts as a triage station for containers, identifying to what grade a box might realistically be repaired, and pricing up the cost of the services which will be required. An estimate will be generated and sent to a shipping company for approval. The repair can then be approved, or declined.

If declined, the box will become an "evacuation container" (EVAC); *id est* it will have no further services performed on it by an empty container depot, except for storage. As it has not been washed, it cannot be used for further work inside New Zealand, and will be removed by the shipping company. If accepted, the estimate will form the basis for the services performed by the empty depot, and will guide shipping company thinking in allocating the box to the next exporter.

This chart is also not indicative of the adjacency problem, *id est* this is a map of process, not of geography. While some sections of the yard are specifically allocated to certain service functions – for example the wash bay, with its expensive infrastructure – most are multi-use spaces. The chart represents the flow of different types of empty containers through a yard, and to give an idea of how long this process generally takes. The adjacency problem will be tackled in a later section of this thesis.

Containers that have been completely repaired and washed according to the estimate, and are ready to be issued to exporters, are stored in the AV stack (available containers stack). They are removed from the AV stack according to demand. Containers are continually being processed and added to the AV stack when services are complete.

The demand for containers is completely dependent upon the customer. Within a region, shippers supply containers – generally from a freight station and distribution centre – while shipping companies request and remove containers from a yard within a region, as needed. These needs of course are based upon the demands of their own customers, those being importers and exporters. Each yard does experience "peak times," where trucks would prefer to arrive or depart, but these are regulated via the use of the VBS to ensure equipment is used steadily over time.

In New Zealand, empty containers are processed on a made-to-stock basis -- meaning that the inventory is already a finished good (Jacobs & Chase, p.148, 2014). Within a depot, processes are done in batches. They are moved by a heavy forkhoist between stations; services are most frequently completed by unskilled labour, who operate handtools to repair, wash, and upgrade boxes. The forkhoists can lift and stack containers up to 9 TEU high, though typically they only stack to 8 TEU or lower depending on multiple constraints: the operations, the regional council requirements, and/or health and safety implications such as high wind speeds.

All of the processes detailed in Figure 6 can be broken down into four discrete groups: Survey, Repair/PTI,[9] Wash, and AV Stack. Reefers are segregated, as they undergo their own quality control standards.

From here, we can draw a value stream map of an empty container depot's current state of operations. Value stream mapping is a tool within lean that is specifically designed to focus on the transformation processes within an operation, and pin-point areas of potential waste (Popescu, 2018).

[9] A PTI or "pre-trip inspection" is the maintenance work required by refrigerated ("reefer") containers. This involves the mechanical inspection and testing of the refrigeration unit to ensure cooling/freezing functions will not fail once loaded with product. While optional, in practice shipping companies PTI every reefer container that is brought through an empty container depot, as the cost of a failed unit is the destruction of the cargo.

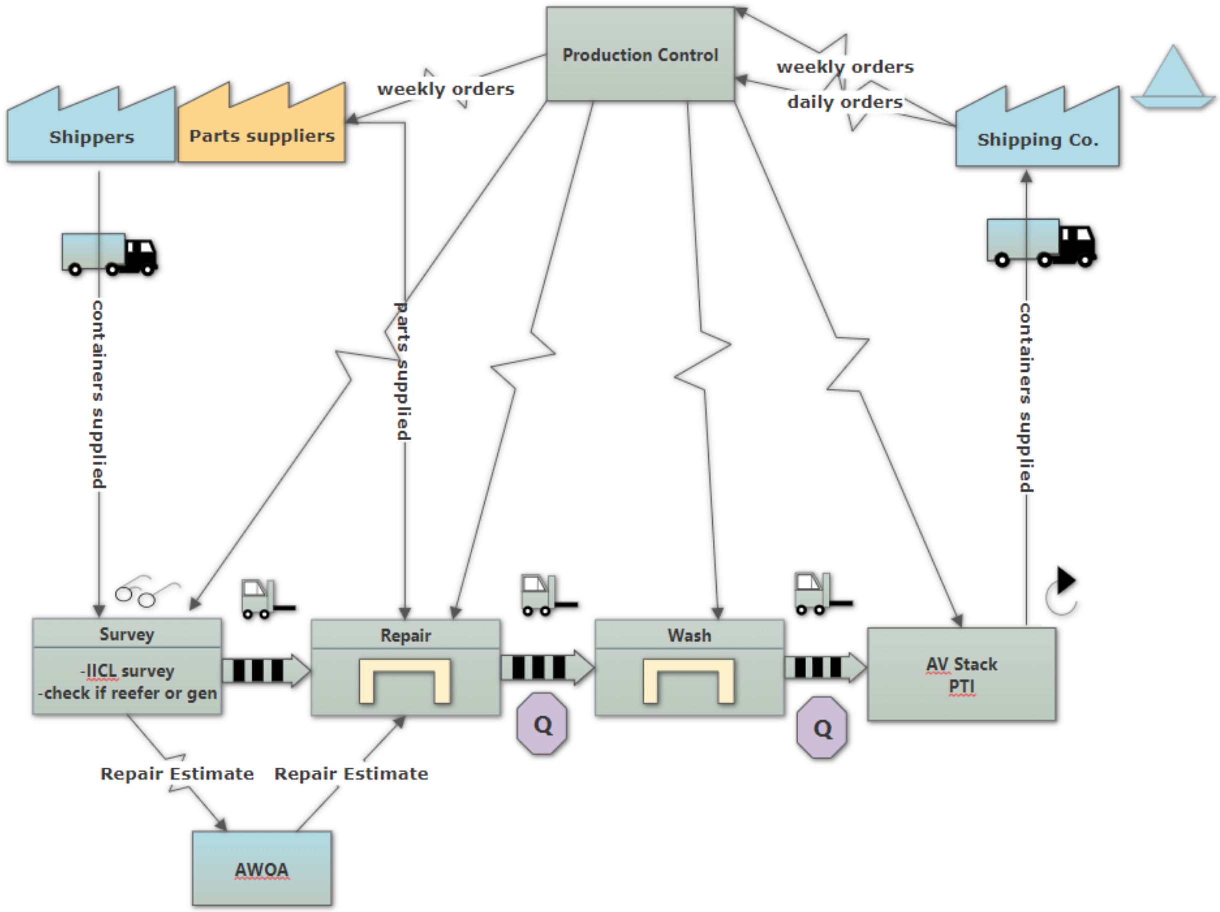


Figure 7 - Value stream map of current empty container depot operations

Ideally, a yard would be broken up into segmented areas dedicated to performing each task; containers would be moved between these spaces. In some cases these dedicated areas are essential, such as in the case of the wash area. This is an MPI (Ministry for Primary Industries) dedicated zone. Ergo it must be free of outside contaminants, and it must follow specific procedures in order to meet the biosecurity requirements of New Zealand (Ministry for Primary Industries, 2018). When looking at how to eliminate waste in these processes therefore, the wash zones must remain separate for legal purposes. Other areas however, can be moved together in order to maximise space occupied and time spent on the tasks in question.

Even without a semi-automated gantry crane, the two processes that can be immediately merged together are: survey and repair. For the majority of work, empty containers will not need heavy repairs. A workshop environment is unnecessary. Facilities for repairs can be downsized, if smaller repair functions are merged with the survey operations. A small workshop and paint area can be maintained on site for these heavier repairs, but a significant number of movements of containers can be removed.

It should be mentioned that, in theory, a depot should await owner approval before starting repair work on a box in question. However, in practice this is often not the case. The owner approval process is time-intensive. Shipping companies force suppliers to produce estimates through a centralised system, which flow through divisions housed in shipping companies overseas. This can take days. The container would therefore sit in a yard without any work being done to it. In the meantime, the local agent for the shipping company will be demanding containers for export. These do not have any say in the owner approval process, which again, is often handled overseas.

The result is that empty container depots often undergo the work they know needs to be done based on local demand, before receiving owner approval. Operationally this smooths the flow of empty containers through the yard, but administratively causes cashflow disruption and the risk that the shipping company will not authorise a repair that has already taken place. As this paper is concerned with operations on the ground however, the AWOA stage will be treated as if no time is lost, though it is left in the Value Stream Map for the sake of accuracy.

Of the containers that enter the yard, 100% of these must be surveyed. Rapid Repair Teams would follow behind the Survey team, and operate in the same geographic space, called a Multi-Use area. Rapid Repair Teams handle small repairs, and limited washes such as sweeping out the box, sanding the floors, or replacing door handles. 100% of containers must be surveyed, 40% are EVAC, 40% are put into AV, and 20% require further wash and repairs. Since Auckland OCP will not be doing further wash and repairs, and that volume will be transferred to the nearby yard at Auckland MCP, the amount of containers deemed EVAC and removed without repair work from Auckland OCP will be approximately 60%.

4.6 CASE STUDY - THE FOUR SITES

The exemplar company (ContainerCo (NZL) Ltd) operates 13 sites both in New Zealand and abroad, however there are many factors in choosing where to install the first crane. When choosing which site to install a crane, the greatest concern was volume and land utilisation. This eliminates many sites outright. ContainerCo's 4 large keystone sites in the North Island remained viable options. These four sites experience the most volume, and are situated in critical regions that have heavy demands on storage capacity and throughput. These regions are: Auckland, Tauranga, and Napier. The crane is predominantly adding value through creating raw storage capacity. Therefore, sites should be evaluated based on a) the need for a greater density of storage, and b) the need to reduce double-handling of containers.

Moreover, since each of these regions has multiple sites that effectively all perform the same services, the addition of a crane allows an opportunity to regionally restructure. The single site to receive the first crane allows the removal of everything but its storage and multi-use area for a survey team and a rapid repair team. This frees up as much space as possible beneath the crane for storage, and allows the other sites in the region to focus on wash and repair operations. The site with a crane would therefore become a focal point for storage, with smaller satellite sites feeding into it.

An overhead gantry crane allows further reduction of handling, and the maximisation of land utilisation. Fork hoists require containers to be stacked in rows with a space between as a roadway. Stacking density is limited by the need for drivers to access containers. This results in wasted space. It also prompts excess handling, as a hoist may have to 'dig' into a stack of containers to fetch a particular grade or type of box. Examples of depots organised around fork hoists are shown in Figures 10-13 below. In each depot, the wash station has been outlined in yellow, repair in red, and survey in blue.

Figure 8: Empty container depot in Auckland, provided by GoogleEarth (OCP)

The first Auckland depot, called OCP, is a 4.2 hectare depot operating at 95% of capacity.[10] The second Auckland depot, called MCP, is a 2.4 hectare depot operating at 98% capacity. Increased efficiencies in the Auckland region are therefore urgent, as to increase volume using current processes would require the purchase of another site. The last such site ContainerCo opened cost approximately $5.1 million dollars just in land development. The Tauranga depot, called MMP, is a 3 hectare depot operating at 85% of capacity. The Napier depot, called NCP, is a 2.8 hectare depot operating at 55% capacity.

[10] All capacity figures are correct as of DEC 2018

Figure 9: Empty container depot in Auckland, provided by GoogleEarth (MCP)

Figure 10: Empty container depot in Tauranga provided by GoogleEarth (MMP)

Figure 11: Empty container park in Napier provided by GoogleEarth (NCP)

All of the depots here have placed their wash, repair, and survey sections in different areas according to what seemed most logical for the operational staff at time of yard construction. However, this has resulted in some containers being handled as many as 6-7 times as it moves from truck/rail, to survey, to wash, to repair, to the AV stack, and then finally back onto truck/rail. This lift-number varies depending on whether the container requires repairs or not. If a standard layout with an overhead gantry crane and a multi-use area is implemented, then some of this overhandling can be eliminated from the process. However, each of these four yards has different shapes, and different volumes.

A single crane has been calculated to increase storage capacity by an average of 1.9x per hectare (Saanen & Valkengoed, p.1567, 2005). Even when taking into account those yards with faster turnover, a crane can still reasonably expect to increase storage capacity by 1.6x per hectare. It achieves this through a higher density of stacking at a lower height. Rather than stacking 8-9 TEU high, a gantry crane would stack 5-6 TEU high, but would not require any space between the containers. This also caps the number of lifts for any particular container at 6 lifts.[11]

The calculations below show both a conservative and a generous estimate of increased efficiencies in land use for each site (Table 1). These calculations are rough, and are only meant to give an indication of which site to pick based on the greatest impact. After the site is picked, these calculations will be finalised in greater detail.

Table 1: Impact of gantry cranes on effective storage capacity of container depots

	Area (hectares)	**Current Storage Capacity (TEUs)**	**Conservative Estimate (1.6x per hectare)**	**Generous Estimate (1.9x per hectare)**
Auckland (OCP)	4.2	5,820	9,312	11,058
Auckland (MCP)	2.4	4,541	7,265	8,627
Tauranga (MMP)	3	4,950	7,920	9,405
Napier (NCP)	2.8	3,216	5,145	6,110

The calculation for the storage capacity of these yards at 100% utility is based on the following:

100% storage capacity = (Usable Land - Survey/Wash/Repair Area - Forkhoist Lanes) x (1200 TEU per hectare stacked at 6 containers high)

100% storage capacity = (Usable Land - Survey/Wash/Repair Area - Forkhoist Lanes) x (1600 TEU per hectare stacked at 8 containers high)

[11] The minimum number of lifts would be: truck to buffer zone, buffer zone to multi-use area, multi-use area to storage, storage to truck. An additional 2 lifts has been added for any housekeeping movements that may be required.

The lanes for forklifts to drive down are set at a standard width of 15.5m. Stacking either 6 TEU high or 8 TEU high depends on council regulations, size of the forkhoists deployed, and other health and safety restrictions, such as high wind speed areas. For high density sites like Auckland and Tauranga, containers will be stacked at 8 TEU high. Whereas at lower density sites like Napier, containers will be stacked at 6 TEU high.

Usable Land is deemed as such according to professional valuations of the yards. For instance, according to a professional valuation of the Auckland OCP yard completed in 2017, the Usable Land is actually only 42,669 sqm. 870 sqm of this is a non-usable drainage strip, with additional non-usable access areas and curtilage areas equalling 4,905 sqm. This makes the site as a whole come to a total of 48,444 sqm, but the yard space actually in use is 4.26 hectares.

In the event of overcapacity, the multi-use space can be decreased in size, with the resulting space used for storage purposes. However, this is considered dangerous and ill-advised. It also reduces the size of the batch which can be processed at once, slowing operations overall.

Most overhead semi-automatic gantry cranes come in a standard size with a span between 20.8 meters and 32.4 meters wide (Liebherr, 2019 & Konecranes, 2019). This standard size has a safe work load of 40-50 tonnes, and stacks 1 TEU over 4 TEU high, meaning that the crane can stack 4 TEU high, with a space above that which the crane uses to lift and move boxes around the stacks. However, as previously mentioned, the gantry crane being discussed here is not a standard model and can stack 1 TEU over 6 TEU, as below. (Kocks, 2016).

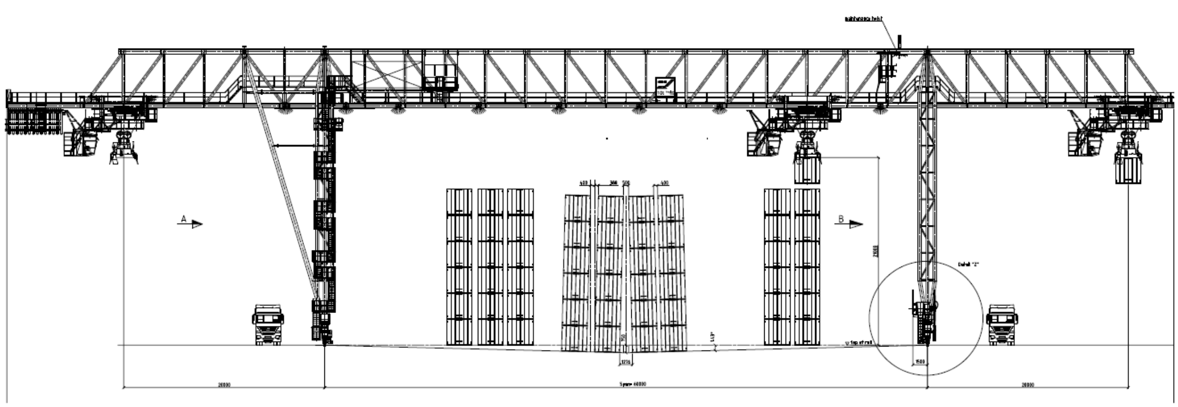


Figure 12: Side-view of a rail mounted gantry crane (image courtesy of Kocks Ardelt)

When deciding where to put the crane for its maximum potential, we must evaluate the context and constraints of each of the sites listed above. Not all of these sites may be suited to the implementation of a crane based on service requirements. Moreover, they each have different shapes and yard layouts. Auckland primarily deals with import containers that have arrived battered and are in need of repair. Tauranga and Napier primarily deal with export containers, and are therefore subjected to the seasonality of New Zealand primary producers. Since Napier is not as large and/or as busy a port as Tauranga, the impacts of seasonality are even more severe, as it does not pick up many additional customers during the off-peak season.

In terms of the adjacency planning and flow of these yards, Napier has the most efficient layout, but only because it tends to run at lower capacity overall. The survey, repair, and wash sections are located closely together, minimising the time a hoist spends in transit between terminuses. The next best configured yard is Tauranga (MMP), which maximises its L-shaped yard by placing its survey, repair, and wash sections at the joint of the yard.

The Auckland MCP yard is a highly developed space; it is one of only two yards ContainerCo operates that has tarmac. However, Auckland MCP is also the smallest of these sites, and would not be able to reap as much benefit from the installation of a crane in terms of raw volume. Moreover, the lease is only on a 3-month by 3-month basis. While the relationship with the landlord is reportedly very good, ContainerCo would not want to install a crane on a site that could not secure a long term lease. The crane would be costly to move, and moving disrupt operations on two sites. On the other hand, the Auckland OCP yard is the largest of the sites. On average, Auckland also operates without seasonality, and at a much higher capacity than the other regions.

Based on the above analysis, an incremental rollout plan was developed. Due to constraints on raising capital, it is not feasible to push cranes into all of these yards at once. Instead, Auckland OCP has been identified as the first target for crane implementation due to its size, its steady flow of import containers, and its high-capacity, high-density operations. After additional capital is raised, another crane can be implemented in Tauranga (MMP). The most seasonal of these sites, Napier, would struggle to justify a crane unless it could smooth out the overall throughput of containers. Otherwise, implementing a crane would see significant asset underutilisation during the off-season.

To further explore the current operations of the chosen depot, below is a graph of each of the stages of the current operations within the Auckland OCP depot. This graph is not meant to show the exact geographic location of each stage. It is simply a representation of the current stages of operations.

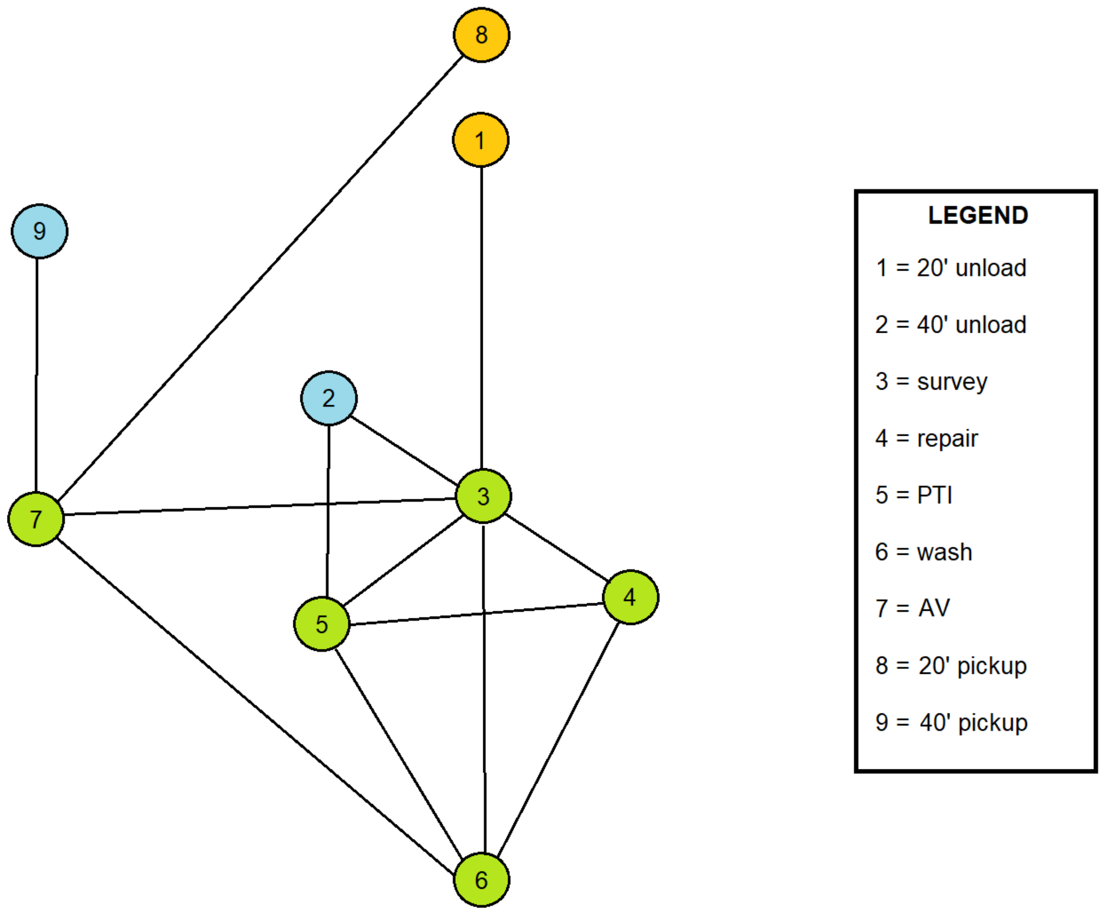


Figure 13 - As is operations interwork centre flow graph

The general location of certain areas will reflect the processes. The AV stacks, for instance, are not localised to a single area; that would be an inefficient use of land. The AV stack is also constantly rotated – shipping companies wish to apply FIFO principles, and lifts are performed to move older stock to the front.

Any calculations around how often and how many containers move around the yard are made difficult due to the fact that the current operations tend to be amorphous. Hoist drivers and yard managers will, on any given day, alter the "picking rules" for taking containers from the stack; this depends on demand, but also on managing outside factors such as the railway timetable or a ship departure. Drivers describe the yard in terms of "rotating stacks." Units from one stack will often be prioritised, usually because they have been in the yard longer, or they are a specific grade of container. (Most shipping companies do not require an exact container unit; rather they ask for a type and grade). Incoming containers are fed into another newer stack. The next day, another stack of older containers will be selected, and another new stack laid down. There is a push and pull flow throughout the yard that is very *ad hoc*. While this makes them more efficient in batch handling processes this increases costs past a certain point as the business scales.

It also means that, when delving into the finer details of the operations, we encounter difficulties in knowing what the current yard layout actually is. It is constantly shifting. This is not helped by the fact that, in the specific case of the business under review, the terminal operating system (TOS) does not currently track individual boxes throughout the yard. Inventory control consists of gate-ins, status changes, and gate-outs. *Id est*: when a truck arrives at the yard with containers, what work has been completed on a particular box, and when a truck leaves the yard with containers. What happens within is a classic black box problem.

In the as-is operations, a box acts like an electron. Generally, one knows what valence it occupies, its vague location in the yard, but one can never know its exact location. The current operations are reliant upon the people who handle these boxes: the container controllers, the hoist drivers, the washers and repairers, the surveyors, and the truck drivers. Add this to the wider constraints of the land itself, as well as the wider global supply chain, and locating the precise position of any one of millions of units becomes a seemingly insurmountable task. And yet, it is done every day.

This is, itself, an excellent representation of practice versus praxis. There are activities happening on the front-line operations that have strategic consequences we must consider. If we do not take into account the everyday *praxes* of front-line staff, then the artefact's effectiveness will be at best underwhelming.

CHAPTER 5: FUTURE IMPLEMENTATION

5.1 SUMMARY

Whereas the last chapter identified what an empty container depot is, how it operates, and what the waste is within these processes, this chapter posits potential solutions for that waste. The chosen site, Auckland OCP, is explored in more depth for possible solutions for how a crane might implemented in the yard. These possible solutions are meant to address the implementation of lean in a working depot. Further analysis of how the implementation of lean may affect the stakeholders and other HRM matters will take place in chapter 6.

For the sake of clarity, an executive summary of all of the major conclusions in the next two chapters has been compiled below. The conclusion is that a single large crane with a configured multi-use area (Solution 5a) should be installed at the Auckland OCP yard. This site is preferred because a crane would stretch over the entirety of the yard, leaving room for trucks to drive, for critical business processes to take place, and for storage. This maximises the storage capacity of the land, removes unnecessary lifts, and streamlines the flow of containers through the geography of the yard. It is also an economical option when compared to forkhoists, as a crane costs less to operate over time. Once additional capital is raised, more cranes then can be installed at other depots via an incremental rollout process.

This summary serves as a reminder to the reader of key facts and figures regarding the argument for implementing a crane:

THE FOUR SITE OPTIONS	Auckland OCP (4.2 hectares) Auckland MCP (2.4 hectares) Tauranga MMP (3 hectares) Napier NCP (2.8 hectares)
CURRENT STORAGE CAPACITY	Auckland OCP = 5,820 TEUs Auckland MCP = 4,541 TEUs Tauranga MMP = 4,950 TEUs Napier NCP = 3,216 TEUS
EXPECTED STORAGE CAPACITY INCREASE WITH A CRANE	Auckland OCP = 9,312 TEUs Auckland MCP = 7,265 TEUs

(CONSERVATIVE ESTIMATE 1.6X)	Tauranga MMP = 7,920 TEUs Napier NCP = 5,145 TEUs
EXPECTED STORAGE CAPACITY INCREASE WITH A CRANE (GENEROUS ESTIMATE 1.9X)	Auckland OCP = 11,058 TEUs Auckland MCP = 8,627 TEUs Tauranga MMP = 9,405 TEUs Napier NCP = 6,110 TEUs
SITE IDENTIFIED FOR CRANE IMPLEMENTATION	Auckland OCP, based on: size of the site, length of the lease term, consistency of volumes, and the need for increased storage facilities in the Auckland region
INCREASE IN VOLUME DEMANDS AT THE SITE OVER 10 YEARS	Using a simple compound interest formula x(1+r)^n where x is 5,820 TEUs and r is the annual interest rate of 6%, the volume demands will increase as follows: 6,288 TEUs in 3 years 7,067 TEUs in 5 years 7,939 TEUs in 7 years 9,455 TEUs in 10 years
MAXIMUM NUMBER OF TRUCKS AND CONTAINER MOVEMENTS	A stress-test day at the Auckland OCP yard might expect 426 gate-ins and gate-outs. This is 216 trucks needing to be serviced every day. Assuming each truck carries 3 containers, this is a total of 1,296 movements per day (not including other lifts around the yard).
Solution 1	One crane covering the whole site. Crane travel = 154m Trolley travel = 232m Maximum Capacity: 12,450 TEU Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.83mins Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width of the crane however, is impractical. This solution is not recommended for use.
Solution 2	One crane covering the whole site with the orientation reversed from Solution 1.

	Crane travel = 232m Trolley travel = 154m Maximum Capacity: 11,856 TEU Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.83mins Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width and speed of the crane is feasible given the constraints. This solution is recommended for a yard that only seeks to store containers, as it does not include a multi-use area.
Solution 3	Two cranes in parallel covering the whole site with the orientation reversed from Solution 1. Crane travel = 117m each Trolley travel = 154m Maximum Capacity: 11,856 TEU Speed: together the cranes can lift and store 3,720 TEUs during productive hours at 2 lifts every 0.83mins. Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width and speed of the crane is feasible given the constraints. However, the cost of implementing two cranes is much higher than the cost of implementing one. If the budget allows, then this solution is recommended for a yard that only seeks to store containers, as it does not include a multi-use area.
Solution 4	One crane from solution 3 across half the site. Crane travel = 117m Trolley travel = 154m Maximum Capacity: 5,928 TEU Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lift every 0.83mins Conclusion: This crane configuration meets the required stacking densities and speeds. The

	operational width and speed of the crane is feasible given the constraints. This configuration also allows for current subleasing and future growth across the unused section of the site. This solution is recommended for a yard that wishes to meet current demands and extend its growth, as well as a yard that only seeks to store containers, as it does not include a multi-use area.
Solution 5	One crane from solution 2 with a multi-use area. Crane travel = 232m Trolley travel = 154m Maximum Capacity: 11,856 TEU Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.92mins. This is 0.09mins short of the required 1 lift every 0.83mins Conclusion: This crane configuration meets the required stacking densities, but does not meet the required speeds. The operational width of the crane is feasible given the constraints. A re-orientation of the zones within this solution is needed to meet the speed requirements.
Solution 6	One crane from solution 4 with a multi-use area Crane travel = 117m Trolley travel = 154m Maximum Capacity: 5,928 TEU Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.92mins. This is 0.09mins short of the required 1 lift every 0.83mins Conclusion: This crane configuration meets the required stacking densities, but does not meet the required speeds. The operational width of the crane is feasible given the constraints. A re-orientation of the zones within this solution is needed to meet the speed requirements.
Solution 5a and 5b	Solution 5a = Solution 5 with Zone 1 orientation reconfigured to be a 20TEUx4TEU block covering

	1,171.2sqm Solution 5b = Solution 5 with Zone 1 orientation reconfigured to be a 6TEUx12TEU block covering 1,054.08sqm Solution 5a allows for more TEUs in Zone 1 at 80TEUs. Solution 5b is the absolute minimum TEUs needed for Zone 1 at 72 TEUs. Both solutions fall within the 1,175sqm space allowed, and the speed requirements of 1 lift every 0.83mins. Conclusion: Solution 5a is recommended. It meets the required stacking densities and speeds. It also gives the mobile survey and repair teams enough space to operate without overcrowding them.
FINANCIAL IMPACTS	A crane at the Auckland OCP yard was found to decrease total costs as well as costs per TEU handled. Total Costs p.a. with 3 hoists = $3,567,471 Total Costs p.a. with 1 crane = $2,425,277 Costs per TEU with 3 hoists = $56.64/TEU Costs per TEU with 1 crane = $38.50/TEU
RISK ANALYSIS	Some of the risks of installing a crane include: • Classic project management risks such as change in schedule and budget, poor communication and implementation, etc. • A shift in available volumes in the Auckland region • A shift in types of containers, which would affect gridding and process flows • An increase in average storage duration decreasing volume turnover • Council regulations interfering with crane implementation or operating hours • The possibility of a breakdown leaving the yard unable to operate for days at a time

5.2 FUTURE SCENARIOS

The plan for Auckland OCP would be to make the site purely a storage facility. Wash and repair facilities would be removed from the site. The multi-use area would remain, with its survey team and rapid repair team. A crane could cover the whole site, and containers funnelled into OCP from the other Auckland sites. This would reduce the overcapacity being experienced by every site in the Auckland region, which is being driven by a structural increase of container volume in the Auckland market.

The greatest strategic constraint for ContainerCo, especially over time, is simple: storage capacity. In Auckland, storage capacity near the port is a race against the growth of the city itself. This growth imposes both demands for more infrastructure, while increasing the price of large sections of land suitable for industrial use. It is essential to quickly secure a means of either:

a) Increasing current capacity through increased density of stacking;
b) Increasing the amount of land leased or purchased by finding cheap sections of land on the outer fringes of the city itself; or,
c) Both a and b.

Kocks Ardelt sent through an example overhead gantry crane with the dimensions of 70mx300m. A crane of this size can fit a maximum of 5,880 TEUs beneath it. To calculate the volumes of TEU beneath a crane, we have used the International Standards Organisation (ISO) container dimensions as follows:

TEU Length = 20ft (6.1m)

TEU Width = 8ft (2.4m)

TEU Height = 9.6ft (2.9m)

Please note that shipping containers can come in a variety of sizes, as well as be heavily modified to suit customer needs. However, for the sake of simplicity these measurements are considered a single standard TEU. It is also assumed that reefer boxes can be stacked with general grade boxes. The crane will treat reefer boxes and general grade boxes the same.[12] To give an idea of how the crane and boxes will be oriented, below is a detailed picture of a rail mounted gantry crane by Konecrane:

Figure 14 - Overhead rail-mounted gantry crane (Boxporter RMG, retrieved 20 February 2019)

It should be noted that this example is a smaller version of what is intended for use in the Auckland yard, however the orientation and mechanisms are the same. The crane would still require some small gaps between stacks of four wide, in order to help the spreader find each box. If they are too densely packed, this slows operational time, since the spreader has to work harder in order to locate the box. This works out to containers stacked to a maximum of 20 across, 49 deep, and 6 TEU high for TEUs. If they were 40ft long boxes, then it would be 24 TEU deep rather than 49 TEU deep.

[12] Reefer boxes will only need to be handled differently by manual survey and repair teams in the multi-use area. Ergo, the crane itself will not need to alter its handling of reefer containers *versus* general grade boxes.

A front view of the stack would therefore be as follows:

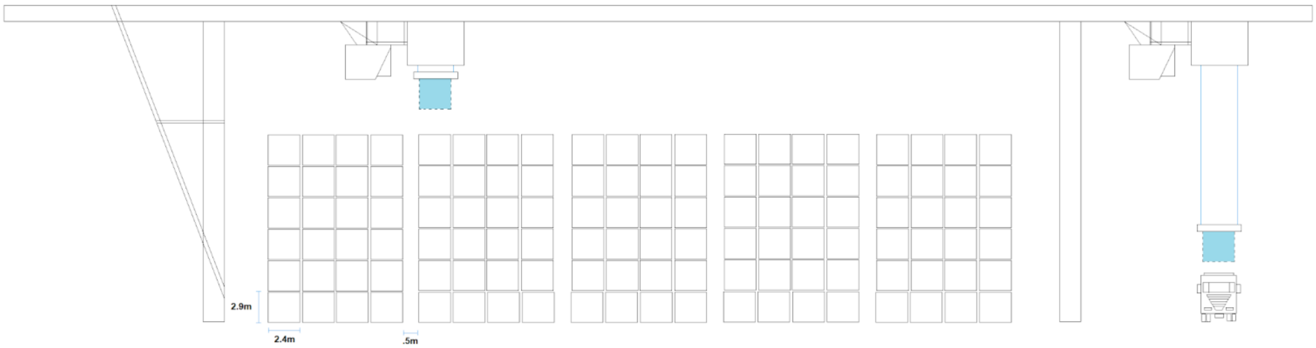


Figure 15 - Front view of the crane stacking

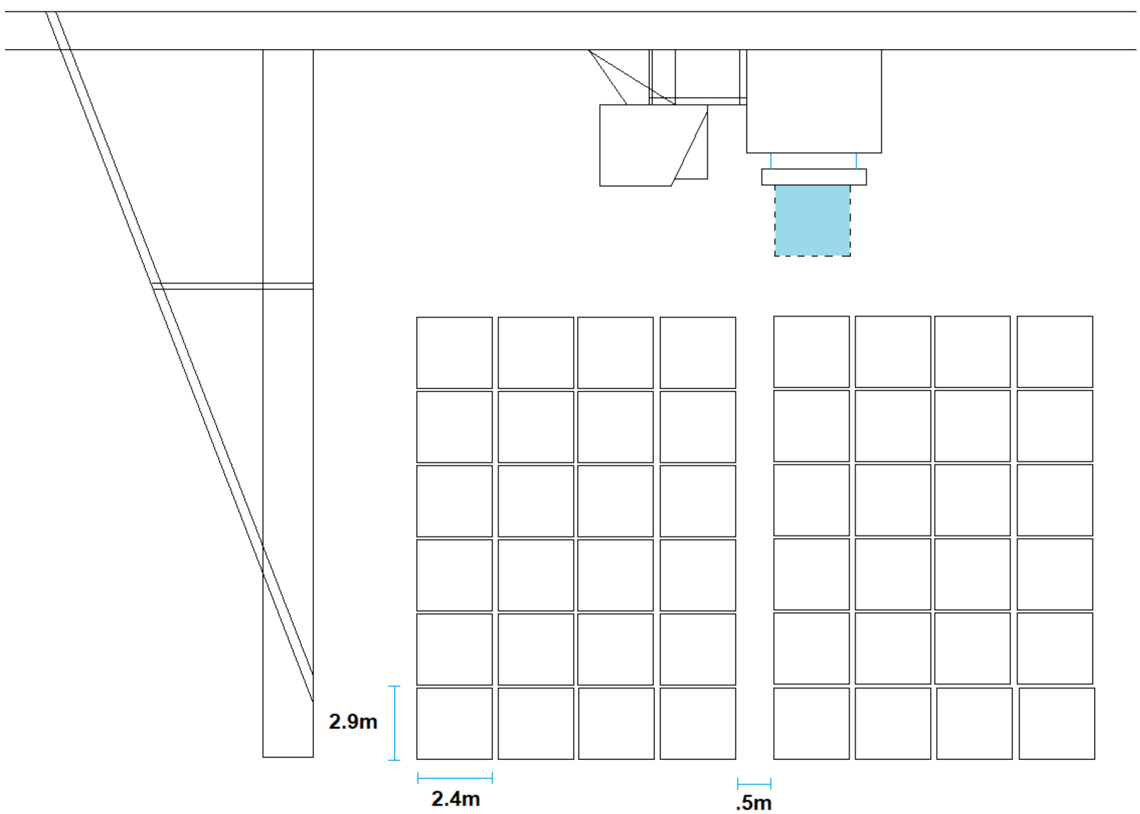


Figure 16 - Close up front view of crane stacking

To further understand the orientation of the crane and the containers, Figure 18 shows how this 70mx300m crane would look when viewed from above. The arrows indicate which way the crane would travel on its wheels along the stacks of containers.

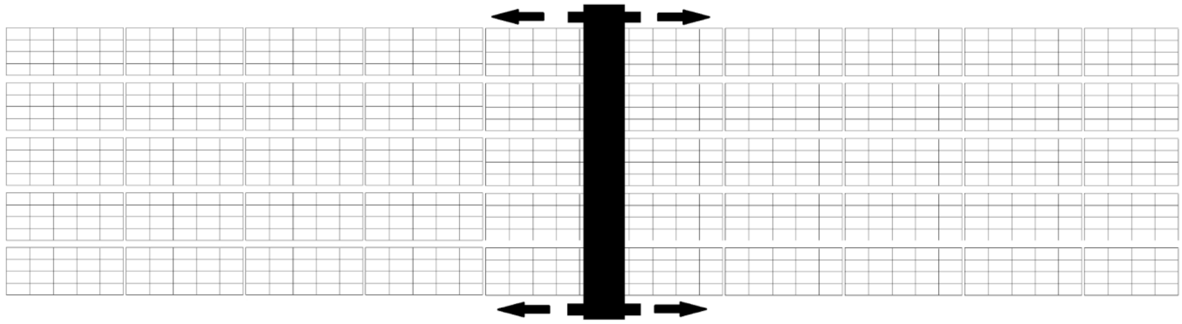


Figure 17 – Example container and crane orientation

The flow of containers through the yard shown in the *as-is* operations of Figure 9, can be updated to match the constraints of a crane. Now, the complete flow of *to-be* operations in the Auckland OCP yard during productive hours with a crane can be mapped as follows:[13]

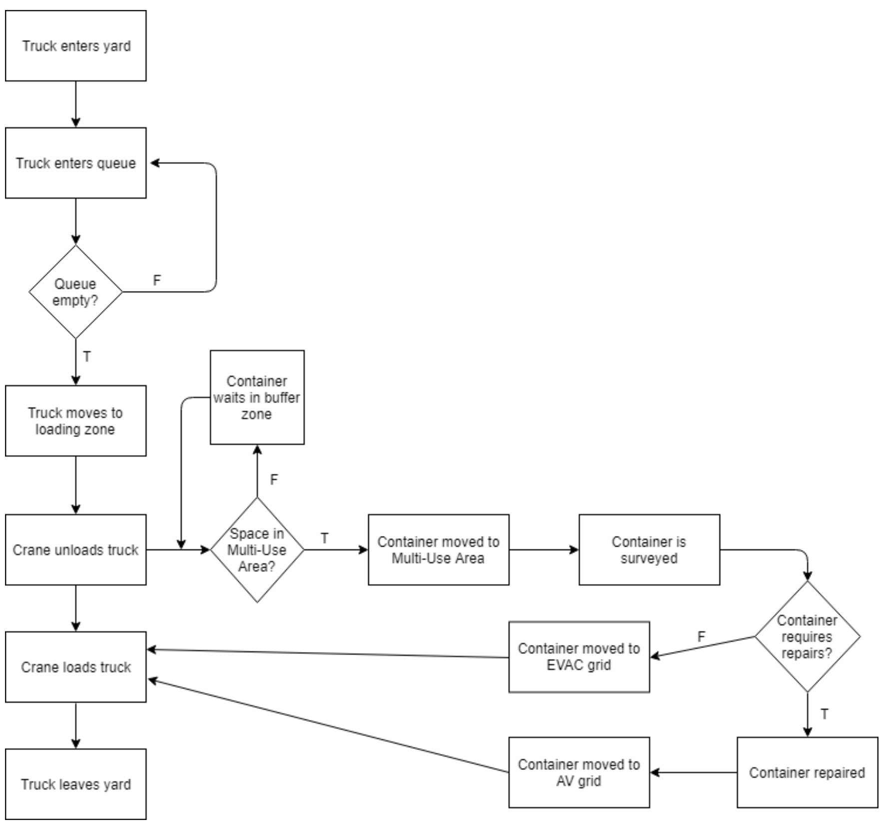


Figure 18 – Final to-be process flow at OCP yard with gantry crane

[13] This process flow does not take into consideration the non-productive 6 hour period between 10pm and 4am, in which the crane will be performing housekeeping movements to prepare for the following day's expected productive lifts.

5.2.1 KEY ASSUMPTIONS

Any crane in practice will need to be custom-designed in order to match the constraints of both the site and the operations. Firstly, the crane must adhere to the dimensions of the site, which are 170m wide x 250m long. Critical factors which must be determined are:

- what this current density requirement is;
- how this density matches container growth projections in New Zealand; and,
- how much land (if any) can be spared for alternative uses, such as subleasing?

The maximum density can be calculated purely based on how large a crane can be fit onto the site, given the site's constraints. These constraints include: 8m roadways for the trucks, and a space for survey operations. Below is a council drawing of the OCP site, including the long driveway leading up to the site itself. The rectangular OCP site is marked number 3, and the driveway travels towards the site from the northwest. This driveway is a shared space that trucks can drive up and down. It has two lanes.

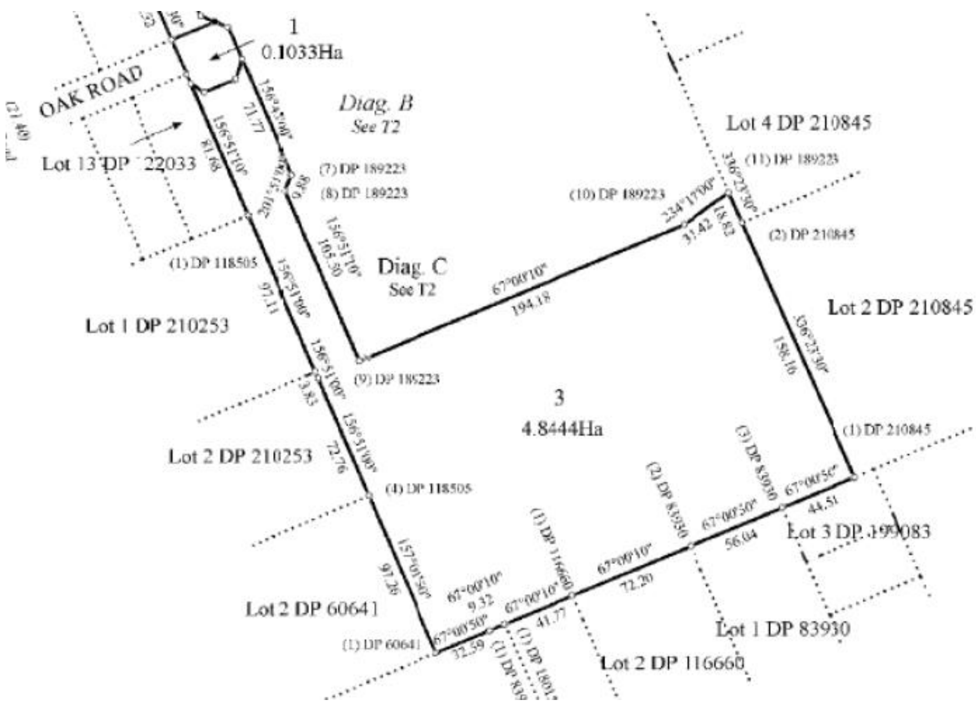


Figure 19 – Oak Road container park (OCP) city council drawing

Each cross-section block within the width of the crane (ie/ each 4x6 TEU stack) requires an additional 10m of operational space, which includes the .5m space between each block.

Ergo, a 70m wide crane can fit 5 blocks of 4x6 TEU stacks. Determining how many TEUs can fit down the length of the crane is simply a matter of dividing the length of the crane by the length of a container at 6.1m, as there is no gap that needs to be left lengthwise in the stacks.

The heaviest day in the last 6 months with regards to truck arrivals and departures at Auckland OCP yard was 426 gate-ins and gate-outs. Truck bookings with VBS are made per container, not per truck. For example: if a single truck is carrying 3 containers, there will be three bookings, not one booking. For the sake of stress-testing the system, if we as assume that each truck is taking a maximum of 3 containers in and out of the yard, this means there were 142 trucks entering the yard, and a total of 1,296 containers being handled in a single day at this site, not including other lifts around the yard.[14]

A series of 6 interlocked solution approaches will be investigated ranging from aspirational to fully checked out/recommended. Site/crane capacity and crane speed are the key variables of interest. If the solution approach produces results that are infeasible, other issues such as truck queue length and truck waiting time are irrelevant and need not be checked out.

As per the specifications given by Kocks Ardelt, the speeds at which the crane moves are indicative for modified barge cranes in general. They are as follows:

Hoist speed = 60 m/min

Trolley travel speed = 120 m/min

Crane travel speed = 100 m/min

Dwell time = 5,820TEU/1,296TEU = 4.49 days; turnover = 5,820 TEU/4 days = 1,455 TEU per day. Each day is split between full production (18 hours) and no production (6 hours). No

[14] Please note that it is incredibly unlikely that every truck would have been bringing in 3 containers and taking out 3 containers. More likely it was bringing in 1 and taking away 1. Moreover, due to regional trade imbalances in the Auckland region, there were a great number more movements in Auckland than normal. This was due to a variety of factors including: one of the Ports of Auckland wharves being down, one of the Ports of Auckland cranes being down, the prospering import trade, and lastly the mass consolidation of the shipping industry. This last in particular means that the shipping companies (ie/ the customers) were massing all of their container numbers together in an attempt to achieve economies of scale, however New Zealand does not have the proper infrastructure to deal with these levels of containers, and so there was a large backup of containers in the market.

production includes double handling by crane and truck of 20% of TEU (1,164) that go offsite for washing and/or heavy cleaning, and movement of TEU within the stack. The maximum expected full production speed = 1,296TEU/18 hours = 72 TEU/hour = 1.2 TEU per minute.

The lift speed requirement is calculated based on the maximum expected full production speed. To understand how quickly 1 TEU must be lifted, a simple proportion is used as follows:

a:b::c:d

1.2 TEU:1min::1TEU:xmin

1.2 = 1x

x= 0.83mins

5.3 SOLUTIONS

Solution approach 1: Search for an ideal solution

One crane covering the whole site. Crane travel = 154m (250m – 2x8m), trolley travel = 232m. The crane must be able to make 1 lift every 0.83mins to meet 1,296 lifts during productive hours. Solution 1 results stack 6 high.

Results:

Maximum Capacity: 12,450 TEU

Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.83mins

Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width of the crane however, is impractical.[15] This solution is not recommended for use.

[15] For example: the largest overhead gantry crane built by Kone is the Goliath, which has the staggering operational width of 210m. While it may be physically possible to build an overhead gantry crane with an operational width of 232m, it would be record-breaking and very expensive, making it not feasible for the budgetary constraints of the company.

232m wide allows the crane to fit 20 blocks of 4x6 TEU stacks and 1 block of 3x6 TEU stack. That means 1 row of containers at 1 TEU deep across 20 blocks is 480 TEU + 18 TEU = 498 TEU slice. At 154m long, the column of containers can extend 25 TEUs deep. 498 TEU x 25 TEU = 12,450 TEUs.

Below is a drawing of what solution approach 1 would look like on the OCP yard. The area in blue indicates the space where the crane would sit. The red indicates the gate. Trucks would enter the gate, immediately turn left and go clockwise around the crane in a full circle before leaving again.

Please note that in Figures 21-26, the containers have been added into the pictures merely as a representation of their orientation, along with the crane. While everything else is to scale, the crane and containers are merely indicative. Moreover, the arrows indicate the flow of trucks around the yard, and the gate and loading/unloading zone has been marked in red.

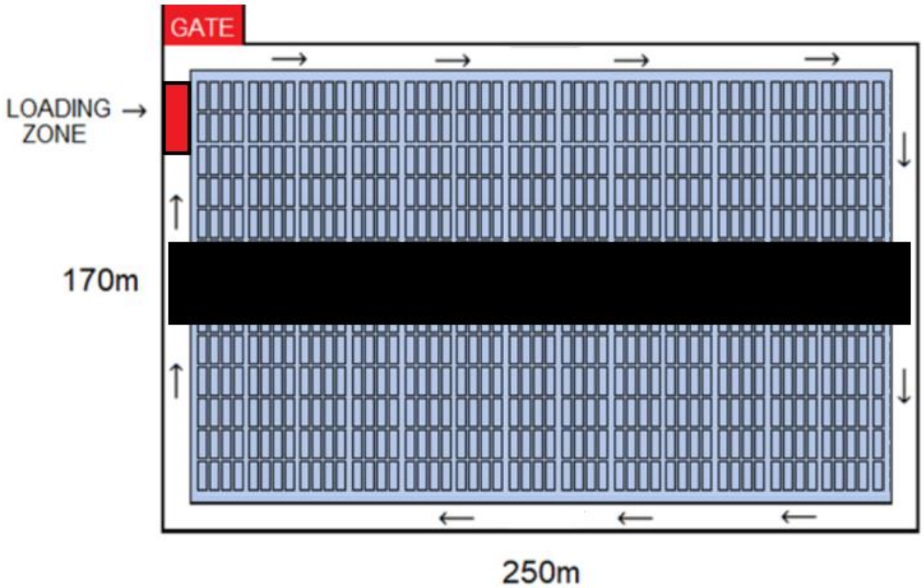


Figure 20 - Solution 1 maximum size of an overhead gantry crane at the Auckland yard

Based on the Solution 1 Speeds Table in the appendices, the crane can perform 1 lift every 0.83mins within a 3,875sqm area nearest the loading zone. 3,875sqm can hold 1,860 TEUs stacked 6 high.

Solution approach 2: A single large crane

One crane covering the whole site, with the orientation of crane and trolley reversed from the solution 1 approach. Crane travel = 232m (250m – 2x8m), trolley travel = 154m. The crane must be able to make 1 lift every 0.83mins to meet 1,296 lifts during productive hours. Solution 2 results stack 6 high.

Results:

Maximum Capacity: 11,856 TEU

Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.83mins

Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width and speed of the crane is feasible given the constraints. This solution is recommended for a yard that only seeks to store containers, as it does not include a multi-use area.

154m wide allows the crane to fit 13 blocks of 4x6 TEU stacks. That means 1 row of containers at 1 TEU deep across 13 blocks is 312 TEU. At 234m long, the column of containers can extend 38 TEUs deep. 312 TEU x 38 TEU = 11,856 TEUs.

Below is a drawing of what solution approach 1 would look like on the OCP yard. The area in blue indicates the space where the crane would sit. The red indicates the gate. Trucks would enter the gate, immediately turn left and go clockwise around the crane in a full circle before leaving again.

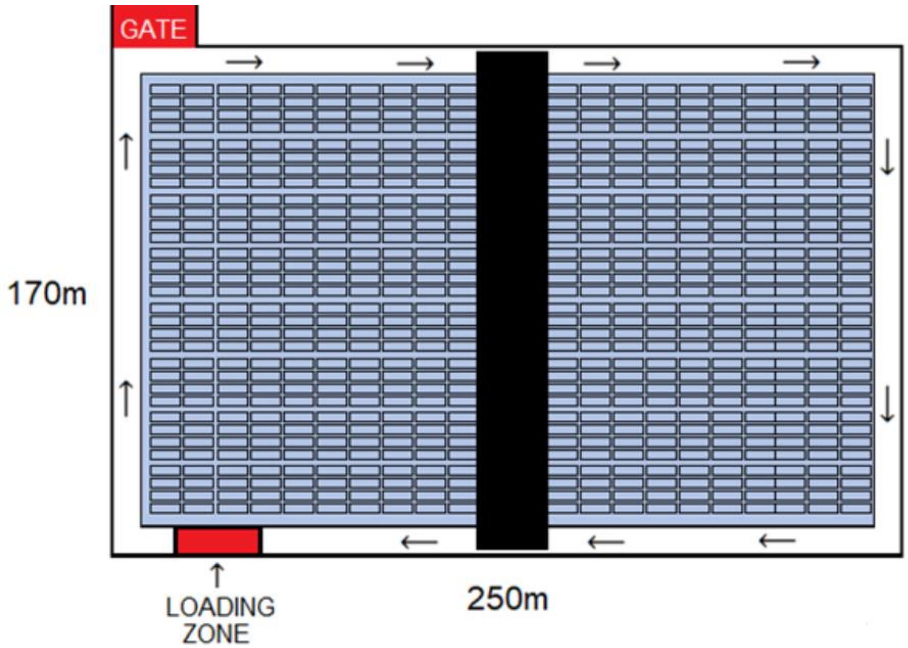


Figure 21 - Solution 2 maximum size of an overhead gantry crane at the Auckland yard

Based on the Solution 2 Speeds Table in the appendices, the crane can perform 1 lift every 0.83mins within a 3,875sqm area nearest the loading zone. 3,875sqm can hold 1,860 TEUs stacked 6 high.

<u>Solution approach 3: Two identical cranes</u>

Two cranes working side by side were explored. Crane travel for each crane = (250m – 2x8m)/2 = 234/2 = 117m. Trolley travel for each crane = 170m -2x8m = 154m. Crane must be able to handle 1,296 TEU lifts a day, at 1 lift every 0.83mins. Solution 3 results stack 6 high.

Results (for the aggregate performance of two cranes):

Maximum Capacity: 11,856 TEU

Speed: together the cranes can lift and store 3,720 TEUs during productive hours at 2 lifts every 0.83mins.

Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width and speed of the crane is feasible given the constraints. However, the cost of implementing two cranes is much higher than the cost of implementing one.

If the budget allows, then this solution is recommended for a yard that only seeks to store containers, as it does not include a multi-use area.

154m wide allows the crane to fit 13 blocks of 4x6 TEU stacks. That means 1 row of containers at 1 TEU deep across 13 blocks is 312 TEU. At two cranes each 117m long, the column of containers can extend 38 TEUs deep. 312 TEU x 38 TEU = 11,856 TEUs.

Below is a drawing of what solution approach 3 would look like on the OCP yard. The area in blue indicates the space where the crane would sit. The red indicates the gate. Trucks would enter the gate, immediately turn left and go clockwise around the crane in a full circle before leaving again.

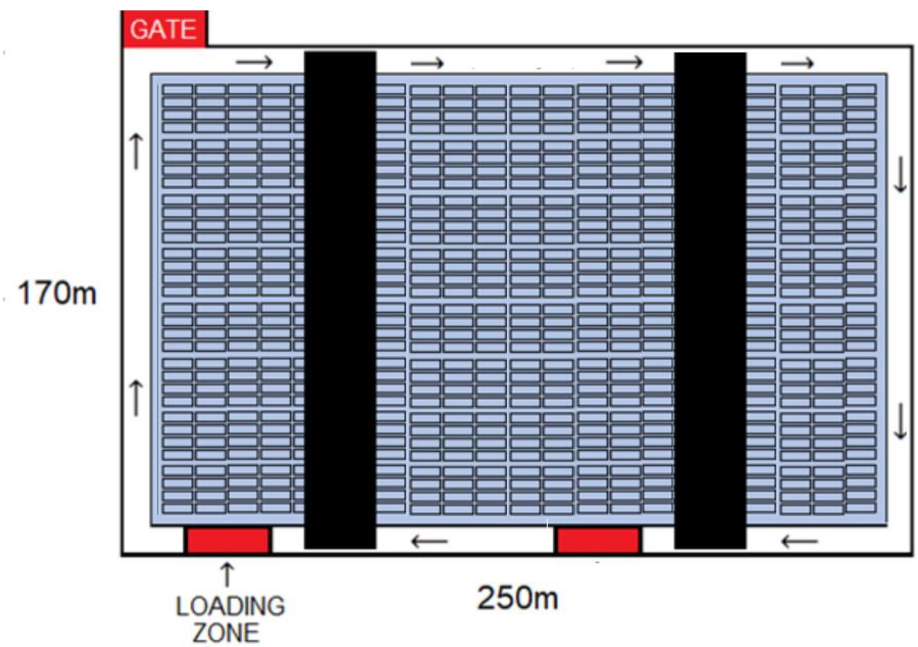


Figure 22 - Solution 3 maximum size of two overhead gantry cranes at the Auckland yard

Based on the Solution 3 Speeds Table in the appendices, each crane can perform 1 lift every 0.83mins within a 3,875sqm area nearest the loading zone. 3,875sqm can hold 1,860 TEUs stacked 6 high. With 2 cranes, this capacity and speed is exactly doubled. Ergo, the cranes together can perform 2 lifts every 0.83mins within 2 x 3,875sqm areas nearest their respective loading zones. This amounts to 3,720 TEUs stacked 6 high over 7,750sqm

Solution approach 4: A single version of the solution 3 crane nearest the gate, lease the rest

One crane from solution 3 was explored. Crane travel = (250m – 2x8m)/2 = 234/2 = 117m. Trolley travel = 170m -2x8m = 154m. Solution 4 results stack 6 high.

Results:

Maximum Capacity: 5,928 TEU

Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lift every 0.83mins

Conclusion: This crane configuration meets the required stacking densities and speeds. The operational width and speed of the crane is feasible given the constraints. This configuration also allows for current subleasing and future growth across the unused section of the site. This solution is recommended for a yard that wishes to meet current demands and extend its growth, as well as a yard that only seeks to store containers, as it does not include a multi-use area.

Solution 4 involving a crane on the Auckland OCP site would differ, in that it would change the crane's specifications so that it would only handle the current volume demands of 5,820 TEUs. If we keep the width of the crane the same, it allows the maximum spread of containers, while also allowing for growth lengthwise.

154m wide allows the crane to fit 13 blocks of 4x6 TEU stacks. That means 1 row of containers at 1 TEU deep across 13 blocks is 312 TEU. At 117m long, the column of containers can extend 19 TEUs deep. 312 TEU x 19 TEU = 5,928 TEUs.

Below is a drawing of what solution approach 4 would look like on the OCP yard. The area in blue indicates the space where the crane would sit. The red indicates the gate. Trucks would enter the gate, immediately turn left and go clockwise around the crane in a full circle before leaving again.

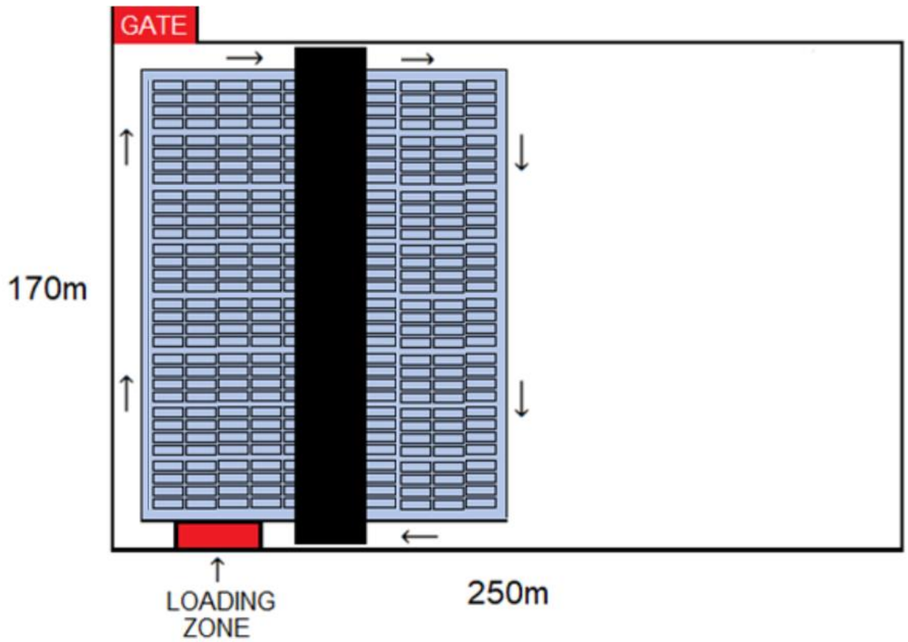


Figure 23 – Solution 4 minimum size of an overhead gantry crane at the Auckland yard

Based on the Solution 4 Speeds Table in the appendices, the crane can perform 1 lift every 0.83mins within a 3,875sqm area nearest the loading zone. 3,875sqm can hold 1,860 TEUs stacked 6 high.

Solution approach 5: Solution approach 2, with multi-use area

One crane covering the whole site was explored. Crane travel = 232m (250m – 2x8m). Trolley travel = 154m.Solution 5 results stack 6 high.

Functions in the multi-use area need to be synchronised with the crane. This is achieved via zoning:

Zone 1 (the rectangle closest to the loading zone with TEU stacked one high, prioritised, expandable)

Zone 2 (the rectangle next further out from Zone 1, priority 2, full height, target location during no production period as well as during full production period; target location during no production period as well as during full production period)

Zone 3 (the rectangle furthest out from the loading zone, priority 3, full height, not expected to move except during non-production period from the hours of 10pm-4am when reshuffling containers)

Results:

Maximum Capacity: 10,896 TEU

Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.92mins. This is 0.09mins short of the required 1 lift every 0.83mins

Conclusion: This crane configuration meets the required stacking densities, but does not meet the required speeds. The operational width of the crane is feasible given the constraints. A re-orientation of the zones within this solution is needed to meet the speed requirements.

154m wide allows the crane to fit 13 blocks of 4x6 TEU stacks. That means 1 row of containers at 1 TEU deep across 13 blocks is 312 TEU. At 234m long, the column of containers can extend 38 TEUs deep. 312 TEU x 38 TEU = 11,856 TEUs. The Zone 1 area (which holds 192 TEUs) must be removed from this total. The multi-use area = 57.6mx48.8m = 24TEU wide x 8TEU long x 6TEU deep = 1,152TEU. Ergo, 11,856 TEU - 1,152TEU + 192 TEUs = 10,896 TEU maximum capacity.

Below is a drawing of what solution approach 5 would look like on the OCP yard. The area in blue indicates the space where the crane would sit. The red indicates the gate. Trucks would enter the gate, immediately turn left and go clockwise around the crane in a full circle before leaving again.

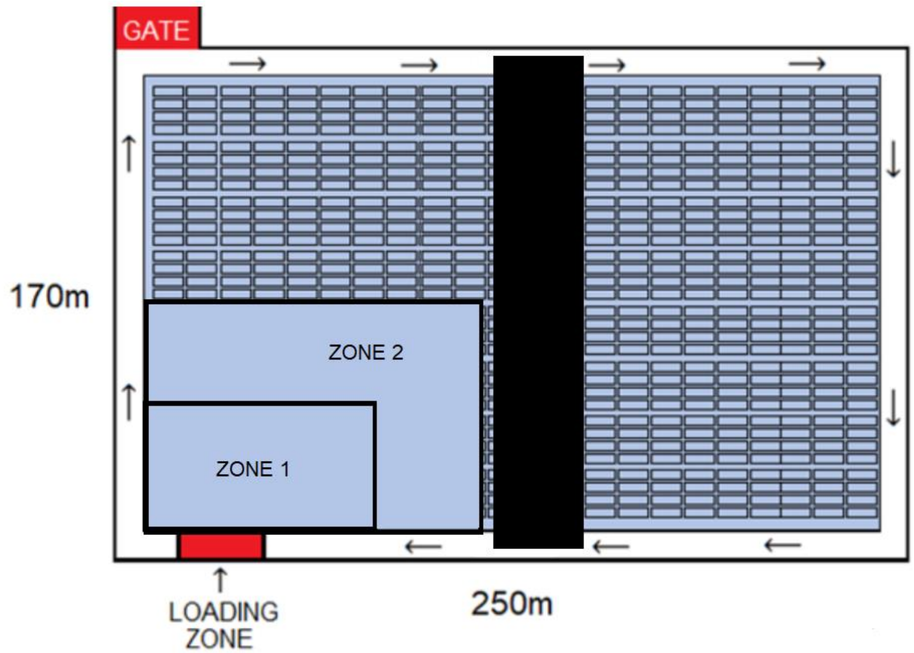


Figure 24 - Solution 5 maximum size of an overhead gantry crane at the Auckland yard

Based on the Solution 5 Speeds Table in the appendices, the crane can perform 1 lift every 0.83mins within a 3,875sqm area nearest the loading zone. Due to the configuration of Zone 1 taking up so large a space near the loading zone, Zone 2 is not within the speed requirements of 1 lift every 0.83mins. The Zone 2 orientation is such that, based on the average speeds in the Solution 5 Speeds Table in the appendices, it can make 1 lift every 0.92mins. This is 0.09mins short of the required speed.

<u>Solution approach 6: Solution approach 4, with multi-use area</u>

One crane from solution 4 was explored. Crane travel for each crane = 170m -2x8m = 154m, trolley travel for each crane = (250m – 2x8m)/2 = 234/2 = 117m; Solution 5 results stack 6 high.

Functions in the multi-use area need to be synchronised with the crane. This is achieved via zoning:

Zone 1 (the rectangle closest to the loading zone with TEU stacked one high, prioritised, expandable)

Zone 2 (the rectangle next further out from Zone 1, priority 2, full height, target location during no production period as well as during full production period; target location during no production period as well as during full production period)

Zone 3 (the rectangle furthest out from the loading zone, priority 3, full height, not expected to move except during non-production period from the hours of 10pm-4am when reshuffling containers)

Results:

Maximum Capacity: 4,968 TEU

Speed: the crane can lift and store 1,860 TEUs during productive hours at 1 lifts every 0.92mins. This is 0.09mins short of the required 1 lift every 0.83mins

Conclusion: This crane configuration meets the required stacking densities, but does not meet the required speeds. The operational width of the crane is feasible given the constraints. A re-orientation of the zones within this solution is needed to meet the speed requirements.

154m wide allows the crane to fit 13 blocks of 4x6 TEU stacks. That means 1 row of containers at 1 TEU deep across 13 blocks is 312 TEU. At 117m long, the column of containers can extend 19 TEUs deep. 312 TEU x 19 TEU = 5,928 TEUs. The Zone 1 area (which holds 192 TEUs) must be removed from this total. The multi-use area = 57.6mx48.8m = 24TEU wide x 8TEU long x 6TEU deep = 1,152TEU. Ergo, 5,928 TEU - 1,152 TEU + 192 TEU = 4,968 TEU maximum capacity.

Below is a drawing of what solution approach 6 would look like on the OCP yard. The area in blue indicates the space where the crane would sit. The red indicates the gate. Trucks would enter the gate, immediately turn left and go clockwise around the crane in a full circle before leaving again.

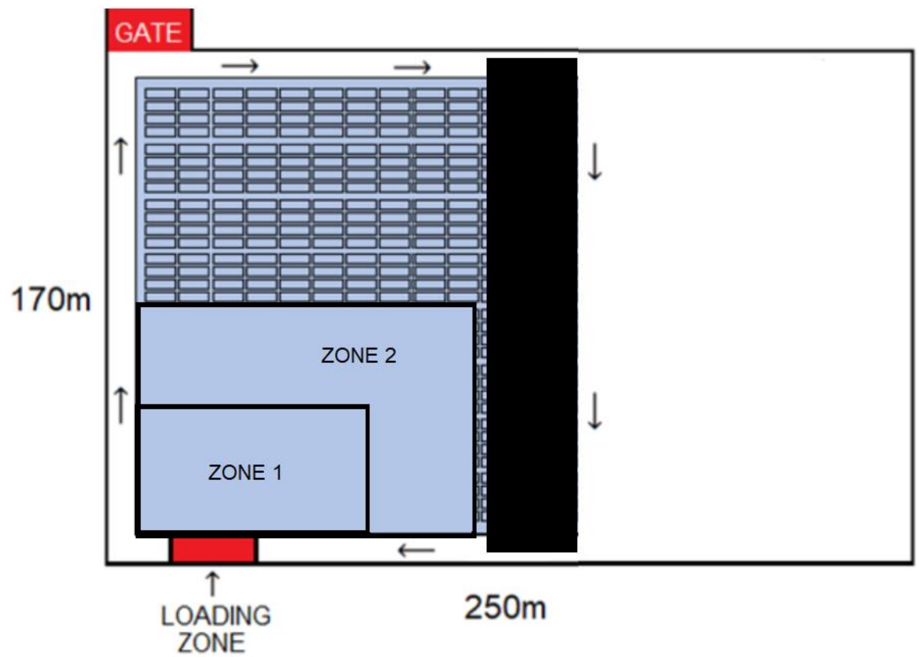


Figure 25 – Solution 6 minimum size of an overhead gantry crane at the Auckland yard

Based on the Solution 6 Speeds Table in the appendices, the crane can perform 1 lift every 0.83mins within a 3,875sqm area nearest the loading zone. Due to the configuration of Zone 1 taking up so large a space near the loading zone, Zone 2 is not within the speed requirements of 1 lift every 0.83mins. The Zone 2 orientation is such that, based on the average speeds in the Solution 6 Speeds Table in the appendices, it can make 1 lift every 0.92mins. This is 0.09mins short of the required speed.

Refining Solutions 5 and 6 Zoning Orientation:

The zoning of solutions 5 and 6 are not compatible with the speeds necessary to handle the maximum expected capacities during productive hours. Because of the zoning added to these scenarios, the number of TEU that can be stored in the 3,875sqm space where lifts can be made within the required speeds is drastically reduced. The Zone 1 multi-use area can only stack TEU 1 high. At 24TEUx8TEU it can store a maximum of 192 TEU of the required 72 TEU per hour turnover required during maximum expected production hours. 24 TEUx8TEU = 57.6mx48.8m = 2,810.88sqm. This leaves 1,064sqm of the 3,875sqm space where the crane can stack 6 high and still make lifts within the required 0.83min timeframe.

We can calculate how many TEU can fit in this 1,064sqm space using a simple proportion as follows

a:b::c:d

3,875sqm:1,860TEU:: 1,064 sqm:xTEU

3,875x=1,979,040

x=510 TEUs

The required number of TEUs that need to be accessible during the full production period is 1,296 TEUs. That leaves the crane speeds for this configuration short by 786 TEUs.

The obvious solution is to shrink and re-orient the size of Zone 1, as it does not require the space to hold 192 TEUs. 1,296 TEUs requires at least 2,700sqms of space stacking 6 high near the loading zone. 3,875sqm-2,700sqm= 1,175sqm area left over for Zone 1.

Solution 5a for Zone 1 orientation = 20TEUx4TEU block (total 80TEU) covering 1,171.2sqm as per figure 27

Solution 5b for Zone 1 orientation = 6TEUx12TEU block (total 72TEU) covering 1,054.08sqm as per figure 28

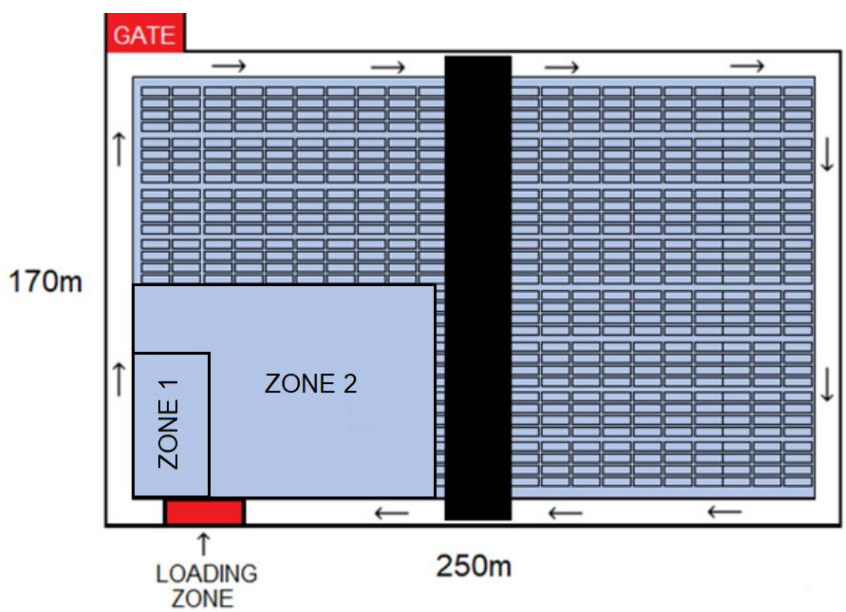


Figure 26 – Solution 5a with reconfigured zones

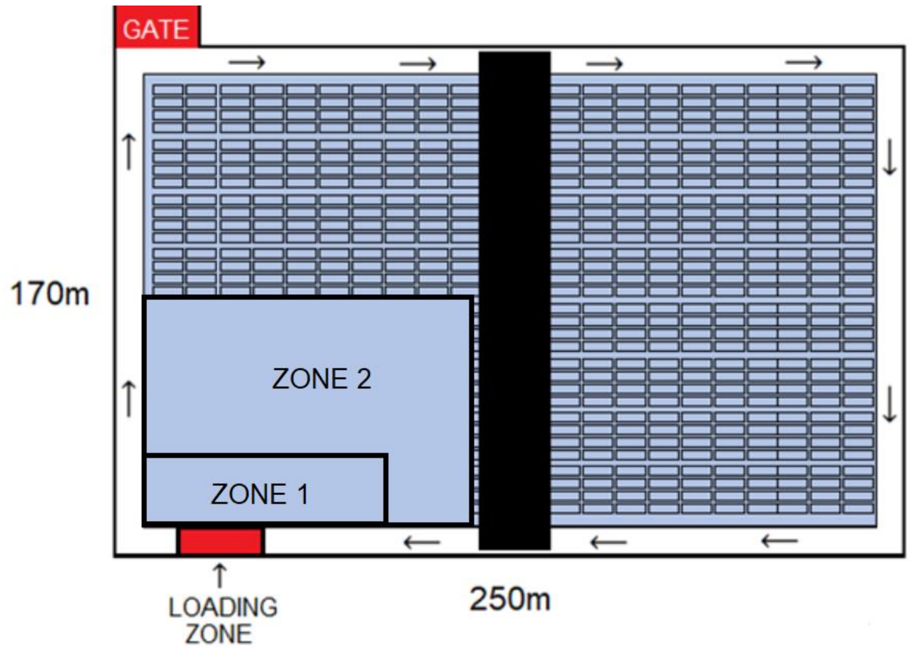


Figure 27 – Solution 5b with reconfigured zones

Solution 5a is allows for more TEUs in Zone 1 at 80TEUs. Solution 5b is the absolute minimum TEUs needed for Zone 1 at 72 TEUs. Both solutions fall within the 1,175sqm space allowed, and the speed requirements of 1 lift every 0.83mins.

Conclusion: Solution 5a is recommended. It meets the required stacking densities and speeds. It also gives the mobile survey and repair teams enough space to operate without overcrowding them.

<u>Solutions 4 and 6 Dead Weight Space:</u>

Solutions 4 and 6 leave a dead weight space to the east of the crane. This unused space is 170mx117m. If ContainerCo were to sublease out more land to one side of the site and shrink its container stacks accordingly, it could regain that land over time as trends in containerised trade increase, and simply lengthen the stacks without needing to purchase a new crane. The operations would simply reclaim that land, and extend the crane out to match.

Being so large, this space allows for flexibility in how it can be used, particularly in regards to a sublease. Potential subtenants would be far more interested in a larger space with generous lease terms over time, than in a smaller more cramped space. This also lessens the overall cost of development for the crane. As stated previously, a large portion of the cost of installing a crane is in developing the yard so that it can support a crane. This yard has already been extensively developed by ContainerCo from when it was, in essence, a swamp, but it would still require further development to be suitable for a semi-automatic gantry crane.

The logic behind subleasing this larger dead weight space is three fold:

- It allows the company to more quickly install a crane, by dividing expenditure into set stages, rather than a single lump sum. This is less of a strain on the company's cashflows, as well as allowing the company to maintain its current operation volume; and,
- It allows the company to collect rent throughout the duration of development. It does this by reclaiming sections of land to develop, and then extend the crane over; and,
- It allows the company to stage its growth to match the projected growth of empty container volume in New Zealand, rather than operating below capacity.

The site itself is on a twenty two year lease, with a final expiry date in 2035, while the crane has an operational lifespan of 20 years. Unless a further renewal on the site can be secured, this leaves 4 years where the crane will have to be moved in order to continue operations elsewhere. If we assume that the volume of containers in New Zealand will grow at 6% year on year, then we can begin to determine how much land the company will need to reclaim from the subleasee for future development. This is assuming that the company chooses to develop over time by building up from the initial shorter crane length of 100m, rather than developing the full length of the crane all at once.

To work out the compound interest of TEU increases at this site, the following simple formula was used:

$$x(1+r)^n$$

Where x is the initial number of TEUs at the site (5,820 TEUs), r is the annual interest rate (6%) and n is the number of years over which this simulation runs. We can expect the capacity demands to reach roughly the following:

6,288 TEUs in 3 years

7,067 TEUs in 5 years

7,939 TEUs in 7 years

9,455 TEUs in 10 years

On this basis, the crane's length could be extended out incrementally to match the volume increase, moving from 16 containers deep to 38 containers deep over time. If the crane's length was increased by 5 TEUs (30.5m) deep every 3 years, this would gradually extend the crane over the entire site, and still give the operations team plenty of buffer space should there be a sudden increase in storage demand in the Auckland region. In the meantime, the company could renegotiate the terms of a sublease to match this incremental groundwork and stretch the remaining development spend over that time period.

Realistically however, the company would choose to install the crane all at once, subject to available capital, rather than develop incrementally. This is because there is a significant and sustained demand in the Auckland market for empty container storage. Auckland OCP is one of 4 yards that the company has in Auckland. With a crane, OCP would free up much-needed space in those other sites, as well as maximise the efficiency of the asset.

As mentioned earlier, Auckland receives far more imports than exports, due to the fact that it is the largest city in New Zealand. Logistically, importers want to be able to unload their goods directly into the final market, or as quickly into the final market as possible. This means that there is a greater amount of full containers that arrive in Auckland that must then be emptied, modified, and outfitted for export. This bottleneck is the largest single factor behind the lack of storage capacity in the Auckland region.

Synchronising the Multi-Use Area

The multi-use area activities are for survey and light repairs performed by mobile teams of workers. The staff do not have to move the containers. All they need to be able to do is a) open the doors and b) have .5m around each box so that they can walk around the container to assess damage.

Based on the company's management reports, 1 surveyor working very quickly can perform a survey every 6 minutes under the current operational constraints. Much of this time is based on how quickly a forkhoist can drop off and pick up a container from the multi-use area. Given that a crane is faster than a single forkhoist feeding containers into the multi-use area, we can reasonably expect a surveyor working very quickly to perform 1 survey every 4 minutes. This is due to the fact that a crane will have lined up all the containers in a row well before the surveyor walks up to the row, rather than in a forkhoist situation where boxes are still being fed into the end of the row like someone laying down train tracks before an oncoming wagon.

Of the entire 1,296 TEUs handled in a day, half are being unloaded from trucks and the other half are being loaded onto trucks. This means that only the half of 1,296 TEUs that are being introduced to the yard will require survey in a day.

1,296 TEUs/2 = 648 TEUs

1 TEU surveyed every 4 minutes = 15 TEU surveyed an hour

15 TEU x 18hours (productive hours) = 270 TEU a day

648 TEU/270TEU = 2.4 surveyors = 3 surveyors on site

This assumes the staff are working constantly and having no breaks. It might be more feasible to have teams working in shifts, so as to maintain steady production hours, while ensuring they are operating safely.

Light repairs will not require any more space than survey. After a box has been surveyed, the rapid repair teams can work behind the surveyors in a far more production-line setting. Exactly what light repairs will be required is not as clear cut, however. Only 40% of boxes introduced to the yard will require rapid repairs at Oak Rd under this stress test scenario. 40% of 648 = 259 TEUs.

The TOS tracks each type of repair, which amounts to hundreds upon hundreds of different repair types. It does not define each type of repair into "heavy repair" and "light repair." From the TOS, all repair data is aggregated in the management reports. Based on aggregate data from the management reports, a repairer can perform 3 repair/hour. This aggregate data includes both light repairs and heavy repairs. Heavy repairs take quite a bit longer, and involves a workshop environment.

In the case of the to-be scenario at OCP, what constitutes a "heavy repair" and a "light repair" will be left to the judgement of the surveyors. Assuming heavy repairs take 75% longer than light repairs, then of the 3 repairs/hour, 45 minutes of this will be spent on a single heavy repair. Ergo, a repairer can perform 1 light repair/15 mins.

1 TEU repaired every 15 mins = 4 TEU repaired every hour

4 TEU x 18 hours (productive hours) = 72 TEU a day

259 TEU/72TEU = 3.6 repairers = 4 repairers on site

This assumes the staff are working constantly and having no breaks. It might be more feasible to have teams working in shifts, so as to maintain steady production hours, while ensuring they are operating safely.

5.4 VBS AND HOUSEKEEPING

Vital to the reduction in the impact of the crane’s lift speed, as well as the queueing of trucks, is the implementation of a Vehicle Booking System (VBS). A number of players in the New Zealand market -- most notably ports -- use a VBS at their gates, and ContainerCo also has a VBS installed at their Auckland sites. It is relatively new. This means that no reliable historical data can be pulled for analysis at this time. Even if this data could be obtained, exception handling would have to be considered. *To wit*; both carriers and shipping companies alike do not enjoy being unable to make a booking if the yard is busy, and will phone the yards to demand manual overrides in the system. This creates exceptions. This lack of queue discipline is also something that will be addressed shortly.

A VBS is necessary for a crane. The booking identifies the truck and the container before arrival. The way a VBS works is: the carrier goes into an online portal; they are prompted to select a depot and timeslot, much the same way one might make a booking on an airline for a seat; they then enter both truck information and container information. There are a limited amount of spaces allotted for each time slot during the day; this smooths out carrier in and out flow. In addition to this, the rates are dynamic for peak hours *versus* off hours in an attempt to manage how many trucks arrive at the gate during busy times of the day.

Information is critical. The VBS both smooths out bottlenecks, and also currently feeds information about container arrivals and departures to the forkhoist drivers. The information would work similarly with a crane. While a forkhoist driver currently looks at a screen to see if the container numbers and truck owner match, the crane's OCR (Optical Character Recognition) cameras will be able to match up bookings based on the information received digitally. VBS also allows the crane's movements to remain steady throughout the day, and significantly reduce queue times.

The current flow of trucks is expected to be greatly simplified through the implementation of a crane. A crane utilises a simple U-shape queue. In comparison, the current flow of trucks through the Auckland OCP yard is as below.

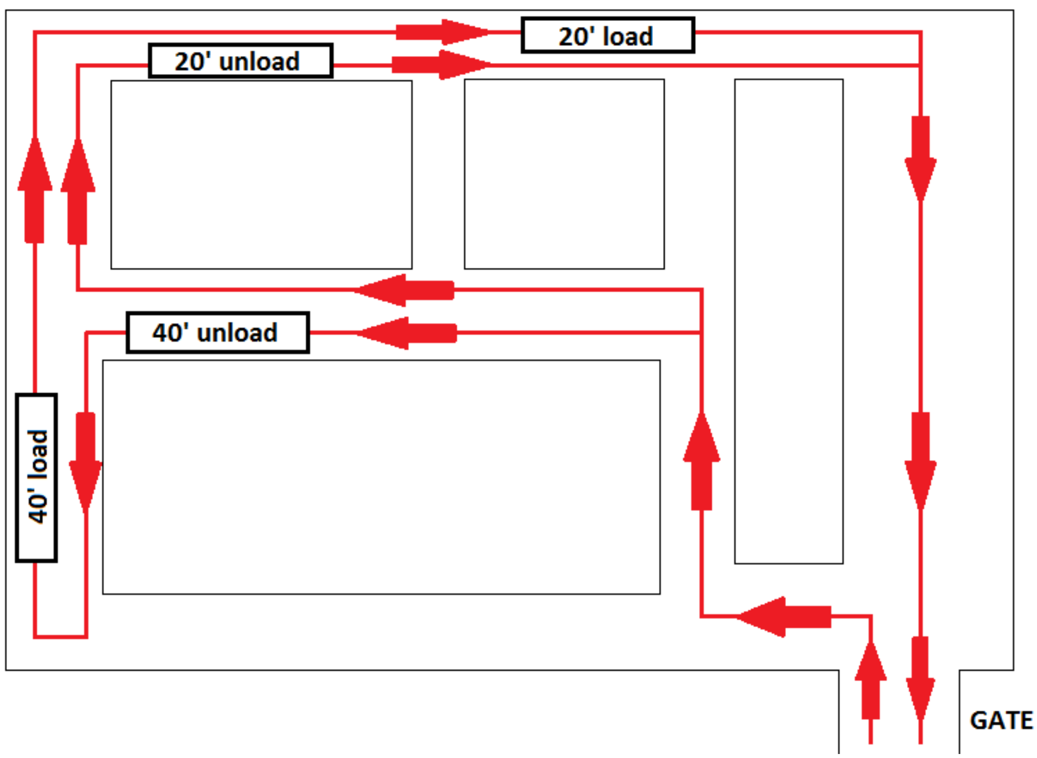


Figure 28 - Current truck flow configuration, Auckland OCP yard

We will start by calculating the maximum number of trucks that can be queued at the site assuming that solution 5a is taken. The queue of trucks will assume that the company chose option A for its crane implementation, and developed the entire yard to install the crane all at once rather than in increments.

The perimeter of the full yard at 250mx170m is 840m. Trucks are not going to be queued after they've been unloaded and unloaded, meaning that the last stretch of 170m leading back to the gate must be subtracted. This brings us to 670m. The main area of the site is accessed by a shared driveway that is approximately 178m in length and wide enough for two lanes of trucks, one going in and the other going out. This gives us an additional 178m to the queue, which adds up to a total of 848m. Trucks entering the yard will have a maximum length of 21.73m, as per the example below:

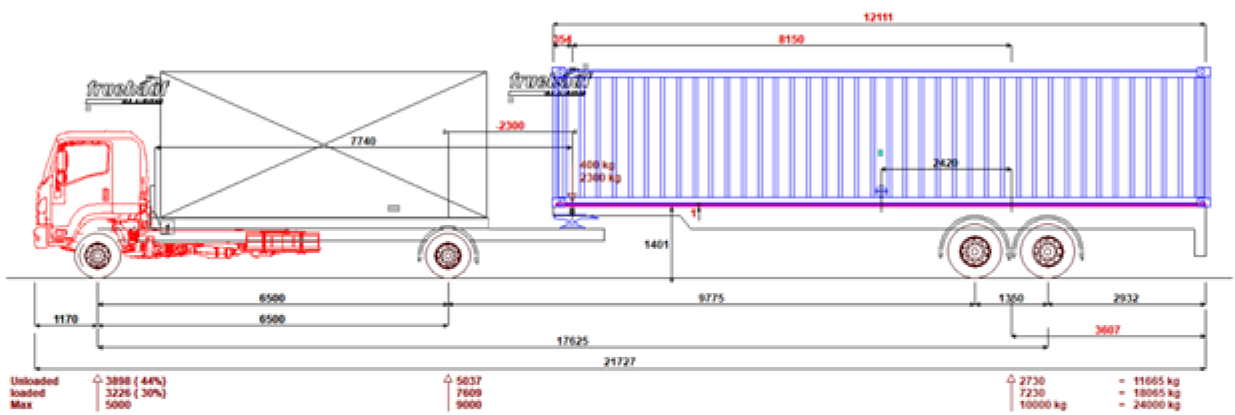


Figure 29 - Container truck and trailer dimensions (courtesy of Fruehauf)

This assumes that the length of the truck includes a trailer on the back carrying an additional two containers, meaning that each truck entering would be delivering 3 TEU, and taking away 3 TEU. In practice of course, some trucks will be arriving at the gate empty to pick up a container, or leaving the yard empty to pick up a container elsewhere. For the sake of this exercise however, we will assume that the trucks are running at full capacity with two way loading. We will also allow for 3m between each truck when they are driving through the yard.

This means that the maximum queue through the yard would be 38.54 trucks. Since there cannot be .54 of a truck -- even taking trailers into consideration -- it will be assumed that the maximum queue of trucks through the yard is 38.

Fortunately, the implementation of a crane improves the line structure of trucks in the yard. The current operations as seen in Figure 26 show that trucks in the yard follow a multichannel, multiphase line structure, in which trucks with different container sizes are directed down different lines for different services before exiting the yard. With a crane however, there is one lane in a classic U-shape. This shifts the multichannel, multiphase line structure to a single channel single phase line structure. Regardless of what they are carrying, trucks drive into the yard to a single location where they are loaded and unloaded, before they then drive out of the yard.

This change in line structure also changes the queue discipline of the trucks. In theory, trucks currently operate on a reservation first queue basis, followed by first come first serve. However, in practice trucks operate on a first come first serve basis, due to poor queueing discipline. Carriers and customers alike will often ignore the need for bookings by demanding manual override bookings of administrative employees working in the office on site. With a crane, there is no more need for an administrative office on site, as any carrier who tries to ignore this booking will simply be turned away at the gate. After all, a crane cannot and will not speak to a truck driver to change their booking.

A crane further enforces queue discipline, because without information the OCR will reject the lift. Not only does it move the line structures to a simpler single channel, single phase structure, it also ensures that queue discipline follows the reservation first model.

Moreover, solving the waiting line problem at this site becomes far easier when a crane is involved, because there are known solutions for a single channel, single phase line structure. We will start by understanding the rate of trucks and service based on the fact that a busy day would see roughly 150 trucks[16] move through the yard over 18 hours:

[16] The number of trucks has been assumed to be slightly higher than 142 so as to give a conservative estimate of the rate of trucks per hour.

Rate of trucks per hour = approximately 9 trucks per hour[17]

Rate of service per minute by crane = 1 truck serviced every 5 minutes (12 per hour)

Rate of service per minute by forkhoist = 1 truck every 8 minutes (6.6 per hour)

This assumes that 1) each truck will have an average of 2 containers that need to be both unloaded and loaded; 2) a crane will perform a movement every minute, whereas a forkhoist will perform a movement every 2 minutes; and 3) each truck will require 1 minute to drive up and to drive away for a crane, but not for a forkhoist.[18] This also assumes that the twist-locks have been undone at the gate by the driver, in order to smooth flow. The alternative would be drivers needing to hop out of their cab at the loading zone beneath the crane to undo the twistlocks. To get around this, the drivers will be required to do so either when waiting in line or at the gate itself.

Below are the variables that will be used in calculating queue times. All formulae and variables were drawn from Jacobs and Chase (Jacobs & Chase, p.231, 2014).

Table 2: Variables for calculating queue times

Variables	**Meanings**
ρ	Utilisation ratio
λ	Arrival rate of trucks per hour
μ	Service rate of trucks per hour
Ls	Average trucks in the system
Wq	Average wait time in line
Lq	Trucks on average waiting in line

In summary, the difference in queueing between a forkhoist and a crane at the site were calculated follows:

[17] The rate of trucks per hour has been calculated at 150 trucks/18 hours = 8.33 trucks. This has been rounded up to 9 from 8.33.

[18] A truck would have to situate itself very precisely in the loading zone for a crane to service it. This would take more time. Whereas with a forkhoist servicing it, a truck can simply drive up without needing to situate itself precisely at all.

Table 3: Comparative queue times for trucks with forkhoists or with a crane

	Forkhoist	Crane
Average number of trucks in the queue	4 trucks	3 trucks
Average waiting time in the queue	27 minutes	15 minutes

If we assume the distribution of trucks through the yard is uniform due to the VBS, then the average utilisation of the crane's loading bay can be determined using the formula:

$$\rho = \frac{\lambda}{\mu}$$

Where ρ is the ratio of total arrival rate to service rate for a single server. λ is arrival rate and μ is service rate determined by:

$$\frac{1}{\textit{service time}}$$

$$\rho = \frac{\lambda}{\mu} = \frac{9}{12} = .75 = 75\%\ \textit{utilisation}$$

We can reasonably expect the crane to have a utilisation of 75% during a busy day, allowing for approximately 25% of downtime to devote to housekeeping movements.

The average number in the system can be determined by using the formula:

$$Ls = \frac{\lambda}{\mu - \lambda} = \frac{9}{12 - 9} = 3\ trucks$$

The average wait time in line can be determined by using the formula:

$$Wq = \frac{Lq}{\lambda}$$

Where

$$Lq = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{81}{12(12-9)} = \frac{81}{36} = 2.25\ trucks\ on\ average\ waiting\ in\ line$$

Which gives us the following:

$$Wq = \frac{Lq}{\lambda} = \frac{2.25}{9} = 0.25\ hours\ of\ average\ wait\ time$$

Since the rate of service was converted to hours, the average wait time of W_q therefore is 15 minutes.

With a truck however, this is considerably slower. Since the forkhoists operate under a multichannel system, the model is a bit different.

The average number in the system is determined with the following formula:

$$Ls = Lq + \lambda/\mu = -10.125 + 9/8 = -9\ (or\ 9\ trucks)$$

The average waiting time in line is determined with the following formula:

$$Wq = Lq/\lambda = -10.125/9 = -1.125\ hours = -67.5\ minutes\ (or\ 67.5\ minutes\ waiting\ in\ line)$$

This is, of course, for one forkhoist. Since there are three active in the yard however, there is a reasonable expectation that they will operate faster than one hoist would alone. They will not reach an optimum three times as fast, as there can be expected delays and inefficiencies with having more plant operating in the same yard. If we assume they are 2.5 times as fast, then the time spent waiting in the queue would be an average of 27 minutes, and there would be an average of 4 trucks waiting in the queue at any point in time.[19]

Even without the aforementioned VBS, the crane can still tell which container it is picking up, and then store in its memory where it has put that container. This would obviously be unideal. However according to ISO 6346:1995, every intermodal container is required to have a specific code painted in a specific place on the container, which can automatically identify the container's owner, size, type, country code, and any other additional information

[19] 4 trucks has been rounded up from 3.6 trucks, since there cannot be .6 of a truck.

attributed to that particular container (ISO, 2019 February 7). This code is unique to each container. It would allow the crane's memory to store the location of a container, and then perform housekeeping movements based on what it knows needs to be lifted out of the stacks in the future.

Many heuristic scheduling papers in the past have been concerned with ensuring that cranes on ports achieve the most efficient throughput and turnaround times (Huang and Guo, 2011; Ng and Mak, 2005), to minimise the number of required relocations (Kim and Hong, 2004; Ehleiter and Jaehn, 2016; Chen et al., 2000), or even to address the adjacency problem in facility layouts (Wascher and Merker, 1997).

The reshuffling of containers -- also called "housekeeping movements" -- occurs during lull periods of the yard's operations (Huang and Guo, p.88, 2011). We have already determined in the section about queueing that the crane will on average have a utilisation of around 75%, which allows for a generous 25% lull time in which to perform housekeeping movements. Most of this will obviously be at night.

Further analysis would be required for more detailed heuristic coding. As time goes on, concepts of machine learning and more advanced data analysis would add value. This would, however, require the crane to have been operational for some time, so that historical data could be used to create predicative scripts. By doing so, the crane could then be programmed to make more and more efficient use of its housekeeping movements as it collects data and learns to expect which containers will be entering and exiting the yard over time.

CHAPTER 6: STAKEHOLDER ANALYSIS

6.1 SUMMARY

Chapter five delivered potential solutions for eliminating waste in a particular yard by implementing a crane, and how this affects operations. Chapter six analyses the human factor by creating a stakeholder map, and then exploring how this change would affect key stakeholders involved in the business, including: employees, customers, carriers and suppliers, competitors, and the wider New Zealand market. The human factor is further explored in the context of the theory of strategy-as-practice.

6.2 THE STAKEHOLDERS

Analysis of a crane must situate it inside its environment. Additionally an artefact must be judged not only at an operational level, but also within its given cultural environment. This environment, or *habitus,* includes employees, carriers and suppliers, customers, competitors, and the wider New Zealand market. These influencers on the artefact will be discussed in this order. By doing so, the exploration of the artefact in its situated environment gradually broadens in scope. Therefore, in order to understand these influencers a stakeholder analysis was undertaken.

A systematic stakeholder analysis consists of the following eight steps (taken from Elias, et al., 2002, p.305):

1) Develop a stakeholder map of the process
2) Prepare a chart of specific stakeholders
3) Identify the stakes of the stakeholders
4) Prepare a power versus stake grid
5) Conduct a process level stakeholder analysis
6) Conduct a transactional level stakeholder analysis

7) Determine the stakeholder management capability of the R&D project

8) Analyse the dynamics of stakeholders.

From here, a stakeholder map was developed as below:

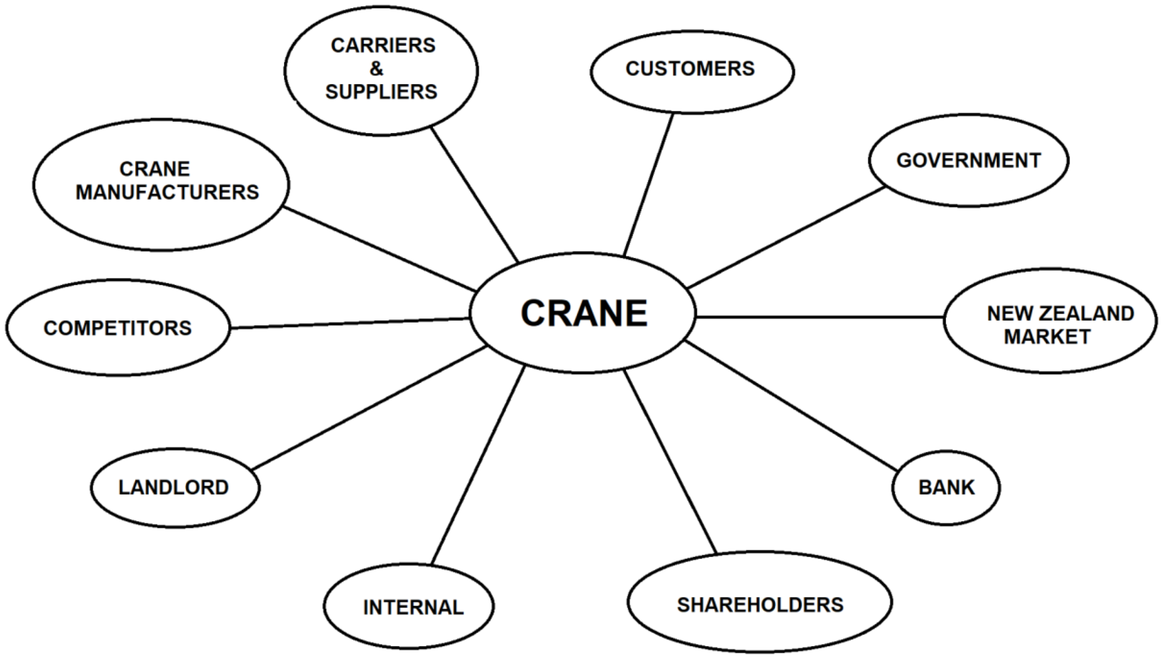


Figure 30 – stakeholder map of the crane project at OCP

Next a table was drawn up detailing the specific stakeholders that exist within each of these categories of stakeholders.

Table 4: specific stakeholders of the crane project at OCP

CUSTOMERS -Maersk -CMA -ONE Network -MSC -OOCL -COSCO Shipping -Other smaller carriers	SHAREHOLDERS -Petroview NZ Ltd -COSCO Shipping	BANK -Westpac -Foreign bank for funding (if any)	LANDLORD -Chalmers Property Ltd	CRANE MANUFACTURERS -Kone Crane -Kocks Ardelt -Liebherr -ZPMC
GOVERNMENT -Auckland City Council -KiwiRail -Ports of Auckland -Ministry of Business Innovation & Employment -Ministry of Transport	COMPETITORS -Specialised Container Services -CSL Containers -Sea Containers	EMPLOYEES -Depot Managers -HR Manager -Frontline Staff (Concon, hoist drivers, surveyors, repairers, internal transport drivers) -CEO -CFO -GM Operations -Board of Directors	CARRIERS & SUPPLIERS -National Road Carriers -numerous transport operators -IRS International -JPC Reefer Services -other third party contractors on site	NZ MARKET -residents of NZ (people who purchase any imported goods) -NZ businesses (especially those which import/export goods)

Of these stakeholders a handful of them were then taken, and their roles and stakes explained in more detail in sections 6.2.1-6.2.6 as below.

6.2.1 SHAREHOLDERS

ContainerCo only has two shareholders. Both own 50% of the company's shares. One is Petroview NZ Ltd, a New Zealand owned and operated private equity and holding company based in Wellington. The other is COSCO Shipping, the world's largest shipping organisation, a wholly owned subsidiary of the Chinese government.

At face value, it would seem these two shareholders have equal power over the future of the project. However, COSCO Shipping's power andurgency as a shareholder is limited. Even though COSCO Shipping owns 50% of the shares of ContainerCo, Petroview NZ Ltd holds the management rights to the business. COSCO Shipping can legally elect a director to represent them on the board, however the Chairman is also the Managing Director of Petroview. This Chairman has ultimate veto rights, and an extra vote as well. Therefore, COSCO Shipping has legitimacy but very little power or urgency as a sleeping shareholder, while Petroview is seen as the definitive stakeholder with the most power, urgency, and legitimacy to both manage and influence the project.

6.2.2 EMPLOYEES

All employees working for ContainerCo (NZL) Ltd will be affected by the implementation of a crane at one of the company's busiest sites, but this is especially true for operational staff at the site itself. Three forkhoist drivers will no longer be needed, and their roles will be disestablished – currently these workers are considered an elite inside the depot hierarchy, and it is unlikely they will be retained in other roles. Workshop repairmen will also no longer be needed at the site, though they may find new roles offered to them in the increased mobile repair work. There would also be an increase in the number of surveyors needed to handle the increased volumes.

Moreover, container controllers (called "Concon staff") would have previously been working on site. Their role includes providing support to the depot staff by manually inputting data - especially which containers are entering and leaving the yard. These Concon staff will also no longer be required, as the mobile survey and repair teams will input data of work done to containers in the multi-use area, and the crane will automatically input data on the entrance, placement, and departure of containers in real time.

Other employees will need to be hired. Already mentioned are increased requirements around survey and rapid repair staff. In addition, technicians to service and maintain the crane will need to be hired. Any new operational staff members will require further training in how to interact with the crane, while any existing operational staff members that have been moved into different roles will need to be trained for these new positions. Furthermore, any existing staff members that continue to work on the site will need to be retrained and re-inducted around the new health and safety risks a crane presents. They are already trained and inducted to deal with existing risks around forkhoists, but not cranes.

There are also new risks that come with new employees, as well as disestablishing or changing roles. There are HR risks around personal grievances inherent to disestablishing roles in New Zealand, as well as legal regulations when introducing new plant to a site. The risks and responsibilities extend all the way to the governance level; this is especially the case for any operation which sees pedestrians interacting with heavy plant and equipment. That being said, there are far fewer health and safety risks involving one semi-automated piece of machinery *versus* three manually driven forkhoists.

The interaction of pedestrian and machinery is a primary concern in New Zealand legislation (Worksafe New Zealand, 2017 September 5; Employment New Zealand, n.d.). Additional traffic plans and safety guidelines will need to be implemented on the site. The board of directors will also need to be regularly updated about the site's risk management framework and internal control processes (Financial Markets Authority, 2018, p.21).

Moreover, there are issues around change management that will need to be taken into careful consideration. Not just for the operational staff directly affected, but also for other staff members across the company. If improperly handled, change management has just as much risk of scuttling the project as delays in transport or construction. Indeed, research suggests that change management can have an even greater impact on a project than nearly any other factor (Legris and Collerette, 2006, p.65). Staff will need to be consulted. Expectations will need to be managed. Performance will need to be monitored so that it does not slip in the interim period.[20] Political interests will also need to be managed (Briggs, 2007, p.123).

Political interests might be the single greatest risk to a project of this scope. Managers especially will have their own political agendas with regards to the crane - for example, around metrics such as budgetary and time constraints. Who is going to be using their time to manage

[20] Though there are to be expected periods where the site will be unusable during the groundworks and installation of the crane.

the implementation of the crane? Whose budget may be adversely or even favourably impacted by such a large expenditure? All of these human factors at an employee level within the company will need to be carefully monitored, addressed, and managed.

6.2.3 CARRIERS AND SUPPLIERS

As previously mentioned, employees would need to be retrained and re-inducted to the site to understand the new health and safety risks of a crane. This is also true of all carriers and suppliers that visit the site. This includes: truck drivers, specialised equipment handlers, and any third-party contractors hired by the customers.[21] Currently all visitors have been inducted to the site and have received the proper training to operate safely. ContainerCo (NZL) Ltd requires they be inducted, and offers free training and frequent consultation to carriers and suppliers for this express purpose.

Retraining and re-inducting carriers and suppliers would be very time intensive. However, a crane on the Auckland OCP site would reduce the number of hazards, and make training and induction easier in the future. Also, a crane would reduce time waiting in queues, which carriers would benefit from greatly. Ultimately, a crane provides the means for a far safer, smoother, and more scaleable operation.

6.2.4 CUSTOMERS

Customers will be equally affected by the implementation of a crane, but in a different manner. Customers don’t generally come to the yard itself, so their interaction with the crane will be at a distance, and involve volume and services. The ability to store and handle an increased capacity means customers can look to expand their volumes in the Auckland region.

---

[21] Customers will hire third-party contractors who specialise in specific operational services (such as reefer quality control) to perform these services on ContainerCo sites. While ContainerCo can often perform these services, the customer retains the right to go to market and select an independent third-party contractor. That being said, ContainerCo itself retains the right to ensure that all people operate safely on their sites, as that is their ultimate responsibility.

It also means that ContainerCo (NZL) Ltd can secure more high volume contracts with these customers.

At the same time, implementing a crane both increases and reduces the customers's buying power (Porter, 1989). On the one hand, there are a limited number of shipping companies in the world. This number is decreasing every year as consolidation occurs due to massive mergers and acquisitions across the shipping industry. As of 2019, a mere eight shipping companies[22] control 80% of global containership capacity (Deloitte, 2018, p.12). ContainerCo can lock in additional volume from these customers by being one of the few players in the New Zealand market that can handle such volumes - but as the number of shipping companies decrease their customer buying power increases. When a single customer is providing over 30% of the work, they can start to make significant demands upon the business.

These customers, however, have fewer options around where to put such high volumes of containers. They can still penny-packet out smaller volumes to competitors, but if they want to gain efficiencies of mass scale, they will have to come to ContainerCo. This brings the topic directly to the competitors.

6.2.5 COMPETITORS

Implementing a crane immediately sets a benchmark in the empty container industry that competitors will look to meet, since nobody else in New Zealand uses a crane in this setting. It also creates a barrier to entry, and reduces the threat of new entrants into the market. Of course, there is no patent or right that forbids competitors from purchasing their own crane. However, not everyone has access to such high levels of volume, or access to so much land. Additionally, not everyone can afford a gantry crane of this scope.

Of course, competitors can still reliably offer a cheap and alternative solution to the market by continuing to use forkhoists in their yards, but they would struggle to match the raw

[22] These companies are: Maersk, MSC, CMA-CGM, COSCO Shipping, ONE Line, Hapag-Lloyd, Yang Ming, and Evergreen Line. The Deloittes article is slightly outdated as of 2019, as it was published before the finished merger and acquisition of OOCL by COSCO Shipping, and the merger of all the Japanese lines, namely: K-Line, MOL, and NYK Group.

scale of volume that a crane can handle. If they could gather the resources to purchase more land and/or a crane, then they could meet this benchmark.

In the meantime, it is imperative that ContainerCo continue to look ahead for further benchmarks to meet themselves. This could be achieved through a number of ways, including: increasing performance and optimisation by making the crane fully automated rather than semi-automatic; by increasing efficiencies through new technologies such as an updated TOS; by offering a wider variety of services and branching out into full containers rather than just empty containers; or by increasing scale into a global market via expanding operations into Fiji, Australia, and other areas.

6.2.6 WIDER NEW ZEALAND MARKET

The crane also has an effect on the broader market. More locally, it would reduce strain on storage capacity in the Auckland region. It would give ContainerCo the further opportunity to make itself a more central hub of gateway activities. The services that ContainerCo can begin to branch into with a crane would alter the company's business scope into something more in line with ports as outlined in chapter 1. The company would still not have to take a port's quayside operations into account, but this change in the company's scope could be taken further by working more closely with local ports to increase regional efficiencies.

At a national level, the implementation of a crane would take more time to show a material impact. A single crane would not be as impactful on its own. However, as more and more cranes are rolled out across the company's yards nation-wide, the efficiencies will continue to scale. Moreover, the use of cranes in empty container depots will become a more entrenched benchmark in the industry. In essence, the use of cranes in empty container depots will become more of a standard practice.

6.3 STAKEHOLDER TYPOLOGY

Based on the discussion of the various key stakeholders and their stakes above, we can now identify a simple power grid of these stakeholders. First, these key stakeholders will be categorised based on their power and interest as in Figure 31 below.

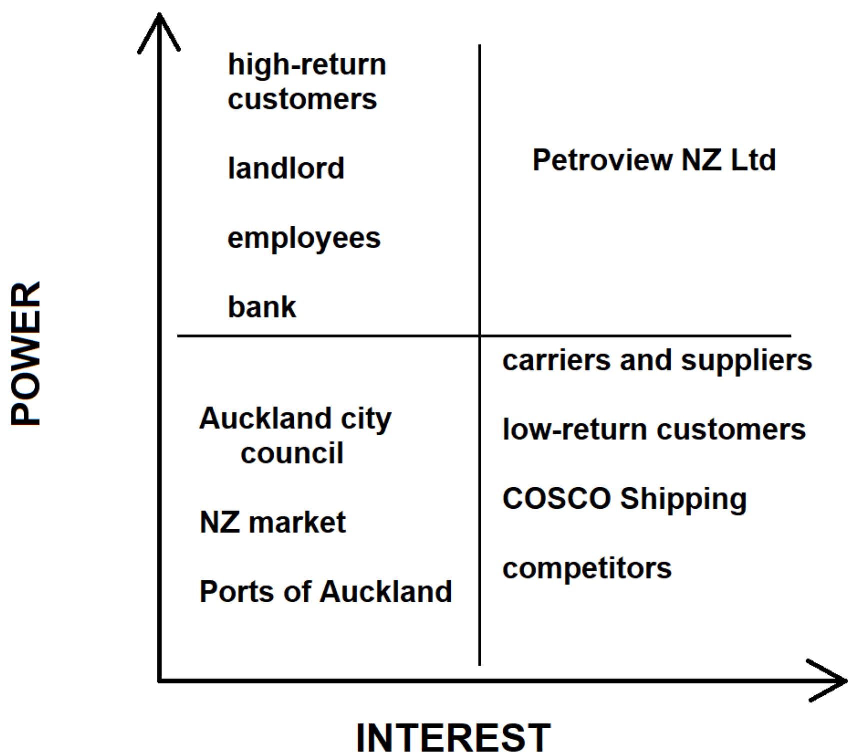


Fig 31 – power versus interest stakeholder grid for the crane at OCP

At this point it is necessary to develop a process level stakeholder analysis and a transactional level stakeholder analysis. The former focuses on how the project management guides its stakeholder relationships, while the latter focuses on how the project management bargains with its stakeholders (Elias et al., 2002, p.306). When looking into management's relationships (both process and transactional), it was found that management had a far better grasp of its external relationships than its internal ones. Specifically relationships with key customers, with the National Road Carriers association, and with the Ports of Auckland were very well maintained. Lines of communication were open and robust. However internal relationships were more lacklustre.

Internal relationships between managers, the executive team, and the board of directors were well maintained, but key staff on the frontlines were more likely to be kept in the dark. HR management internally did little to engage with frontline staff in order to assuage any fears or explain the upcoming processes around the project. This may be due to the fact that the project was still in its early stages of scoping, and therefore not yet seen to have a direct impact upon these staff members. As the crane project progresses and this impact becomes more clear, it is recommended that HR engage more closely with these stakeholders.

This ties directly into the stakeholder capability index of the project. During the course of this thesis while interacting with the project management, it was apparent that the management team had a high understanding of their stakeholders, and a relatively effective transactional relationship with key stakeholders. In some instances, such as with internal HR stakeholders as mentioned just above, these relationships were ineffective, but this was primarily due to the early stage of the project. As such, the index is currently high in both process and transactions, though this is liable to change as the project progresses.

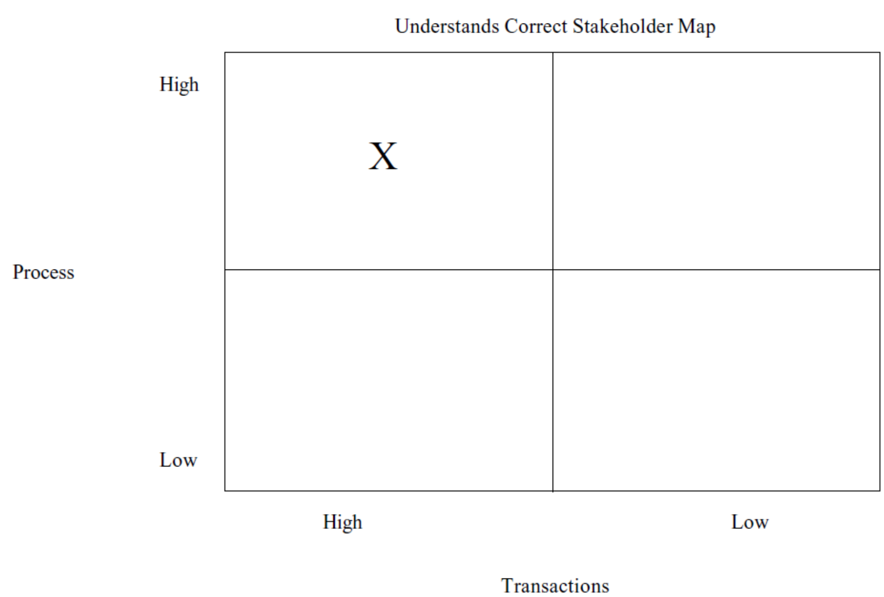


Fig 32 – stakeholder management capability of the OCP crane project (modified from Elias et al., 2002, p.308)

From here, the dynamics of key stakeholders were analysed. The stakeholders were further broken up into power, legitimacy, and urgency, as per Mitchell et al's 1997 stakeholder typology diagram shown in Figure 33.

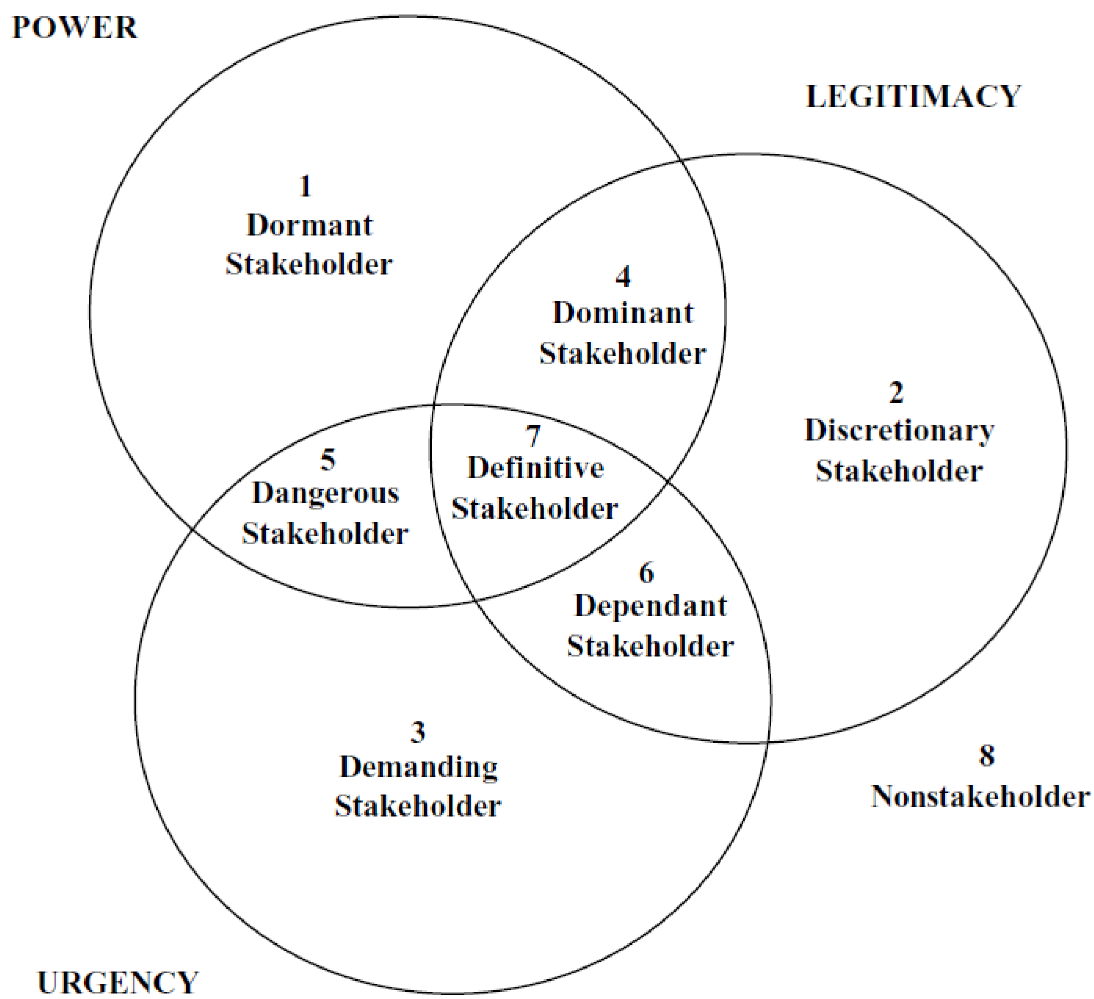


Fig 33 – Stakeholder typology (from Mitchell et al., 1997, Fig 2, p.874)

Based on the above, the key stakeholders were categorised and analysed in Table 5.

Table 5: Key stakeholder typology for the crane at OCP

Dormant	Auckland City Council Ports of Auckland
Dominant	Board of Directors Employees (especially hoist drivers and Concon staff) HR manager CEO/CFO High-return customers
Definitive	Petroview NZ Ltd
Discretionary	COSCO Shipping
Dependent	Carriers and suppliers National Road Carriers Crane manufacturers
Demanding	Low-return customers
Dangerous	Landlord Competitors

Key staff members (especially frontline staff whose jobs would be directly impacted by the implementation of the crane) have been placed into the dominant category in this instance. The project management team currently would view this stakeholder as being in the discretionary category, meaning they have legitimacy but very little power or urgency at this point in the project. In the minds of the project management team, this stakeholder would move over time towards the dominant category.

6.4 STRATEGY AS PRACTICE

The implementation of a crane will materially affect the social norms and practices of ContainerCo. Some of these changes have been discussed above. It is also important to explore how practices can materially affect an artefact. Since practices are in part transactional in nature, any human interaction with the crane – be it an employee, or customer, or competitor -- is an act of transactional sense-making. The crane becomes more than an artefact, it becomes a symbol. How that symbol is understood in turn flows into everyday *praxes*, and then proceeds to shape how the artefact is used.

Classic change management often stresses the need to break routines in an unfreezing and refreezing process. These routines themselves are actions that are "saturated with taken for grantedness" (Nicolini, 2012, p.48). Moreover routines provide "both cognitive economy and anxiety reduction and control" (Nicolini, 2012, p.48). Practitioners will rarely question the assumptions behind their activities, and in fact the more routine they are, the more accepted and anxiety-reducing they are. Habit is "neither a form of knowledge nor an involuntary action" (Merleau-Ponty, 1962, p.144). *Why* people form these routines is not of particular interest to this thesis. Rather, *how* they form these routines is. The reason for this being that actions and practices are "always situated in history and context and therefore only make sense in relation to such location" (Nicolini, 2012, p.48). Practice, like any other human social behaviour, is recursive. It is not "brought into being by social actors but continually recreated by them via the very means whereby they express themselves as actors" (Giddens, 1984, p.2).

There is the implication in Whittington (2006) that *praxis* both creates and diffuses influential practices (Whittington, 2006, p.625). In turn however, *praxis* -- in order to be effective -- relies heavily on the practitioners' capacity to access and deploy prevailing strategic practices. This could be due to ineffective preparation for strategic *praxes*, or it could point to the inability to include middle managers in the implementation of practices. This would result in a failure for practice to become *praxis*, where practice falls short and never quite makes it into the everyday actions of people operating in the organisation. By drawing attention to the impact of strategy-as-practice on an artefact, this thesis hopes to avoid that failing.

Consider a historical example: Heron of Alexandria's simple steam powered engine. Heron (also known as Hero) was an ancient Greek lived in Alexandria, Egypt in the mid 1st century AD. During his life, he was an inventor, mathematician, and engineer (Folkerts and Waldner, 2006). In his work, *Pneumatica*, he described a series of mechanically driven curiosities, such as puppets, coin-operated machines, a fire engine, a water organ, and a steam powered engine.

They were, in essence, innovative artefacts that had no pragmatic purpose because of how they were shaped by *praxes*, and situated in their localised *habitus*. What is perhaps even more remarkable is that the invention of a steam powered engine was not an isolated event. After Heron, the Roman architect and engineer known as Vitruvius writes about one in his book *De Architectura*. Furthermore, Heron himself was basing this device from the work of the Greek inventor and mathematician, Ctesibius, who was writing on the science of steam pumps and compressed air nearly 200 years prior (Krafft, 2006).

This example illustrates practice in regards to an artefact. Now, people understand that a steam powered engine could have practical applications, but at the time these artefacts were mere curiosities. A crane is a known solution in another space. However, if the intuitive leap by staff does not link the artefact to another capacity, then it will simply not be useful. It will not offer a pragmatic solution outside of its bounded space and understanding.

A crane in one sense is simply a symbol through which members of a strategy team are attempting to convey meaning in order to encourage a particular transaction. Practice is itself "the conduct of transactional life, which involves the temporally-unfolding, symbolically-mediated interweaving of experience and action" (Simpson, 2014, p.1338). It is a dynamic and emergent process. The crane has to have meaning that is mutually accepted in order to constructively convey that meaning. The agents in this transaction are varied: they are members of the management team; they are the operational staff; they are the customers whose goods are being handled; and they are competitors who must react to the introduction of this artefact to the marketplace. In this case, everyone must agree upon what the crane means and does in the context of an empty container depot, and that sense-making will materially affect how it is used.

CHAPTER 7: CONCLUSIONS

7.1 SUMMARY

Chapter six discussed the key stakeholders, their stakes, and how they are affected by the implementation of a crane into a major operational environment. In this final chapter, the results are summarised, and before the thesis is concluded, the limitations of research and future areas for research are outlined.

7.2 RESEARCH APPLICATIONS AND LIMITATIONS

The specific problem for ContainerCo is around the application of semi-automatic gantry cranes inside its operation. Much of the existing literature on the subject of semi-automatic gantry cranes in an operational environment is either centred on ports, or large-scale warehousing operations, and has not specifically addressed empty container depots. These studies include the many different criteria and constraints that a quayside port must operate under, but which an empty container depot would not need to take into consideration. On a quayside port, an empty container depot serves as a middle-man between various other operations, such as warehousing and packing, and full storage stacks and stevedoring. "As a consequence," Kemme notes, "the operational performance of seaport container terminals as a whole – which is often measured in terms of quay-crane productivities and vessel-turn-around times – is greatly affected by the operations of the container-storage yard" (Kemme, p.2-3, 2013). Moreover, rubber-tyre gantry cranes are normally used at seaport container terminals for storage purposes, and are therefore combined with other equipment for the performance of the horizontal transport between the quay and the storage yard as Kemme pointed out above.

However, empty container depots – and even to some extent inland ports – do not encounter these performance requirements with rubber-tyre gantry cranes. Rather, they operate under a whole raft of different constraints and services that their customers demand, but that which a port would not encounter; this includes extensive repairs and maintenance of containers, long-term storage, surveying, cleaning, and hinterland transportation.

There are some limitations of this research. The first is that while this thesis draws upon the philosophy of JIT, it is not an optimisation project. Various potential scenarios will be explored during the course of the case study for ContainerCo. These scenarios are to be considered preliminary explorations of implementing a semi-automated gantry crane at an empty container depot. Further research will be necessary before actually implementing a crane at a site.

Another limitation of this research is in its scope of lean. While it is not necessary to implement all bundles of lean in order for an organisation to see the creation of value or the reduction of costs, the gap in the research that this thesis will address is the relationship between JIT and HRM (Galeazzo and Furlan, p.517, 2018). This does present a limitation of the research, however. There is space for further research regarding TPM and TQM in the implementation of semi-automatic gantry cranes into empty container depots that this work will not address. In particular, TPM would be a necessary aspect of the artefact to explore before implementation so as to automate and reduce the need for maintenance in the future. Since a crane is such a large and important piece of plant to a single site, ensuring it encounters as little down time as possible due to maintenance is vital. On the other hand, applying TQM in depth to the space of empty container depots – even without the application of a crane – could greatly lift value further along in the value stream by ensuring that the finished product meets or exceeds customer expectations.

7.3 CONCLUSIONS

At its core, this thesis takes a pragmatic approach, which aims to offer a solution to a practical problem, while then exploring the effects of this change on key stakeholders. Here, lean operations in conjunction with semi-automated gantry cranes can improve efficiencies in some but not all empty container yards. There must be consistent and sufficient volumes within a region to justify a crane. Moreover, an artefact of this scale cannot afford to ignore qualitative risks and human factors that can have a significant impact on the artefact’s efficacy.

Based on this research, waste can be identified and eliminated around excess handling, land utilisation, adjacency planning, and the flow of goods in empty container depots. Future research will enhance the robustness of the case through applying a crane to a greater variety of empty container depot shapes, and through intensive coding within a TOS to ensure all data can be captured. After a crane has been installed and operations commence, more data can be pulled and analysed, and solutions implemented to continuously improve operational efficiencies over time. Additional improvements could be further made by moving to a fully automated crane as well. This would free up a crane operator's time, as well as pave the way for automating additional services within the yard, moving from batch processing to a more assembly line solution.

Apart from the efficiencies and strategic implications of this research, there are other modular applications that could link into this automation technology. Examples of this would be utilising the data generated by a semi-automated gantry crane within empty container parks in: blockchain formation, internet of things, and heuristical housekeeping stacking of containers to smooth overall operational processes. Other applications could be the installation of a conveyor system to mimic a manufacturing plant, which would maximise the flow of operations and minimise health and safety risks around people interacting with heavy machinery. Simply put, the more data an organisation can gather about its operations, the more it is able to better manipulate those operations for greater efficiencies and increased innovation.

Because of the ubiquitous nature of shipping containers in the modern global economy, as well as the increasing rate of containerisation, the need for empty container depots is only expected to grow in tandem with the growth of world trade. The process of an empty container depot is replicated all over the world in much the same way, and there is very little variation from these norms. In places like Rotterdam where experts are looking to implement similar solutions, the problems they face remain essentially the same: how to decrease costs, smooth the flow of operations, and increase the density of current sites in cities where land is very expensive. The practical applications of this research are scalable on a vast level, and by focusing on a small portion of the supply chain it can eliminate waste in the overall global supply chain.

APPENDICES

SOLUTION 1 SPEEDS

TROLLEY TRAVEL (METERS) \ CRANE TRAVEL (METERS)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155
5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
50	0.6	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41	1.44	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.47	1.51	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
110	1.1	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46	1.50	1.54	1.57	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.53	1.57	1.60	1.64	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73
120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.67	1.70	1.4	1.43	1.5	1.5	1.6	1.6	1.7	1.7
125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56	1.59	1.62	1.66	1.69	1.73	1.77	1.4	1.5	1.5	1.6	1.6	1.7	1.7
130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.76	1.80	1.83	1.5	1.5	1.6	1.6	1.7	1.7
135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.75	1.79	1.82	1.86	1.90	1.5	1.6	1.6	1.7	1.7
140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.82	1.85	1.89	1.93	1.96	1.6	1.6	1.7	1.7
145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88	1.92	1.95	1.99	2.03	1.6	1.7	1.7
150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88	1.91	1.95	1.98	2.02	2.06	2.09	1.7	1.7
155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75	1.78	1.81	1.84	1.88	1.91	1.94	1.98	2.01	2.05	2.08	2.12	2.16	1.7
160	1.51	1.52	1.52	1.53	1.54	1.55	1.56	1.57	1.59	1.60	1.62	1.64	1.66	1.69	1.71	1.73	1.76	1.79	1.82	1.85	1.88	1.91	1.94	1.97	2.01	2.04	2.08	2.11	2.15	2.19	2.22
165	1.56	1.56	1.56	1.57	1.58	1.59	1.60	1.61	1.63	1.64	1.66	1.68	1.70	1.72	1.75	1.77	1.80	1.82	1.85	1.88	1.91	1.94	1.97	2.01	2.04	2.07	2.11	2.14	2.18	2.21	2.25
170	1.6	1.60	1.60	1.61	1.62	1.63	1.64	1.65	1.67	1.68	1.70	1.72	1.74	1.76	1.78	1.81	1.83	1.86	1.89	1.91	1.94	1.97	2.00	2.04	2.07	2.10	2.14	2.17	2.21	2.24	2.28
175	1.64	1.64	1.65	1.65	1.66	1.67	1.68	1.69	1.71	1.72	1.74	1.76	1.78	1.80	1.82	1.84	1.87	1.89	1.92	1.95	1.98	2.01	2.04	2.07	2.10	2.13	2.17	2.20	2.24	2.27	2.31
180	1.68	1.68	1.69	1.69	1.70	1.71	1.72	1.73	1.75	1.76	1.78	1.80	1.81	1.84	1.86	1.88	1.90	1.93	1.96	1.98	2.01	2.04	2.07	2.10	2.13	2.16	2.20	2.23	2.27	2.30	2.34
185	1.72	1.72	1.73	1.73	1.74	1.75	1.76	1.77	1.79	1.80	1.82	1.83	1.85	1.87	1.89	1.92	1.94	1.97	1.99	2.02	2.05	2.07	2.10	2.13	2.16	2.20	2.23	2.26	2.30	2.33	2.37
190	1.76	1.77	1.77	1.78	1.78	1.79	1.80	1.81	1.83	1.84	1.86	1.87	1.89	1.91	1.93	1.95	1.98	2.00	2.03	2.05	2.08	2.11	2.14	2.17	2.20	2.23	2.26	2.29	2.33	2.36	2.40
195	1.81	1.81	1.81	1.82	1.82	1.83	1.84	1.85	1.87	1.88	1.90	1.91	1.93	1.95	1.97	1.99	2.01	2.04	2.06	2.09	2.11	2.14	2.17	2.20	2.23	2.26	2.29	2.32	2.36	2.39	2.43
200	1.85	1.85	1.85	1.86	1.87	1.87	1.88	1.89	1.91	1.92	1.94	1.95	1.97	1.99	2.01	2.03	2.05	2.07	2.10	2.12	2.15	2.18	2.20	2.23	2.26	2.29	2.32	2.36	2.39	2.42	2.46
205	1.89	1.89	1.89	1.90	1.91	1.91	1.92	1.93	1.95	1.96	1.97	1.99	2.01	2.03	2.05	2.07	2.09	2.11	2.13	2.16	2.19	2.21	2.24	2.27	2.30	2.33	2.36	2.39	2.42	2.45	2.49
210	1.93	1.93	1.94	1.94	1.95	1.96	1.96	1.98	1.99	2.00	2.01	2.03	2.05	2.06	2.08	2.10	2.13	2.15	2.17	2.20	2.22	2.25	2.27	2.30	2.33	2.36	2.39	2.42	2.45	2.48	2.52
215	1.97	1.97	1.98	1.98	1.99	2.00	2.01	2.02	2.03	2.04	2.05	2.07	2.09	2.10	2.12	2.14	2.16	2.19	2.21	2.23	2.26	2.28	2.31	2.34	2.36	2.39	2.42	2.45	2.48	2.52	2.55
220	2.01	2.02	2.02	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.09	2.11	2.13	2.14	2.16	2.18	2.20	2.22	2.24	2.27	2.29	2.32	2.34	2.37	2.40	2.43	2.46	2.49	2.52	2.55	2.58
225	2.06	2.06	2.06	2.07	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.15	2.16	2.18	2.20	2.22	2.24	2.26	2.28	2.31	2.33	2.35	2.38	2.41	2.43	2.46	2.49	2.52	2.55	2.58	2.61
230	2.1	2.10	2.10	2.11	2.11	2.12	2.13	2.14	2.15	2.16	2.17	2.19	2.20	2.22	2.24	2.26	2.28	2.30	2.32	2.34	2.37	2.39	2.42	2.44	2.47	2.50	2.52	2.55	2.58	2.61	2.64

*everything beneath the yellow line is calculated using the Pythagorean Theorum
under the assumption that the trolley will be moving at the same time as the crane

*blue indicates any movement at 0.82mins or less. Red indicates any movement at 2mins or more

* 0.18 indicates the 2 shortest hoist movements along the Z axis of 5.4meters at 60m/min

SOLUTION 2 SPEEDS

CRANE TRAVEL (METERS)

		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235
	5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	50	0.60	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
TROLLEY TRAVEL (METERS)	75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41	1.44	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.47	1.51	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	110	1.10	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46	1.50	1.54	1.57	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.53	1.57	1.60	1.64	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
	120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.67	1.70	1.4	1.43	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56	1.59	1.62	1.66	1.69	1.73	1.77	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.76	1.80	1.83	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.75	1.79	1.82	1.86	1.90	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.82	1.85	1.89	1.93	1.96	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88	1.92	1.95	1.99	2.03	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88	1.91	1.95	1.98	2.02	2.06	2.09	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
	155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75	1.78	1.81	1.84	1.88	1.91	1.94	1.98	2.01	2.05	2.08	2.12	2.16	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5

*everything beneath the yellow line is calculated using the Pythagorean Theorum
under the assumption that the trolley will be moving at the same time as the crane

*blue indicates any movement at 0.82mins or less. Red indicates any movement at 2mins or more

* 0.18 indicates the 2 shortest hoist movements along the Z axis of 5.4meters at 60m/min

SOLUTION 3 SPEEDS

CRANE 1 TRAVEL (METERS)

TROLLEY TRAVEL (METERS)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
50	0.60	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08	1.13	1.18	1.23	1.28	1.33
90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08	1.13	1.18	1.23	1.28	1.33
95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38	1.13	1.18	1.23	1.28	1.33
100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41	1.44	1.18	1.23	1.28	1.33
105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.47	1.51	1.23	1.28	1.33
110	1.10	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46	1.50	1.54	1.57	1.28	1.33
115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.53	1.57	1.60	1.64	1.33
120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.67	1.70
125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56	1.59	1.62	1.66	1.69	1.73
130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.76
135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.75	1.79
140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.82
145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.85
150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88
155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75	1.78	1.81	1.84	1.88	1.91

*everything beneath the yellow line is calculated using the Pythagorean Theorum
under the assumption that the trolley will be moving at the same time as the crane

*blue indicates any movement at 0.82mins or less. Red indicates any movement at 2mins or more

* 0.18 indicates the 2 shortest hoist movements along the Z axis of 5.4meters at 60m/min

CRANE 2 TRAVEL (METERS)

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
50	0.60	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33
85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08	1.13	1.18	1.23	1.28	1.33
90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08	1.13	1.18	1.23	1.28	1.33
95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38	1.13	1.18	1.23	1.28	1.33
100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41	1.44	1.18	1.23	1.28	1.33
105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.47	1.51	1.23	1.28	1.33
110	1.10	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46	1.50	1.54	1.57	1.28	1.33
115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.53	1.57	1.60	1.64	1.33
120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.67	1.70
125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56	1.59	1.62	1.66	1.69	1.73
130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.76
135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.75	1.79
140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.82
145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.85
150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88
155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75	1.78	1.81	1.84	1.88	1.91

SOLUTION 4 SPEEDS

CRANE TRAVEL (METERS

TROLLEY TRAVEL (METERS)

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
50	0.60	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08	1.13	1.18	1.23	1.28	1.33	1.38
95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38	1.13	1.18	1.23	1.28	1.33	1.38
100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41	1.44	1.18	1.23	1.28	1.33	1.38
105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.47	1.51	1.23	1.28	1.33	1.38
110	1.10	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46	1.50	1.54	1.57	1.28	1.33	1.38
115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.53	1.57	1.60	1.64	1.33	1.38
120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.67	1.70	1.4
125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56	1.59	1.62	1.66	1.69	1.73	1.77
130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.76	1.80
135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.75	1.79	1.82
140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.82	1.85
145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88
150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88	1.91
155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75	1.78	1.81	1.84	1.88	1.91	1.94

*everything beneath the yellow line is calculated using the Pythagorean Theorum
under the assumption that the trolley will be moving at the same time as the crane

*blue indicates any movement at 0.82mins or less. Red indicates any movement at 2mins or more

* 0.18 indicates the 2 shortest hoist movements along the Z axis of 5.4meters at 60m/min

SOLUTION 5 SPEEDS

CRANE TRAVEL (METERS)

TROLLEY TRAVEL (METERS)

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
50	0.60	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08
60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08
65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08
70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08
75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08
80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08
85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08
90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08
95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38
100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41
105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44
110	1.10	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46
115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49
120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53
125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56
130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59
135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62
140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65
145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69
150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72
155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75
AVER	0.79	0.79	0.80	0.82	0.83	0.86	0.88	0.91	0.94	0.97	0.98	0.99	0.91	0.94	0.98	1.01	1.05	1.08

	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235
5	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
10	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
15	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
20	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
25	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
30	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
35	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
40	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
45	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
50	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
55	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
60	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
65	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
70	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
75	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
80	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
85	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
90	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
95	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
100	1.44	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
105	1.47	1.51	1.23	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
110	1.50	1.54	1.57	1.28	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
115	1.53	1.57	1.60	1.64	1.33	1.38	1.43	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93	1.98	2.03	2.08	2.13	2.18	2.23	2.28	2.33	2.38	2.43	2.48	2.53
120	1.56	1.59	1.63	1.67	1.70	1.4	1.43	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
125	1.59	1.62	1.66	1.69	1.73	1.77	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
130	1.62	1.65	1.69	1.72	1.76	1.80	1.83	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
135	1.65	1.69	1.72	1.75	1.79	1.82	1.86	1.90	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
140	1.68	1.72	1.75	1.78	1.82	1.85	1.89	1.93	1.96	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
145	1.72	1.75	1.78	1.81	1.85	1.88	1.92	1.95	1.99	2.03	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
150	1.75	1.78	1.81	1.85	1.88	1.91	1.95	1.98	2.02	2.06	2.09	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
155	1.78	1.81	1.84	1.88	1.91	1.94	1.98	2.01	2.05	2.08	2.12	2.16	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
AVER	**0.92**																												

*everything beneath the yellow line is calculated using the Pythagorean Theorum

under the assumption that the trolley will be moving at the same time as the crane

*blue indicates any movement at 0.82mins or less. Red indicates any movement at 2mins or more

* 0.18 indicates the 2 shortest hoist movements along the Z axis of 5.4meters at 60m/min

TOTAL AVERAGE ZONE 2 SPEEDS

SOLUTION 6 SPEEDS

CRANE TRAVEL (METERS)

TROLLEY TRAVEL (METERS)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
5	0.27	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
10	0.28	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
15	0.31	0.34	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
20	0.35	0.37	0.40	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
25	0.39	0.41	0.44	0.47	0.43	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
30	0.43	0.45	0.47	0.50	0.53	0.48	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
35	0.48	0.49	0.51	0.53	0.56	0.60	0.53	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
40	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
45	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.73	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
50	0.60	0.61	0.62	0.64	0.67	0.69	0.72	0.76	0.79	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
55	0.64	0.65	0.66	0.68	0.70	0.73	0.76	0.79	0.82	0.86	0.73	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
60	0.68	0.69	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.92	0.78	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
65	0.72	0.73	0.74	0.76	0.78	0.80	0.82	0.85	0.88	0.92	0.95	0.99	0.83	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
70	0.77	0.77	0.78	0.80	0.81	0.84	0.86	0.89	0.92	0.95	0.98	1.02	1.05	0.88	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
75	0.81	0.81	0.82	0.84	0.85	0.87	0.90	0.92	0.95	0.98	1.01	1.05	1.08	1.12	0.93	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
80	0.85	0.85	0.86	0.88	0.89	0.91	0.93	0.96	0.98	1.01	1.04	1.08	1.11	1.15	1.18	0.98	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
85	0.89	0.90	0.90	0.92	0.93	0.95	0.97	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.03	1.08	1.13	1.18	1.23	1.28	1.33	1.38
90	0.93	0.94	0.94	0.96	0.97	0.99	1.01	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.31	1.08	1.13	1.18	1.23	1.28	1.33	1.38
95	0.97	0.98	0.99	1.00	1.01	1.03	1.05	1.07	1.09	1.12	1.14	1.17	1.20	1.24	1.27	1.31	1.34	1.38	1.13	1.18	1.23	1.28	1.33	1.38
100	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.27	1.30	1.34	1.37	1.41	1.44	1.18	1.23	1.28	1.33	1.38
105	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.47	1.51	1.23	1.28	1.33	1.38
110	1.10	1.10	1.11	1.12	1.13	1.14	1.16	1.18	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.40	1.43	1.46	1.50	1.54	1.57	1.28	1.33	1.38
115	1.14	1.14	1.15	1.16	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.53	1.57	1.60	1.64	1.33	1.38
120	1.18	1.18	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.32	1.35	1.37	1.40	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.67	1.70	1.4
125	1.22	1.23	1.23	1.24	1.25	1.26	1.28	1.30	1.31	1.34	1.36	1.38	1.41	1.22	1.46	1.49	1.52	1.56	1.59	1.62	1.66	1.69	1.73	1.77
130	1.26	1.27	1.27	1.28	1.29	1.30	1.32	1.33	1.35	1.37	1.39	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.76	1.80
135	1.31	1.31	1.31	1.32	1.33	1.34	1.36	1.37	1.39	1.41	1.43	1.46	1.48	1.51	1.53	1.56	1.59	1.62	1.65	1.69	1.72	1.75	1.79	1.82
140	1.35	1.35	1.36	1.36	1.37	1.38	1.40	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.82	1.85
145	1.39	1.39	1.40	1.40	1.41	1.43	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.63	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88
150	1.43	1.43	1.44	1.45	1.45	1.47	1.48	1.49	1.51	1.53	1.55	1.57	1.59	1.61	1.64	1.66	1.69	1.72	1.75	1.78	1.81	1.85	1.88	1.91
155	1.47	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.55	1.57	1.58	1.60	1.63	1.65	1.67	1.70	1.73	1.75	1.78	1.81	1.84	1.88	1.91	1.94

*everything beneath the yellow line is calculated using the Pythagorean Theorum
under the assumption that the trolley will be moving at the same time as the crane

*blue indicates any movement at 0.82mins or less. Red indicates any movement at 2mins or more

* 0.18 indicates the 2 shortest hoist movements along the Z axis of 5.4meters at 60m/min

REFERENCES

Adkins, A.W.H. (1978). "Theoria versus Praxia in the Nicomachean Ethics and the Republic." Classical Philology. 73(4). 297-313.

Ahuja, I.P.S., and J.S. Khamba, J.S. (2008). Total productive maintenance: literature review and directions. *International Journal of Quality & Reliability Management,* 25(7). 709-756. https://doi.org/10.1108/02656710810890890

Alho, T., Pettersson, T., & Haapa-Aho, M. (2018). The path to automation in an RTG terminal. *Kalmar,*1-24. Retrieved April 3, 2019, from https://www.kalmar.at/news--insights/2018/20180228_converting-to-autortg--the-next-step-towards-improving-performance/.

Alvesson, M., & Skoldberg, K. (2009). *Reflexive Methodology - 2nd Ed.: New Vistas for Qualitative Research*. London: Sage Publications.

Ansah, R. H., Sorooshian, S., Mustafa, S. B., & Oludapo, O. S. (2017). Constructions project management risks' framework. *Calitatea, 18*(158), 90-95. Retrieved from https://search-proquest-com.helicon.vuw.ac.nz/docview/1912585467?accountid=14782

Aoun, M., Hasnan, N., Al-Aaraj, H. (2018). Relationship between lean practices, soft total quality management and innovation skills in Lebanese hospitals. *East Mediterr Health,* 24(3): 269-276

Arlbjørn, J. S., Freytag, P. V., & Haas, H. D. (2011). Service supply chain management. *International Journal of Physical Distribution & Logistics Management*,41(3), 277-295. doi:10.1108/09600031111123796

Baird, K., et al. (2011). The relationships between organisation culture, total quality management practices and operational performance. *International Journal of Operations and Production Management,* 31(7), 789-814.

Baker, P., & Canessa, M. (2009). Warehouse design: A structured approach. *European Journal of Operational Research*,193(2), 425-436. doi:10.1016/j.ejor.2007.11.045

Bamber, G.J., Stanton, P., Bartram, T., & Ballardie, R. (2014).
Human resource management, Lean processes and outcomes for employees: towards a research agenda, *The International Journal of Human Resource Management*, 25:21, 2881-2891, DOI: 10.1080/09585192.2014.962563

Belfiore, E. (1983). “Aristotle’s Concept of Praxis in the Poetics.” The Classical Journal. 79(2). 110-124.

Bednar, P., & Sadok, M. (2015). Bridging the Gap Between Theory and Practice: Socio-Technical Toolbox. Lecture Notes in Information Systems and Organisation Empowering Organizations,51-62. doi:10.1007/978-3-319-23784-8_5

Bhamu, J., & Sangwan, K. S. (2014). Lean manufacturing: Literature review and research issues. *International Journal of Operations & Production Management,34*(7), 876-940. doi:10.1108/ijopm-08-2012-0315

Bourdieu, P. (1977). Outline of a theory of practice (R. Nice, Trans.). New York: Cambridge University Press.

BOXPORTER RMG. (n.d.). Retrieved February 20, 2019, from https://www.konecranes.com/equipment/container-handling-equipment/boxporter-rmg

Braekers, K., Janssens, G. K., & Caris, A. (2011). Challenges in Managing Empty Container Movements at Multiple Planning Levels. *Transport Reviews*,31(6), 681-708. doi:10.1080/01441647.2011.584979

Briggs, L. (2007). Program Management and Organisational Change: New Directions for Implementation. In *Improving Implementation*(pp. 123-132). ANU Press.

Brunet, A.P., & New, S. (2003). Kaizen in Japan: an empirical study. *International Journal of Operations & Production Management*, 23(12), 1426-1446. doi:10.1108/01443570310506704

Bryman, A., & Bell, E. (2015). Business Research methods (4th ed.). Oxford: Oxford University Press.

Casaca, A. C. (2005). Simulation and the Lean Port Environment. *Maritime Economics & Logistics,*7(3), 262-280. doi:10.1057/palgrave.mel.9100137

Chen, T., Lin, K., & Juang, Y. (2000). Empirical studies on yard operations Part 2: Quantifying unproductive moves undertaken in quay transfer operations. Maritime Policy & Management,27(2), 191-207. doi:10.1080/030888300286608

Cherrafi, A., et al. (2016). The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model. *Journal of Cleaner Production,139*, 828-846. doi:10.1016/j.jclepro.2016.08.101

Creswell, J. W., & Plano Clark, V. L. (2006). Designing and Conducting Mixed Methods Research. Thousand Oaks, CA: Sage

Cudney, E., & Elrod, C. (2011). A comparative analysis of integrating lean concepts into supply chain management in manufacturing and service industries. *International Journal of Lean Six Sigma*,2(1), 5-22. doi:10.1108/20401461111119422

Cullinane, K., & Song, D. (2006). Estimating the Relative Efficiency of European Container Ports: A Stochastic Frontier Analysis. *Research in Transportation Economics*,16, 85-115. doi:10.1016/s0739-8859(06)16005-9

Deloitte. (2016). *New Zealand Ports and Freight Yearbook 2016*. 1-56.

Deloitte. (2018). *New Zealand Ports and Freight Yearbook 2018*. 1-68.

Deloitte. (2019). *New Zealand Ports and Freight Yearbook 2019*. 1-71.

Demeter, K., & Matyusz, Z. (2011). The impact of lean practices on inventory turnover. *International Journal of Production Economics*,133(1), 154-163. doi:10.1016/j.ijpe.2009.10.031

Dotoli, M., Epicoco, N., Falagario, M., & Costantino, N. (2013). A lean warehousing integrated approach: A case study. *2013 IEEE 18th Conference on Emerging Technologies & Factory Automation* (ETFA). doi:10.1109/etfa.2013.6648030

Ehleiter, A., & Jaehn, F. (2016). Housekeeping: Foresightful container repositioning. International Journal of Production Economics,179, 203-211. doi:10.1016/j.ijpe.2016.06.009

Elias, A.A., Cavana, R.Y., & Jackson, L.S. (2002). Stakeholder analysis for R&D project management. *R&D Management, 32(4)*, 301-310. doi:10/1111/1467-9310.00262

Elias, A. A., & Davis, D. (2018). Analysing public sector continuous improvement: A systems approach. *International Journal of Public Sector Management,31*(1), 2-13. doi:10.1108/ijpsm-08-2016-0135

Employment New Zealand. (n.d.). Health and safety at work. Retrieved April 3, 2019, from https://www.employment.govt.nz/workplace-policies/health-and-safety-at-work/

Fenton, C., & Langley, A. (2011). "Strategy as Practice and the Narrative Turn." Organisation Studies, 32 (9). 1171-1196.

Financial Markets Authority. (2018, February 28). Corporate Governance in New Zealand: Principles and Guidelines. Retrieved April 3, 2019, from http://www.fma.govt.nz/compliance/guidance-library/corporate-governance-in-new-zealand-principles-and-guidelines/

Folkerts, M., & Waldner, K. (2006). "Hero", in: Brill's New Pauly, Antiquity volumes edited by: Hubert Cancik and , Helmuth Schneider, English Edition by: Christine F. Salazar, Classical Tradition volumes edited by: Manfred Landfester, English Edition by: Francis G. Gentry. Consulted online on 14 March 2019 <http://dx.doi.org.helicon.vuw.ac.nz/10.1163/1574-9347_bnp_brill060050>

Friedli, T., Goetzfried, M., & Basu, P. (2010). Analysis of the Implementation of Total Productive Maintenance, Total Quality Management, and Just-In-Time in Pharmaceutical Manufacturing. *Journal of Pharmaceutical Innovation,5*(4), 181-192. doi:10.1007/s12247-010-9095-x

Furlan, A., Vinelli, A., Dal Pont, G. (2011). Complementarity and lean manufacturing bundles: an empirical analysis. *International Journal of Operations and Production Management,* 31(8); 835-850.

Galeazzo, A., & Furlan, A. (2018). Lean bundles and configurations: a fsQCA approach. *International Journal of Operations & Production Management.* 38(2), 513-533.

García-Alcaraz, J. L., & Maldonado-Macías, A. A. (2016). *Just-in-time elements and benefits*. Cham: Springer.

Goldkuhl, G. (2012). Pragmatism vs. interpretivism in qualitative information systems research. European Journal of Information Systems. 21, 135-146.

Gregor, S., and Hevner, A. (2013). Positioning and Presenting Design Science Research for Maximum Impact. MIS Quarterly. 37(2)., 337-355.

Haack, S. (1993). Evidence and Inquiry: Towards reconstruction in epistemology. Oxford: Blackwell.

Hevner, A. (2007). A Three Cycle View of Design Science Research. Scandinavian Journal of Information Systems, 19(2)., 87-92.

Hiltrop, J.M. (1992), "Just-in-time manufacturing: Implications for the management of human resources", European Management Journal, Vol. 10 No. 1, pp. 49-55.

Hossain, M. (2017). Mapping the frugal innovation phenomenon. Technology in Society,51, 199-208. doi:10.1016/j.techsoc.2017.09.006

Hossain, M. (2018). Frugal innovation: A review and research agenda. Journal of Cleaner Production,182, 926-936. doi:10.1016/j.jclepro.2018.02.091

Huang, S. Y., & Guo, X. (2011). An improved Least Cost Heuristic for dynamic yard crane deployment in container terminals. 2011 IEEE International Conference on Automation Science and Engineering. doi:10.1109/case.2011.6042520

Ibn-Mohammed, T. (2017). Application of mixed-mode research paradigms to the building sector: A review and case study towards decarbonising the built and natural environment. *Sustainable Cities and Society,35*, 692-714. doi:10.1016/j.scs.2017.09.027

ISO. (2019, February 07). ISO 6346:1995. Retrieved February 28, 2019, from https://www.iso.org/standard/20453.html

Imports and exports | Stats NZ. (2018). Retrieved September 10, 2018, from https://www.stats.govt.nz/topics/imports-and-exports

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. Field Methods,18(1), 3-20. doi:10.1177/1525822x05282260

Jacobs, F. R., & Chase, R. B. (2014). Operations and supply chain management / F. Robert Jacobs and Richard B. Chase. New York: McGraw-Hill/Irwin.

Jasti, N. & Kodali, R. (2015) Lean production: literature review and trends, International Journal of Production Research, 53:3, 867-885, DOI: 10.1080/00207543.2014.937508

Jarzabkowski, P., Balogun, J. and Seidl, D. (2007). "Strategizing: the challenges of a practice perspective." Human Relations, 60(1). 5-27

Jarzabkowsi, P., & Seidl, D. (2008). “The Role of Meetings in the Social Practice of Strategy.” Organisation Studies, 29(11). 1391-1426

Jiang, X., Chew, E. P., & Lee, L. H. (2014). Innovative Container Terminals to Improve Global Container Transport Chains. *International Series in Operations Research & Management Science Handbook of Ocean Container Transport Logistics*,3-41. doi:10.1007/978-3-319-11891-8_1

Karlsson, C., & Åhlström, P. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management*,16(2), 24-41. doi:10.1108/01443579610109820

Kemme, N. (2012). Container-Storage Yard. *Contributions to Management Science Design and Operation of Semi-automated Container Storage Systems*,53-87. doi:10.1007/978-3-7908-2885-6_3

Kim, K. H., & Günther, H. (2005). Container terminals and terminal operations. *Container Terminals and Cargo Systems*,3-12. doi:10.1007/978-3-540-49550-5_1

Kim, K. H., & Hong, G. (2006). A heuristic rule for relocating blocks. Computers & Operations Research,33(4), 940-954. doi:10.1016/j.cor.2004.08.005

Konecranes. (April 3). Automated Cranes. Retrieved from https://www.konecranes.com/equipment/overhead-cranes/automated-cranes

Krafft, F. (2006). “Ctesibius”, in: Brill’s New Pauly, Antiquity volumes edited by: Hubert Cancik and , Helmuth Schneider, English Edition by: Christine F. Salazar, Classical Tradition volumes edited by: Manfred Landfester, English Edition by: Francis G. Gentry. Consulted online on 15 March 2019 <http://dx.doi.org.helicon.vuw.ac.nz/10.1163/1574-9347_bnp_e623840>

Legris, P., & Collerette, P. (2006). A Roadmap for it Project Implementation: Integrating Stakeholders and Change Management Issues. *Project Management Journal,37*(5), 64-75. doi:10.1177/875697280603700507

Leopold, K., & Kaltenecker, S. (2015). *Kanban change leadership: Creating a culture of continuous improvement*. Hoboken, NJ: Wiley.

Lian, Y., & Landeghem, H. V. (2007). Analysing the effects of Lean manufacturing using a value stream mapping-based simulation generator. *International Journal of Production Research*,45(13), 3037-3058. doi:10.1080/00207540600791590

Lim, C., & Fujimoto, T. (2018). Frugal innovation and design changes expanding the cost-performance frontier: A Schumpeterian approach. Research Policy. doi:10.1016/j.respol.2018.10.014

Lindsay, C.M. (1984). *Applied Price Theory.* Chicago: Dryden Press.

MacDuffie, J.P. (1995), “Human resource bundles and manufacturing performance: organizational logic and flexible production systems in the world auto industry”, Industrial and Labor Relations Review, Vol. 48 No. 2, pp. 197-221.

Mangan, J., Lalwani, C., & Fynes, B. (2008). Port-centric logistics. *The International Journal of Logistics Management*,19(1), 29-41. doi:10.1108/09574090810872587

Martínez-Jurado, P.J., Moyano-Fuentes, J., Gómez, P.J., (2013). HR management during lean production adoption, *Management Decision*, 51 (4), 742-760, https://doi.org/10.1108/00251741311326545

Martínez-Lorente, A.R., Dewhurst, F., Dale, B.G., (1998). Total quality management: origins and evolution of the term, *The TQM Magazine.* 10(5), 378-386, https://doi.org/10.1108/09544789810231261

Melton, T. (2005). The Benefits of Lean Manufacturing: What Lean Thinking Has to Offer Process Industries. *ICheme*,83(A6), 662-673. doi:doi: 10.1205/cherd.04351

Menand, L. (2001). The Metaphysical Club. New York: Farrar, Straus, and Giroux.

Ministry for Primary Industries. (2018, September 12). Containers and cargo. Retrieved from https://www.mpi.govt.nz/importing/border-clearance/containers-and-cargo/

Mitchell, R., Agle, B., & Wood, D. (1997). Towards a theory of stakeholder identification and salience: defining the principle of who and what really counts. *Academy of Management Review, 22 (4),* 853-886.

Mittal, N., Boile, M., Baveja, A., & Theofanis, S. (2013). Determining optimal inland-empty-container depot locations under stochastic demand. *Research in Transportation Economics*,42(1), 50-60. doi:10.1016/j.retrec.2012.11.007

Nakajima, S. (1988). “Introduction to TPM”, *Productivity Press,* Cambridge, MA.

Navarro, Z. (2006) ‘In Search of Cultural Interpretation of Power’, IDS Bulletin 37(6): 11-22.

Ng, W. C., & Mak, K. L. (2005). An effective heuristic for scheduling a yard crane to handle jobs with different ready times. Engineering Optimization,37(8), 867-877. doi:10.1080/03052150500323849

Nicolini, D. (2012). Practice Theory, Work, and Organisation: An Introduction. Oxford University Press. 23-43.

O’Leary, Z. (2007). The essential guide to doing research. London; SAGE

Peppard, J. et al. (2014). Information systems strategy as practice: micro strategy and strategizing for IS. Journal of Strategic Information Systems, 23., 1-10.

Pérez-Rodríguez, N., & Holguín-Veras, J. (2014). The Accumulation of Empty Containers in Urban Areas: Policy Implications from a Stochastic Formulation. *Networks and Spatial Economics*,14(3-4), 379-408. doi:10.1007/s11067-014-9231-0

Pinto, J. L., Matias, J. C., Pimentel, C., Azevedo, S. G., & Govindan, K. (2018). *Just in time factory implementation through lean manufacturing tools*. Cham: Springer.

Popescu, M. C. (2018). Eliminating transportation waste using the transportation value stream map. *Proceedings of the International Conference on Business Excellence,12*(1), 793-803. doi:10.2478/picbe-2018-0071

Porter, M. E. (1989). How Competitive Forces Shape Strategy. *Readings in Strategic Management*,133-143. doi:10.1007/978-1-349-20317-8_10

Prajogo, D., et al. (2016). Supply chain processes: linking supply logistics integration, supply performance, lean processes and competitive performance. *International Journal of Operations and Production Management,* 36(2). 220-238. doi:10.1108/IJOPM-03-2014-0129

Ruttmann, B.G. (2018). *Lean compendium: Introduction to modern manufacturing theory*. Cham, Switzerland: Springer.

Saanen, Y., & Valkengoed, M. (2005). Comparison of Three Automated Stacking Alternatives by Means of Simulation. Proceedings of the Winter Simulation Conference, 2005.doi:10.1109/wsc.2005.1574425

Schonberger, R. J. (2007). Japanese production management: An evolution—With mixed success. *Journal of Operations Management*,25(2), 403-419. doi:10.1016/j.jom.2006.04.003

Schuldt, A. (2011). Implementing Autonomous Logistics. *Multiagent Coordination Enabling Autonomous Logistics*,177-194. doi:10.1007/978-3-642-20092-2_8

Seidl, D., & Whittington, R. (2014). "Enlarging the Strategy-as-Practice Research Agenda: Towards Taller and Flatter Ontologies." Organisation Studies, 35(10). 1407-1421.

Shadur, M.A., Rodwell, J.J. and Bamber, G.J. (1995), "Factors predicting employees' approval of lean production", Human Relations, Vol. 48 No. 12, pp. 1403-1425.

Shah, R. (2003). Lean manufacturing: Context, practice bundles, and performance. *Journal of Operations Management*,21(2), 129-149. doi:10.1016/s0272-6963(02)00108-0

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*,25(4), 785-805. doi:10.1016/j.jom.2007.01.019

Singh, J., & Singh, H. (2015). Continuous improvement philosophy – literature review and directions. *Benchmarking: An International Journal,22*(1), 75-119. doi:10.1108/bij-06-2012-0038

Singh, J., & Singh, H. (2019). *Strategic implementation of continuous improvement approach improving the performance of small and medium-sized enterprises*. Cham: Springer.

Slack, N., & Lewis, M. (2015). Operations strategy. Harlow, England: Pearson.

Sreejesh, S., Mohapatra, S., & Anusree, M. R. (2014). *Business research methods: An applied orientation*. Cham: Springer.

Stone, K. (2012). Four decaes of lean: a systematic literature review. *International Journal of Lean Six Sigma,* 3(2), 112-132, doi:10.1108/20401461211243702

Stopford, M. (1997). *Maritime Economics*. doi:10.4324/9780203442661

Theofanis, S., & Boile, M. (2008). Empty marine container logistics: Facts, issues and management strategies. *GeoJournal*,74(1), 51-65. doi:10.1007/s10708-008-9214-0

UNCTAD (1997). Review of Maritime Transport. 1-139. http://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

UNCTAD (2017). Review of Maritime Transport. 1-130. http://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

Wascher, G., & Merker, J. (1997). A comparative evaluation of heuristics forthe adjacency problem in facility layout planning. International Journal of Production Research,35(2), 447-466. doi:10.1080/002075497195849

Wee, H., & Wu, S. (2009). Lean supply chain and its effect on product cost and quality: A case study on Ford Motor Company. *Supply Chain Management: An International Journal*,14(5), 335-341. doi:10.1108/13598540910980242

Whittington, R. (2014). Information Systems Strategy and Strategy-as-Practice: A join agenda. Journal of Strategic Information Systems 23., 87-91.

Whittington, R. (2006). Completing the Practice Turn in Strategy Research. Organisation Studies, 27(5), 613-634.

Womack, J.P., Jones, D.T. and Ross, D. (1990), The Machine that Changed the World, MacMillan/Rawson Associates, New York, NY.

Worksafe New Zealand. (2017, September 05). Keeping safe around moving plant. Retrieved April 3, 2019, from https://worksafe.govt.nz/topic-and-industry/plant-and-equipment/moving-plant-fs/

Yang, C., and Yang, K. (2013). An integrated model of the Toyota Production System with Total Quality Management and People Factors. *Human Factors and Ergonomics in Manufacturing and Service Industries*, 23(5), 450-461.