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Potential improvements in a container terminal through information sharing

Master's Thesis in the Master's Programme
Supply Chain Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: STS cranes together with straddle carriers and a container ship.

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Abstract

Around 90% of world trade is currently transported through the shipping industry. The competitiveness is high and companies in the industry are continuously searching for new ways to increase performance and cut costs. Seaport terminals are important actors in the shipping industry since they are the connection between sea and land transport. One problem today at some seaports, which is reflected in literature and at a case terminal, is the limited information that is shared with the manual straddle carriers.

This master's thesis aims to investigate whether increased information in one container terminal can improve its operational effects. Interviews, observations and tests were performed at a case terminal to evaluate the impact of increased information sharing for straddle carriers moving containers to and from the ship-to-shore cranes. During the tests, additional information was shared to the straddle carrier drivers through a text message function, with a maximum limit of 38 characters. The operational effect of the STS-crane was measured during the test and the result was evaluated with the usage of a statistical z-test.

The findings were, by increasing the shared information to straddle carriers, the operational effects were statistically significant that the ship-to-shore cranes increased their performance. If the possibility to share information would increase further than the current limit of 38 characters, the performance of STS-cranes and straddle carriers could possibly be improved even more. Therefore, suggestions for additional information that did not fit in the text message are also presented in this thesis.

Keywords: Information Sharing, Container Terminal, Seaport, Straddle Carrier, Ship-to-shore Crane.

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Firstly, we would like to thank the case terminal for letting us perform our measurements. Our contact person at the terminal for providing us with access and connections. The workers at the case terminal who participated during the interviews and allowed us to accompany them in their machines during their daily work. We would also like to thank the dispatchers and planners who helped us during our measurements by lending computers, teaching us how the system work and gave us free access to anything we requested during the progression.

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Gothenburg, June 2019
Arvid Edforss
Jesper Hansson

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List of Abbreviations

AGV	Automated guided vehicle
FEU	Forty-foot equivalent unit
KPI	Key performance indicator
RMG crane	Rail mounted gantry crane
RTG crane	Rubber tyre gantry crane
SC	Straddle carrier
STS crane	Ship-to-Shore crane
TEU	Twenty-foot equivalent unit

1

Introduction

This chapter presents the background to the issue investigated in this thesis. It also describes the purpose of the work and the research questions to be answered.

1.1 Background

Container transport is the most important transportation mode for international trade, and it is considered a key for economic globalization (L. Chen, Xu, Zhang, & Zhang, 2018). The international shipping industry is currently responsible for around 90% of world trade (Grbic, 2016). The competitiveness is high and concepts like slow-steaming, when vessels reduce speed to lower fuel consumption, is commonly used to reduce cost and increase profit (Ha & Seo, 2017; Liang, 2014). For sea transport to be operable there has to be some kind of transshipment between sea and land. These transshipments are usually managed by ports around the world where the goods are moved between trucks, railway and vessels. Ports are also important for the economic activities in the hinterland since they are the connection between sea and land transport (Dwarakisha & Salima, 2015).

Ports throughout the world are connected by several complex networks of long going and temporary shipping lanes (Ducruet, Rozenblat, & Zaidi, 2010; Kaluza, Kölzsch, Gastner, & Blasius, 2010; Mærsk, 2017). The main lanes of major shipping companies are operated with some of the largest vessels in the world (Mærsk, 2018; MSC, 2015; OOIL Group, 2017), which are able to carry over 21 000 'Twenty-foot Equivalent Units' (TEU) (Lumsden, 2007). The size of these vessels limits which terminals are able to accommodate them due to harbor depth, size of ship-to-shore gantry cranes (STS cranes) and demand (Thoresen, 2014). This is significant to determine the delegation of vessels to different shipping lanes (Mærsk, 2018). Major ports are connected by direct lanes and feeder traffic which simply is transshipment to minor ports with smaller vessels. Feeder traffic distributes and collects goods to support the intercontinental lanes and gain economy of scale (Mærsk, 2017; Unifeeder, 2019).

Most ports are the connection between sea transport and land-based transports on trucks or railway (Lumsden, 2007). The difference in capacity between vessels and land-based transportation modes are handled by either storing containers in the terminal or large number of trucks and trains connected to the arrival of the vessel. Most common is to store containers which divide the intermodal change over an extended period of time compared to the duration when vessels are at the port. The port operator is the one who manage most of the activities in the terminal such as storing, discharging and loading. Both at quay with different vessels and land side with multiple trucks and train sets at the railway (Lumsden, 2007).

Terminals are operated quite different depending on the invested infrastructure (Thoresen, 2014). Some terminals are more automated than others, using automated guided vehicles (AGVs) to move containers between STS cranes and storage (Pjevcevica, Nikolica, Vidicb, & Vukadinovica, 2017). Other port operators are more manual and use straddle carriers, terminal trucks and/or reach stackers. These machines are driven by operators to move containers and oversized good (Lumsden, 2007; Thoresen, 2014).

AGV shuttles or straddle carriers are typical machines serving the STS cranes with containers, they are referred to as the 'fed delivery service'. STS cranes are used in most container ports to unload and load the vessels at quay. The modern STS cranes can accomplish about 30-40 containers lifts per hour if the fed delivery service is working properly. In the largest port there can be up to six STS cranes who works simultaneously with the same container vessel (Thoresen, 2014). The ones who allocate the jobs in the terminal for both straddle carriers and STS cranes are called dispatchers. When the vessel is planned a computer-software distribute the jobs but if the unexpected happens the dispatcher manually select the jobs to make sure everything will work in the end (Bish et al., 2005). Figure 1.1 depicts a side view of a container terminal with the STS cranes at the quay and container stacking straddle carriers in the yard.

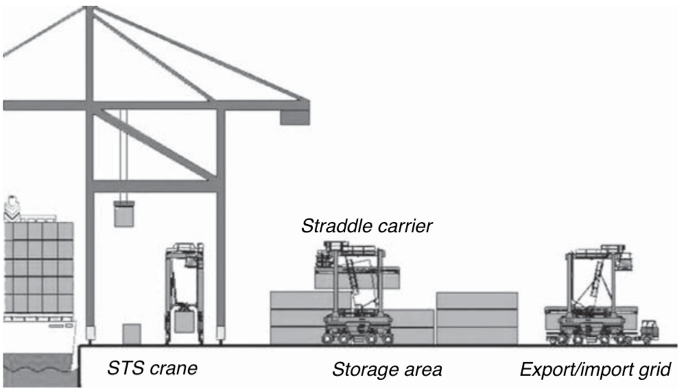

Figure 1.1: Side view of a container terminal adapted by Thoresen (2014).

Studies show that by using higher number of AGVs when running a terminal operation, the utilization of the STS cranes increases and in the same time the utilization of the AGVs decrease (Pjevcevica et al., 2017). The utilization is the extent to which space, workforce or equipment like STS cranes, AGVs and straddle carriers, are used (Jadayil, Khraisat, & Shakoor, 2017). For instance, idling, which is when machines are standing still, gives a negative impact on the utilization (Burgess, Peffers, &

Silverman, 2009). Being able to balance the utilization of the different operating machines can decrease the time it takes to turnaround a vessel in port and ensure that it departs on time (Pjevcevica et al., 2017; Zhen, Xu, Wang, & Ding, 2016). Information sharing is the transfer of data between individuals and it can potentially decrease the turnaround time at seaport that uses a more traditional container handling (Sonnenwald, 2006). Enhancing the workers with information through new technology could increase the ports' performance (Romero et al., 2016). As a comparison to an automated operator who is only able to add more vehicles to improve performance if it is truly efficiently programmed. According to Folan, Browne, and Jagdev (2007), when a firm operates and expands, the firm itself would not be able to resist, analyzing how this change are compared to present or other similar operations. The performance is the objective in which this comparison eventuates in (Folan et al., 2007).

Mili and Gassara (2015) state in their article that even if the distance traveled for manual straddle carriers is minimized as much as possible, by for example genetic algorithms, there is still a possibility of human error. Especially if the operators find it difficult to follow the complicated itineraries assigned to them. These errors could be reduced by using a proper communication and tracking system (Mili & Gassara, 2015). Reducing the errors will give a positive operational effect. Operational effect is when a new implementation affects the operation, the implementation can have either a positive or negative effect (Duistermaat et al., 2007).

1.2 Case terminal

Most part of the thesis was carried out at a case terminal were one of the authors had previously worked. The authors had access to the terminal during the whole project and this was where the observations, interviews and measurements took place. The case terminal should be thought of as a seaport and a big actor among the world's container transports and hubs. The investigated case terminal uses the operating system Navis which is used by around 70% of the world's terminal operators (Navis, 2018). Today's settings might limit the machine operator which needs to be investigated further if it affects the overall performance.

1.3 Purpose

The purpose of this work is to investigate how unnecessary stops of STS cranes can be reduced by improved management of straddle carriers through information sharing. The STS cranes performance are crucial for terminal operators to be able to assure turnaround times so vessels can depart on time (Pjevcevica et al., 2017; Zhen et al., 2016). Improved information sharing to the straddle carrier operators could lower the risk of unnecessary stops for STS cranes and increase opportunities for operators to take own initiatives. The information could also allow them to make decisions that improves production rates, increases movement, reduces the stress level and intriguing the employee to actively look for things around them that can be improved or acted upon.

1.4 Research questions

To fulfil the purpose of this work, three research questions need to be answered.

RQ1 - *How are STS cranes and straddle carriers operated in container terminals?*

This is done to clarify how the container and straddle carrier flows are operated around the STS cranes. What different settings and operations that are performed to discharge and load container vessels.

RQ2 - *What information is required to be shared to improve the performance of straddle carriers in container terminals?*

There might be many improvements for the straddle carriers that could emerge from shared information. It is valuable to find differentiated improvements depending on operations related to discharge, loading and preparation work etc.

RQ3 - *What are the operational effects of information sharing in container terminals?*

The findings will have to be evaluated. Some of them will be tested in live production to see if the outcomes support the theoretical improvements.

2

Review of relevant literature

Within this chapter, literature related to general container terminals, the particular case terminal and framed scope of this thesis work is reviewed.

2.1 Intermodal container transports

Container transport are a pristine intermodal solution, having standard units that are transferred between different modes of transportation, normally sea, rail and truck. Transfers are performed at several nodes in the transportation networks connecting different terminals and, in the end, almost any destination in the world (Lumsden, 2007; Roso, 2013). Typical intermodal transports can contain both truck and railway transports before and after a voyage on a container vessel (Roso, 2013).

2.1.1 Containers

According to literature, a container is a reinforced steel box developed to allow goods to be packed and sent without any additional handling before discharge at the final destination (Babicz, 2015). Containers have corner fittings in all corners, which are the connection points for machines, locking devices and lashing equipment, in order for the container to be transported and handled (Thoresen, 2014). There are several different characteristics a container can bear. They can be ventilated, insulated, refrigerated, open top, bulk liquid, flat rack, vehicle rack or equipped with interior devices (Babicz, 2015). Common measures are (TEU) 'twenty feet equivalent unit' and (FEU) 'forty feet equivalent unit'. TEU and FEU describes the twenty feet (20') and forty feet (40') containers (Babicz, 2015; Rushton, Croucher, & Baker, 2010). As an example; vessels are measured by the number of TEUs they can carry to describe a vessels maximum capacity. When containers in general differs in sizes this is used as a common equivalent measurement index (Thoresen, 2014).

Containers are part of the ISO standard and sometimes described as 'ISO containers'. Within this standardization the containers are defined with measures and features to enhance the use all over the world (Rushton et al., 2010). The standard lengths are 20' and 40', but there are containers with lengths of 24', 45', 48' and 53'. Containers can also differ in height and width. Height is either eight feet six inches (8’6") for a normal cube (DV), also known as dry van, and 9’6" for a high cube (HC). Width is either 8’0" or 8’6" for ordinary cubes (Babicz, 2015; Rushton et al., 2010; SeaRates LTD, 2019). There are also possibilities that vehicle racks, flat racks and open top containers can be loaded with oversized goods, the first two with wider loads and all three with higher loads than the standard container heights (SeaRates LTD, 2019). How they are further handled and what machines are used to be loaded or discharged from vessels are explained in section 2.1.4 under *"Oversized goods"*.

2.1.2 Container terminal

According to Babicz (2015) a container terminal is "An area designated for the stowage of containers; usually accessible by truck, railroad and marine transportation. Containers are picked up, dropped off, maintained and housed there".

2.1.3 Operations in container terminals

Container terminal operations are dependent on long term investment. What is acquired today is calculated to be in production for many years, if not several decades (Bartošek & Marek, 2013). When demand changes over time, increased volume and calls of larger vessels arriving to the terminal is constrained to be serviced by these assets. Already invested infrastructure that initially were calculated might be outdated or fairly undersized. This does not mean that new investments and potential optimization would be viable before already existing infrastructure has been paid off or become obsolete (Bartošek & Marek, 2013). Terminals, old and new, are having these challenges. Not only performing on every container move, but at what level the terminal area is used, which is considered a limited resource. Even smaller terminals can change their ability to handle larger volumes through a change of infrastructure, but reasons as costs, foundation and ground support, duration of the transition and current equipment and its life span intervals can be part of that decision.

2.1.4 Equipment in container terminals

In this section, basic container handling equipment is presented. This is done to later provide the reader with information on how the equipment is used in the terminal. By defining the equipment, the reader will be able to understand the work-related issues presented in ’Chapter 4’ that can affect measures and the way the authors have performed their experiment and data gathering to avoid those issues.

Ship-to-shore Cranes are electric rail mounted cranes that operates along the quay, directly perpendicular to the vessels berth position (Bartošek & Marek, 2013). The cranes are able to move along the side of the vessels to operate all possible container positions on board. Containers are then moved between the vessel and land side where it is handled by the 'fed delivery service'. According to Bartošek and Marek (2013), the first STS crane dates back to 1959, and was built in Alameda, USA. That crane was designed to handle containers weighing 23 tons, lifting 16 meters over the rail and with an outreach of 24 meters over the vessel. Today's cranes have more than doubled in size and are capable of lifting 75 meters high and with an outreach of over 70 meters weighing up to 1800 metric tons (Bartošek & Marek, 2013). STS cranes are calculated to operate over a period of 25 years, but effective life span will not exceed 20 years. Vessels are continually getting larger and STS cranes are directly connected and needs to be able to handle these future new vessels (Bartošek & Marek, 2013).

STS cranes are capable of handling 30 to 40 container lifts per hour, averaging cycles lifts between 90-120 seconds. Terminals that are equipped with straddle carriers are able to support the highest numbers with an ability to produce up to 40 lifts per hour (Thoresen, 2014). Terminals equipped with terminal trucks are only able to achieve between 28-35 lifts per hour Thoresen (2014).

On the STS crane, there are two major openings that goes straight through the construction, (1) first one is in the bottom of the crane and runs parallel to the vessel, the width of this space is also referred to as the 'crane rail gauge' (Bartošek & Marek, 2013), and (2) the opening underneath the beam that stretches over the vessel underneath and behind the STS crane, which is known as the outreach and back reach. The space below the beam runs perpendicular to the vessel and rail and allows containers to be lifted between vessel and shore. The lower opening creates a space formed as a roofless tunnel with the crane structure that limit the entrance. This space is used by the 'fed delivery service' to operate in and through. This tunnel runs parallel to the quay and rail beneath the STS crane. The height of the entrance and width of this tunnel differs between STS cranes, much due to already invested infrastructure or machines e.g. already existing rail or chosen fed delivery service (straddle carrier or AGV shuttle carrier). Normally the rail gauge is between 16-35 meters and the minimum height is twelve meters (Thoresen, 2014). A rail gauge of 35 meters will allow six truck lanes between the STS crane legs (Thoresen, 2014). The second opening runs through the crane construction above the leg structure and perpendicular to the vessel, rail and tunnel. The opening underneath the beam is connected to the tunnel and creates an operational space, the width of this space is minimum 16 meters (Thoresen, 2014). The weight of the STS crane is resting on the rail, both at the quay side and at the land side legs. The two openings and their connection allow the crane to operate containers and hatch covers either over the vessel, under or behind the STS crane and in between.

Straddle carrier is a specialized container handling vehicle that allows a terminal to stack containers three high with a minor gap between the container rows, to be able to access them. The straddle carrier is a high raised vehicle which straddles the container and carry the container in its belly (N Spasovic, Professor, Sideris, Das, & Chao, 1999). The machines are diesel electric or diesel hydraulic which powers the four center wheels and with steering on all eight (KoneCranes, 2017b). The four front wheels turn in one direction and the four in the back turns in the other direction, which gives the vehicle extraordinary maneuverability in the terminal, both under cranes and around the yard. Depending on model, they can lift from first to a fourth layer, able to operate every individual container within a few extra moves, independent of position and length of the rows (KoneCranes, 2017b).

The straddle carrier is equipped with a yoke, also known as spreader, that attaches to the containers corner fittings. The machine is able to lower twin boxes to handle twin 20' containers. The yoke is adjustable between 20', 30' and 40'. All containers can be lifted with the 20' and 40' position and the 30' is dedicated to move the cone handling platform, which is further explained in section 4.1.2 under *platform* (KoneCranes, 2017a). When the yoke is in 40' position, twin boxes can be lowered, which enables the machine to lift and handle two 20' containers as twins. To easier lift separated 20' containers or just create a gap between the containers when placed in the yard e.g. when placing them on top of other already placed containers that may be separately placed. The yoke is guided by the construction and can be adjusted by hydraulic pistons to easier align and lift targeted containers. The joke is then lifted by four cables, one in each corner of the yokes fixed guiding construction. Straddle carriers are often top heavy, the construction is heavy since the engine is placed in the top of the machine together with other lifting accessories. In addition, when the spreader and container are lifted the center of gravity shifts, especially when carrying a loaded container. Operating speed is limited in transport mode and further decreased when the container is lifted higher to reduce the risk of tumbling over (KoneCranes, 2017a, 2017b).

Straddle carriers are suited for smaller terminals, with minor need for reinforcement of the terminal pavement and fairly simple ways of making alterations to the terminal layout (Thoresen, 2014). Terminals with straddle carriers stack containers either two or three high. This system is normally the fastest system for a terminal that handles 100 000 to about 3 000 000 TEU per year (Kalmar, 2007; Thoresen, 2014). According to Thoresen (2014) typical generalization to a straddle carrier system are; (1) three to five straddle carriers per crane, (2) straddle carriers perform an average of 10 moves per hour, (3) the medium density in the yard is 500-750 TEU per ha, (4) the STS cranes have a high productivity with a buffer zone under the crane, (5) the system carries a high labor, capital and operation cost, (6) the system is very flexible in regard of relocation within the terminal, (7) the terminal layout is easy to alter, (8) high control, when trucks are restricted to certain receiving areas.

Terminal tractor is a type of truck equipped with a fifth wheel coupling to transport trailers short distances mainly within industrial areas or ports (KalmarOttawa, 2018; Thoresen, 2014). This specialized vehicle can hitch trailers, flatbeds and wagons and raise the trailer front without raising the landing gear. Often used in different terminals and other transport businesses, moving trailers and other equipment (KalmarOttawa, 2018). Container terminals use basic wagons that are adapted to keep containers in place during the short transports within the terminal area. With small elevated lumps for the containers corner fittings that are placed along the wagon's chassis at standard distances.

Reach stackers is another vehicle that is used to stack containers in terminal yards. It has the ability to stack containers with a high density which gives an increased yard utilization in the terminal. Reach stackers can be used to load and unload flatbeds that are moved with terminal trucks serving as the fed delivery service. A reach stacker system is suited for small terminals handling approximately 200 000-300 000 TEU per year. This system can stack 4 containers deep in stacks of six high but in many places, containers are just stacked 2 in depth and 3-4 high, to avoid large amounts of reshuffling when needed in other orders (Thoresen, 2014). According to Thoresen (2014) there are generalizations that can apply to the reach stacker system; (1) there are normally three to five terminal trucks and two reach stackers per STS crane, (2) the yard will only be utilized with about 500 TEU per ha with stacks of 4 high, (3) will contain a medium productivity for the STS crane with a non-buffer zone beneath the STS crane, (4) low capital and operations cost, but high labor costs and (5) low control, allowing trucks in the stacking area.

Oversized goods are transported in vehicle racks, flat racks or open top containers (SeaRates LTD, 2019). Special over height frames are placed on the container frames working as an extension to avoid damages to the goods (Tec Container Asia Pacific, 2015). These are located in the terminal and transported to and from the vessel by the fed delivery service. These goods are often handled in a parallel flow, loaded on flatbeds pulled by terminal tractors, and loaded and unloaded with reach stackers in the terminal and by STS crane at the vessel. These goods are often loaded on board, either on top of containers, below or above deck when they constrain what is able to be loaded around or above (SeaRates LTD, 2019).

Rail mounted gantry (RMG) and rubber tyre gantry (RTG) cranes are used to stack containers in the yard. From a vessel, the STS crane places the container on a shuttle carrier or a terminal tractor which moves the load to the RMG or RTG system. These two cranes drive over several rows of containers that are placed rather tight together. They can span between 20-50 meters depending on construction, but usually 5-9 containers wide, around 10x40' containers in length and between 4-6 containers in each stack (Nidec, 2009; Thoresen, 2014). When running normally the number of moves can differ between 15 to 25 containers per hour (Thoresen, 2014). According to Thoresen (2014) these systems are economically viable for terminals that handles over 200 000 TEU per year. RTG or RMG cranes are the only practical solution for terminals with either restricted or expensive land areas when handling large numbers of containers. The yard density of this system when containers are stacked four high are about 800 TEU per ha. RTG cranes in particular have been used worldwide in terminals for many years. There are several different manufacturers lowering both maintenance and capital infrastructure costs (Thoresen, 2014). According to Thoresen (2014) generalizations can be applied to RMG and RTG supported by shuttle carriers; (1) high productivity for the STS crane with buffer zone under the crane, (2) one STS crane is supported by two RTG/RMG cranes and two to three straddle carriers, depending on distance from the yard cranes to the berth sight, (3) the system requires high capital costs, medium operating costs and low labor costs. When operated with support of terminal tractors. According to Thoresen (2014) generalizations apply; (1) medium productivity for the STS cranes and no buffer zone under the cranes, (2) one STS crane is supported by two RTG/RMG cranes and two to three shuttle carriers, depending on distance from the yard cranes to the berth sight, (3) the system requires medium capital and operation costs but high labor costs.

RMGs are fixed installations that runs along rails and RTGs are able to move between the different yard blocks. RTGs are able to turn the wheels 90 degrees and travel perpendicular to the blocks, along the yard, to operate in different blocks depending on need and utility. These crane types can be one, two or three in combined settings in one block. If more than one, they are either two identical or one that is higher than the other, that can move over, making them switch places in the yard block. This setting is normally performed with RMGs that follows individual tracks, keeping the two cranes away from each other when passing to avoid collisions. There are also combinations with two identical cranes, with a third, larger crane, that can over pass the two others. Increasing the productivity and availability in the yard (Carlo et al., 2014).

In addition to road connections, some terminals are connected with railway from the inland. These types of inter-modal connections are handled with one or more RTGs that span several rail tracks (Carlo et al., 2014). Containers are then transported to inland container terminals, often referred to as inland ports or dry ports (Carlo et al., 2014; Roso, 2013).

2.1.5 Vessel structure

Over the year's vessels have become larger and larger and miner improvements are implemented regularly in newer vessels. Many vessels are tailored to fit the specific shipping companies needs regarding ocean liners or feeders and they are often built in series of at least a few sister ships to divide and carry the development costs (Lumsden, 2007; Mærsk, 2017). Even if the vessels are individually developed, they follow some basic structures and features, which some are explained in this section (Babicz, 2015).

Bays and lashing bridges, aboard a vessel, bays are a vertical division of a vessel from steam to stern, used as one part of the indication of the container stowage position together with rows and tiers. Odd bay numbers indicate a 20' position and even bay numbers indicate 40' positions. The numbers start from low numbers close to the steam to highest in the stern (Babicz, 2015). Some vessels are equipped with dedicated single bays for 20' containers, mainly vessels with extended guides above deck or vessel called open hutch, that are further described in section 2.1.5. Guides above deck can hold both 20' and 40' containers, with the addition that 20' twin containers are in need of cones to stay in position, avoiding sliding out of place and damage other goods (Babicz, 2015).

The largest vessels today are able to stack ten containers above deck. Containers by themselves are not structurally fit to cope with the forces and motions affecting them on the transoceanic voyages (Babicz, 2015). To be able to stack containers higher they are strapped to the vessel with lashing which is further explained in the section 2.1.5. There is a certain level that can be unleashed over the top lashed containers and to allow higher tiers, lashing bridges are built on each side of the bay hatches to simply reach higher lashing points and increase the tiers in each stack. Lashing bridges are strong steal structures built on deck raising from a few meters to several stories. The distance to the lashing bridge from the locked position of the containers are restricted by a minimum distance to be able to perform the lashing (Babicz, 2015). There is certain level that needs to be exceeded to stack longer containers e.g. 45' containers, creating a distance from the lashing bridges and enable lashing in bottom of the container or in layers below.

Hatch covers and holds, containers on board vessels are stacked both above deck and below in holds. To maintain a weather proof volume and to ensure a safe journey, the vessel is sealed with hatch covers dividing the load above and below deck, which is illustrated in figure 2.1. Hatch covers distribute the weight of the load to spread the forces throughout the vessels construction and prevent water to enter the holds below deck. On the larger vessels hatch covers can weigh more than 20 metric tons and be structurally strong enough to carry several hundred metric tons of cargo (Babicz, 2015).

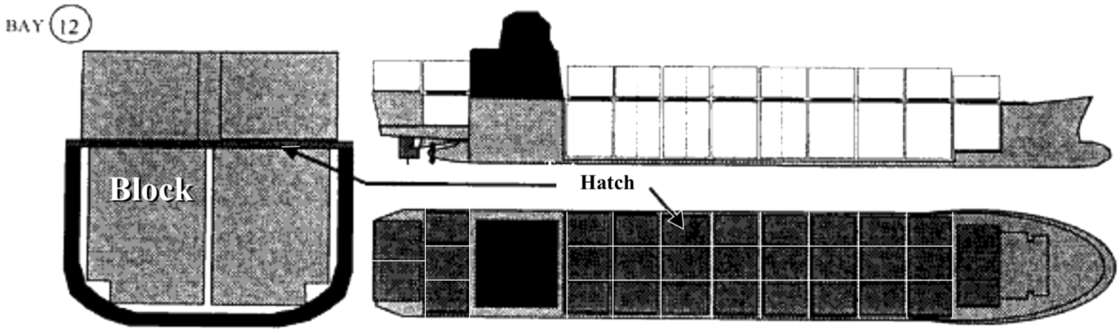

Figure 2.1: Blocked container vessel abstraction (Wilson & Roach, 2000).

There are a few types of hatch covers that are used on different vessels. Some are mounted on hinges and lifted by hydraulic cylinders and maneuvered by the deck men on board. Others are lifted off the vessel and are placed on the docks concrete paving, either between the legs of the STS crane or behind the STS crane (Babicz, 2015). In rare cases hatch covers are placed above another hatch cover on board, mainly on larger vessels where there are multiple hatch covers in the same bay. Hydraulic systems are generally used on smaller vessels with one hatch cover in each bay (Babicz, 2015).

A specific type of container vessel goes under the name of 'open-top' or 'open-hatch'. This type of vessel, in all or some of the bays, have robust guides built above the normal deck line and lack hatch covers over the holds. In general, this design is common on feeder vessels and are used on vessels designed to carry up to approximately 4000 TEUs (Babicz, 2015). These vessels are designed with large pumps that are dimensioned to handle excessive amount of water during the worst severe storms and weather conditions at sea, that risk to flood the open holds (Babicz, 2015). This type of vessel is designed to minimize the use of lashing equipment in an attempt to reduce the turnaround time at the terminal (Babicz, 2015).

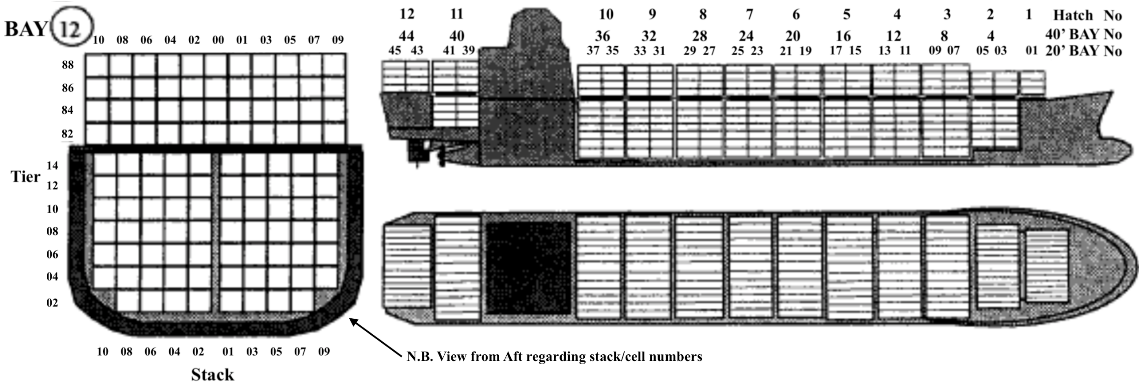

Figure 2.2: Stowage arrangement for a container vessel, adapted, by Wilson and Roach (2000)

The holds are dimensioned to carry 40' containers that are fixed within guides along the fore and aft of the bay. By fixating the containers, the need for lashing or cones are eliminated (Babicz, 2015). Each row or cell have their own guides. The heaviest goods are often loaded in 20' containers. Two 20' containers placed in twin are among the heaviest units that covers a 40' footprint lifted aboard the vessel. Combining them in to a twin and placing them in the bottom layers in the holds aboard is standard procedure to guaranty the vessels stability. This leaves the center of the twin to be able to slide out of position if not fixated by cones, these cones are further explained in section 2.1.5. The heaviest containers are loaded in the bottom and units with lower weight are placed higher up in the stacks. Placing 40' containers above twin 20' containers is a common procedure, but the other way around is prohibited when the 40' containers are not structurally designed to carry that load in the center of the container. The stowage plan is showed in figure 2.2, which is an illustration of a vessel's available stowage positions, with standardized numbering and logic for all container positions (Babicz, 2015).

Vessel equipment, to perform the discharge and loading sequence at port the vessel brings their own equipment, mainly 'cones' and 'cone bins' to be used by terminal workers, but also 'lashing rods' and associated 'turnbuckles'. Every vessel got a limit to what number of containers they can carry, and the equipment is by that reason limited by the possible combinations of stowage (Babicz, 2015).

Cones are locking mechanisms that are placed in the bottom corner fittings of containers (Babicz, 2015; Thoresen, 2014). This is done either at the cone fitting platform or in special sequences or conditions on board the vessel. There are a few different types of cones, some prevent the containers from sliding sideways and some securely lock them to the container below. In cases where cones with locking mechanism are used, either deck men or terminal workers need to unlock them before the STS crane can discharge the containers (Babicz, 2015).

If the containers are stacked high, they are lashed to the deck or lashing bridges with 'lashing rods' and turnbuckles. The 'lashing rod' is placed in the 'corner fittings' of the containers at certain levels to secure the stacks on deck. This can differ between different vessels and how the containers are stacked. The turnbuckles are either secured to the lashing bridge, hatch covers or the deck. 'Lashing rods' are lose metal rods with a few lumps on the end and a hinged hook in the other end. The rods are positioned in the corner fittings of containers and placed in an angle that locks the container. These lashing rods are aligned with the turnbuckle and the turnbuckle is attached to a suitable lump and screwed down to a tight fit. Unused lashing rods are stored either upon the lashing bridge or on deck (Babicz, 2015).

2.2 Yard management

Terminals today are operated with different equipment, there are three widely spread types of systems in use to stack and store containers; (1) a forklift and reach stacker system, (2) a straddle carrier system, (3) a 'rubber tyre gantry' (RTG) and/or 'rail mounted gantry' (RMG) system, (4) combinations or mixtures of these three (Thoresen, 2014). Depending on what equipment is used there are unique options to optimize and run the terminal efficient. There are many ways to measure the efficiency of storage systems, one way is to compare the number of TEUs stored per hectare which can be seen in figure 2.3.

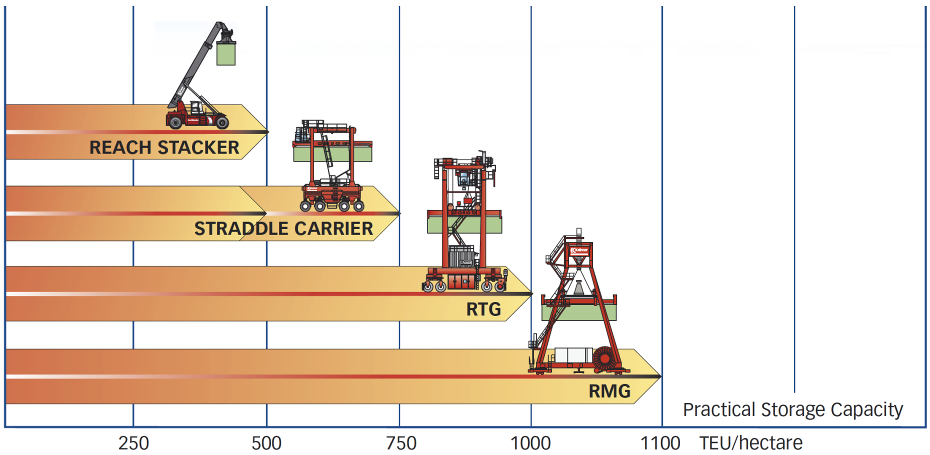

Figure 2.3: Note: actual storage capacity depends on operational aspects such as required selectivity etc. (Kalmar, 2007).

To generalize yard layouts, they consist of multiple rectangular blocks which are served by either one or several material handling machines (Carlo et al., 2014). The material handling machines are the decision basis for what type of strategy the individual terminals yard management team are using. In a study where 114 terminals where represented, 63.2 % of the terminals used RTGs as their main material handling equipment. Making RTGs the number one main handling system, followed by straddle carriers that in the same study where the main material handling equipment in 20.2 % of the terminals according to Carlo et al. (2014).

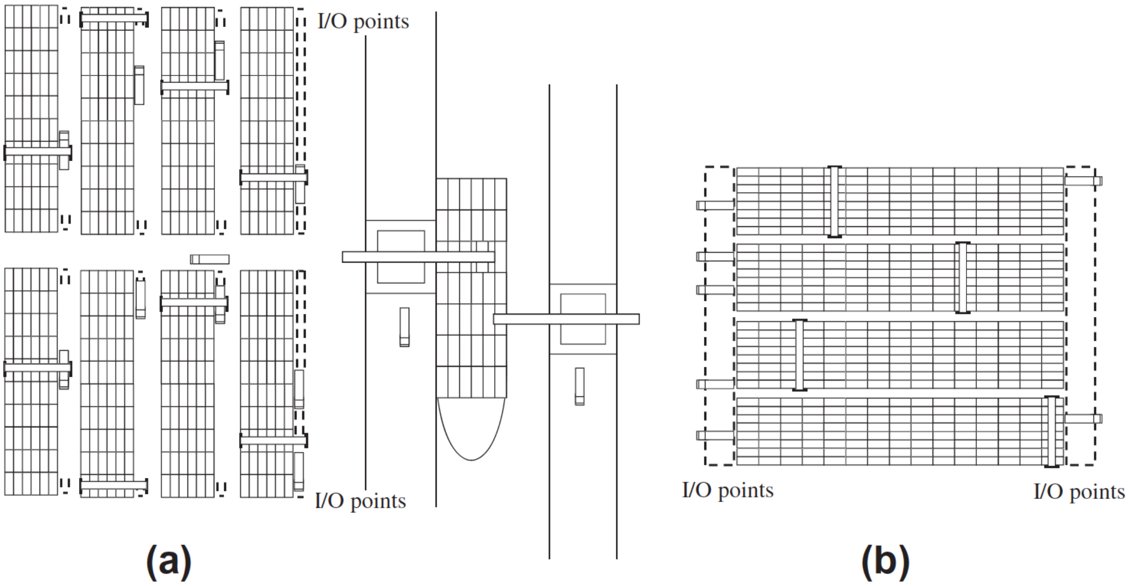

Figure 2.4: Asian (a) and European (b) storage yard layout (Carlo et al., 2014).

The utilization of RTGs and RMGs can differ between terminals. Partially depending on the different types of fed delivery service that is used in the terminal and the level of control e.g. if external truck drivers are allowed in to the yard area or not (Carlo et al., 2014; Thoresen, 2014). As seen in figure 2.4 the layout and storage under the cranes and the input/output (I/O) points, where the containers are loaded and unloaded differ from long-side in example (a) and short-side in example (b). This doesn't only affect the number of possible stored containers under the crane but also how the terminal wants to store and stack containers in the yard. Utilizing storage type (a) showed in figure 2.4, the fed delivery service parks close to the container or its planned position beneath the gantry crane to be lifted. This saves time when the lifting distance to and from the vehicle is reduced, but the traveling distance of the vehicle is longer. Utilizing storage type (b) showed in figure 2.4, makes the distance from and to the berth place shorter for each vehicle and an increased storage beneath each gantry crane. This alternative provides longer traveling distance for the crane and preferred option of having the container position close to the I/O point in close connection to the berth if it is an export container and closer to the land side I/O point if it is an import container. Containers are then moved within the block to prepare imports and exports for later transition. As mentioned in section 2.1.4 under *"Rail mounted gantry (RMG) and rubber tyre gantry cranes (RTG)"*, the blocks can be served with more than one RTG or RMG crane at once. This increases the ability to re-handle and prepare the blocks to reduce time when containers are ready for a move to be loaded on vessels or trucks (Carlo et al., 2014).

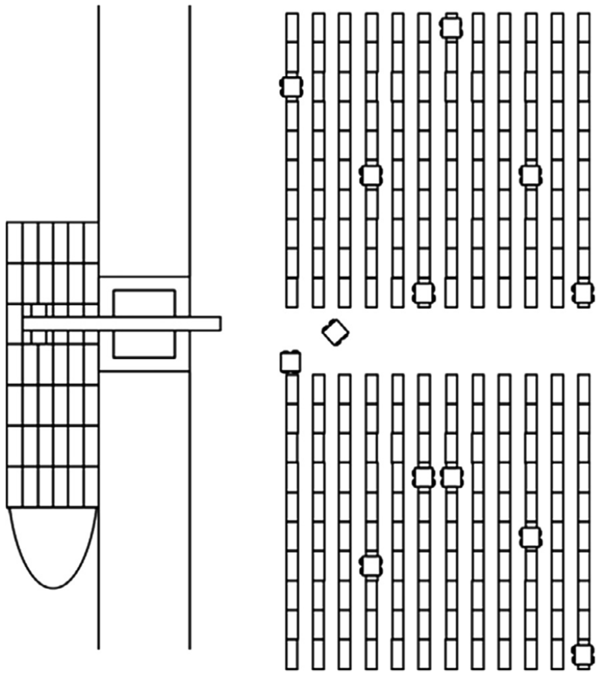

Figure 2.5: Storage yard layout for straddle carrier (Carlo et al., 2014).

Terminals that uses straddle carriers as their main handling system are also using several rectangular blocks as storage areas, with the miner difference of having larger gaps between the container rows. Normally a distance of half a container width is used, making the blocks generally 50 % wider compared to when the containers are stacked close together. A straddle carrier yard layout is roughly illustrated in figure 2.5 with machines and gaps. These gaps are required for the machine to be able to straddle and move within the row to stack containers. The rows are referred to as linear stacking. Figure 2.5 shows the rows parallel to the quay but there are blocks in straddle carrier terminals that are perpendicular to the quays (Carlo et al., 2014).

All different systems used in ports requires terminal operators to stack containers on top of each other and in specific places and orders, where in the end, there is a need of a re-positioning. Either to make place for other containers or to move the containers closer to the I/O points to reduce the time it takes to perform the planned moves during the call of the vessel. There are also types of re-handling where containers are gathered in the same area, where they are either going to the same port or they are specifically placed in sequences to be loaded in a certain order on the vessel. These types of moves are referred to as re-marshalling or housekeeping (Carlo et al., 2014).

Terminals can be divided into a primary and a secondary yard area. The primary area considers the storage area for loaded containers in direct contact with the berth area, where the STS cranes are active (Thoresen, 2014). The secondary yard includes the empty flow with storage area, container maintenance, repair areas and equipment storage e.g. extension frames, lashing cages for manual work on unreachable heights and chains to lift damaged containers (Thoresen, 2014).

2.3 Information sharing

Information is data that can lead to less uncertainty and increased understanding. It is timely, accurate and presented in a relevant and meaningful way. Information is important since it can influence actions, decisions or results taken by different actors (Losee, 1998).

Information sharing is the transfer of data between people, organizations and technologies. Sharing information, either upon request or proactively, changes a person's view of the world and creates a mutually compatible understanding of the environment (Sonnenwald, 2006). It includes supplying information, confirming that the information is understood and that it has been received. Information sharing is an important activity when people collaborate with each other. When a group works together, there must be a continual information flow between the members and an ability to understand the information that others provide. If information is not shared in a good and effective way, the collaborative work fails (Sonnenwald, 2006).

According to Mohr and Nevin (1990), there are four fundamental parts when communicating information: frequency, direction, modality and content. Frequency refers to the amount of shared information between actors in the organization. The frequency can be both big and small. A minimum amount of shared information is crucial but sharing too much information can give negative effects. The direction describes if the information is shared vertically or horizontally among the actors in the organization. Generally, information is shared downwards from the more powerful actor to the weaker actor. The direction can also be either unidirectional or bi-directional, e.g. information is shared in one direction or two directions. The modality specifies the method which is used to share the information. It can be done by writing, telephoning, speaking face-to-face or in other ways. Modality can also be defined as if the information sharing is structured and adjusted or spontaneous and non-adjusted. The final part is content which refers to the kind of information that is shared. Two frequent ways of categorizing content is the type of shared information and the type of influence strategy in the shared information (Mohr & Nevin, 1990).

Heilig and Voß (2017) state in their article that sharing information through different systems have become essential for the competitiveness of ports. It enhances the decision making which gives increased reliability, productivity and security in ports. Real-time information and data have increased in importance to improve the planning and coordination of activities among actors in port operations. The positioning data of objects, such as containers, are necessary for forecasting which is a foundation for long- and short-term decision making. The importance of shared information will increase in the future due to challenges and competitiveness faced by ports around the world (Heilig & Voß, 2017).

2.4 ARA-model

The ARA-model contribute with a theoretical framework of the operation and results of interaction. It is mainly used to describe the interaction between companies in business relationships. A relationship is a jointly cooperation between mutually dedicated groups. The model contains three different layers: Actor Bonds, Activity Links and Resource Ties (Håkansson & Snehota, 1995). The model suggests that each of the three layers are closely related and affects each other (Ford, Gadde, Håkansson, Snehota, & Waluszewski, 2010).

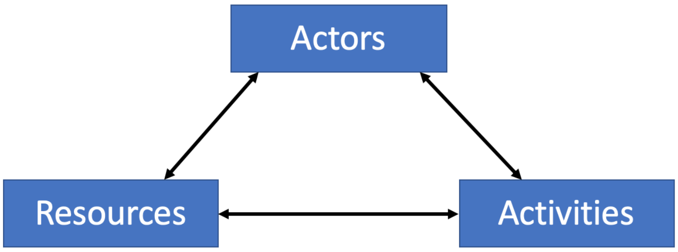

Figure 2.6: The ARA-model with its three layers (Håkansson & Snehota, 1995)

2.4.1 Actors

Individuals are the ones that affect what happens in networks. They do not act by themselves, instead they interact with each other and their actions becomes systematized. The actor dimension is restricted by the activity and resource dimension. In some industries changes in connection and actor design might take several years due to inactivity and resource status. The actor layer goes beyond the other two and it is more complex than the other with more soft and abstract values (Håkansson & Snehota, 1995). The layer is constructed on how much the actors know see and feel close to one another. How they like, impact and trust each other and evolve a dedication together. Connections between actors differs in strength which influences how the involved individuals see possibilities and achievable directions for the interaction (Ford et al., 2010).

2.4.2 Resources

Actors use resources which can be in the form of financial, personal, technical or other shape. Resources can be tangible such as physical items like equipment or a factory and intangible like knowledge. There is no actor that has all the required resources, so resources are shared between actors. The resource layer describe how resources are used between actors when their interaction develops. Sharing resource between each other can increase the degree of utilization of each resource (Ford et al., 2010). Studies show that actors develop resources, new products and use products in new ways. These improvements of resources often advance from relationships between actors since when sharing something together increases the chance of confronting how a resource is produced (Håkansson & Snehota, 1995).

2.4.3 Activities

Activities are carried out by actors, there are different activities like buy and sell, develop, logistics, information handling and production. A large number of activities are performed by actors. The way that the activities are accomplished regulates the revenues and costs for actors. It is not only important to do things right, but actors should also do right things. Several activities are not carried out in isolation instead the activities performed by different actors are connected and dependent on each other (Håkansson & Snehota, 1995). The actor's activity structures can become more or less linked and integrated. It has been shown that the stability and strength of the activity links have a great impact on the financial effects for the concerned actors (Ford et al., 2010).

2.5 Lean

Lean originates from the Japanese company; Toyota and it is a method used in manufacturing processes to minimize and eliminate waste. The lean technique contains several different principles which are all important to know before adopting the method (SixSigma, 2017).

According to SixSigma (2017), the first principle is, as mentioned before, to eliminate waste. When eliminating waste, companies should examine all different areas in the system and detect the work that does not contribute with any value. Everything in the manufacturing operation that does not add value to the products is considered a waste. In Toyota, seven different wastes were found which can be seen below (Berlec & Starbek, 2019).

1. Overproduction
2. Waiting
3. Transport
4. Inappropriate Processing
5. Unnecessary Inventory
6. Unnecessary Motion
7. Manufacturing Defects

Another principle is that companies should aim for having a leveled production, which means that the workload should be evenly distributed over all working days. The risk of overproducing is significantly increased if a company increase the production effort when they get a large volume order. The most important principle in lean methodology is to have continuous improvements. A company will not have any progress at all if they do not improve. But it does not matter if the organization have small or big improvements, the important thing is that the company is open for new enhancements, which in the end will lead to progress (SixSigma, 2017).

Liker (2004) summarizes Toyotas lean thinking with the 4P model (see figure 2.7). The first part of the **4P model** is **Philosophy**, a company should base their decisions on long-term thinking even though it might lead to costs in the short-term. The second part is **Process**, if the leaders adopt the right process, they get the right results. They should create process flows that unveil problems and implement standardized work as a foundation for continuous improvements and the workers participation. Another important part in lean is the **People and partners**, companies should evolve leaders that understand the work, practice the company's philosophy and learn it to others. If a person wants to grow personally and has the capacity to do it then they are to invest in. The last and final part is **Problem solving**, lean encourage people to go and see the problem themselves to really understand the situation and by that take the right decision. Companies should become a learning organization by continuously reflecting and constantly improving (Liker, 2004).

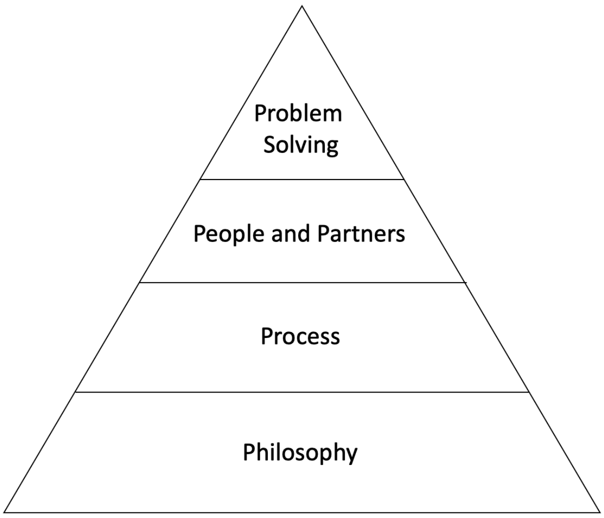

Figure 2.7: 4P model (Liker, 2004).

2.5.1 Lean in container terminals

According to Christopher (2000), lean works best when the demand is predictable, relatively stable, and the volumes are high. A container terminal differs from manufacturing since it does not produce anything and terminals handles containers in two flows, both export and import. Vessels could also be loaded and discharged at the same time which requires high coordination and has led to a more complex process (Casaca & Bernard Marlow, 2003). Therefore, lean needs some modifications before implementing it at a container terminal since it is primary constructed for the manufacturing industry (Olesen et al., 2015). Olesen et al. (2015) recommends a framework which can be used when implementing lean at container terminals, the framework consists of four fundamental principles which can be used to enhance the physical flow in terminals. The framework can be seen in figure 2.8.

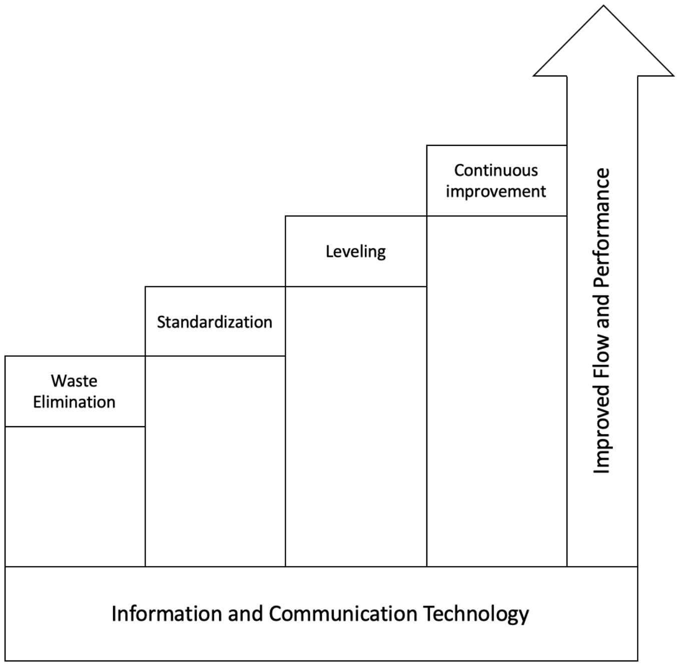

Figure 2.8: Framework which can be used when implementing lean at container terminals (Olesen et al., 2015).

The first principle is waste elimination. Olesen et al. (2015) declare that the concept of waste elimination has to be changed since some of the wastes in lean are hard to translate when considering terminals. For instance, transportation is considered a waste in lean, but this is the main reason for why terminals exist. Another waste is inventory, but since terminals are paid for keeping inventory, it should be seen as a value adding service instead of waste (Olesen et al., 2015).

The second principle is standardization. According to Olesen et al. (2015), one of the main reasons for using standardization is to minimize the variation in processes and to encourage continuous improvement. It is suggested to use standard work when trying to eliminate variation in operations at container terminals (Shingo, 1989). One important part in standardized work is visualization. Normal work procedures should always be at the workplace and up to date. These work procedures are called standard operations and procedures (SOPs). By instantly visualize crucial information the risk for confusion and time for trying to find the information is reduced (Bicheno & Holweg, 2009).

The third principle is leveling. Jones (2006) states in his article that leveling is used for smoothing the variation between internal operations. It is used in lean with the purpose to establish a more coordinated flow and to deal with the variability of vessel arrivals. Variability between internal processes leads to irregularities in activities and an overburdening of workers. By using the depot function more in a terminal the loading and unloading could be leveled through preparations before peak demand (Olesen et al., 2015).

The fourth and last principle is continuous improvement. The concept has been used successfully at plenty of organization to encourage workers to continuously look for improvements in their daily operations (Imai, 1986). By using basic activity mapping tools, a terminal could reach proper countermeasures which can improve operations and increase value-adding processes (Olesen et al., 2015).

2.5.2 Measure activity time

According to Rubin and Babbie (2009), it is not simple to find and eliminate waste and measuring the difference between various solutions could also be problematic. One way to measure the time of activities is to let the machine operators do self-observations. However, measuring activities with self-observation could lead to biased data both by changing the data and also by working in a different way than usually just to improve the data (Rubin & Babbie, 2009). The machine operators' tasks can also require a lot of focus, which can imply that they do not have time to register everything which results in lack of data, especially when data is gathered by hand. To contribute to increased motivation and thereby better data, one can use apps for phones to measure times by pressing button. StarDriver is a smartphone-app with the task to measure activities of truck drivers. It is built on the lean framework to find and eliminate time waste (Prockl & Sternberg, 2015).

Machines operators might also do multiple activities at the same time which lead to a risk of increased confusion when measuring different activities. An option to increase the details in the data is to measure with participant observations. The quality of data improves but it is costly and if much data is needed it is not feasible. Also, if the sample is relatively small the participants who gathers the data are reserved with reporting special situations since it could threaten the anonymity of the operators. It is, however, apparent that the data quality is better when measured by participant observations compared to self-observations (Prockl & Sternberg, 2015).

2.6 Statistical testing

Statistical testing is used to give meaning of data series, it involves planning, data collection, analyzing and concluding (Ali & Bhaskar, 2016). Statistical hypothesis testing is popular when an analyst wants to define a substantive claim (Veazie, 2015). A hypothesis is a theory or a suggestion which is used for explaining why an observed phenomenon happened (S. Dubois, 2017). If a scientific hypothesis is proven correct in repeatable experiments, it could become a theory or even a law of nature. Hypothesis testing is commonly used to make decisions from gathered data. Simply put, a hypothesis test concludes if an observed phenomenon is likely to really reflect the reality based on statistics. According to S. Dubois (2017), hypothesis testing is one of the most essential parts in statistics since it determines if something really occurred.

S. Dubois (2017) states in her article that before testing the observed phenomena, a hypothesis or guess of what could happen has to be made. The hypothesis could be that certain groups differ from each other or that an improvement in a process has a measurable outcome. By establishing your hypothesis there are two possible outcomes, the first one is the null hypothesis that there was no difference or that the improvement did not have any effect and the second is the alternative hypothesis which means that the guess is correct. In other words, when you are testing a hypothesis, you attempt to identify if something occurred and are comparing against the likelihood that nothing occurred. This is pretty confusing since you are attempting to disprove that nothing occurred. By disproving that nothing occurred, the conclusion that something occurred can be made. You draw your conclusions when all the data is collected, and you tested the hypothesis against the risk for chance. If the null hypothesis is rejected, you are claiming that the outcome did not occur by luck and that it is statistically significant. By rejecting the null hypothesis, the alternative hypothesis is accepted. If the null hypothesis cannot be rejected the conclusion is that there is no difference in the study (S. Dubois, 2017).

Significance levels are used to show how likely the result from your data is due to chance (du Prel, Hommel, Röhrig, & Blettner, 2009). Significance limits are generally stated in advance to allow a determination between the null hypothesis and the alternative hypothesis. The most common used significance level is 0.05 (or 5%), at this point the result is considered to be good enough to be believed. This significance level also minimizes the risk that the null hypothesis is wrongly rejected. When the significance level is 0.05 the risk that the null hypothesis is wrongly rejected is 5% (du Prel et al., 2009).

The result of a statistical test is the p-value. The p-value is the probability that the null hypothesis is false. If the p-value is less than the significance level the result is considered significant, the null hypothesis is rejected and the alternative hypothesis is accepted which means that there is a difference (du Prel et al., 2009).

2.6.1 Boxplot

According to Portela, Ribeiro, and Gama (2019), an outlier is an extreme value in data series which lies far from other data points. Outliers are normally regarded as unusual values affecting the overall test due to their extreme values and they should therefore be removed. Outliers could originate from errors in measurements which might lead to over- or underestimates of studies (Portela et al., 2019).

One of the most common methods for detecting outliers is a boxplot analysis (Portela et al., 2019). It is a simple graphing tool that provides a lot of details about the distribution in data series (Krzywinski & Altman, 2014). An example of a boxplot can be seen in figure 2.9.

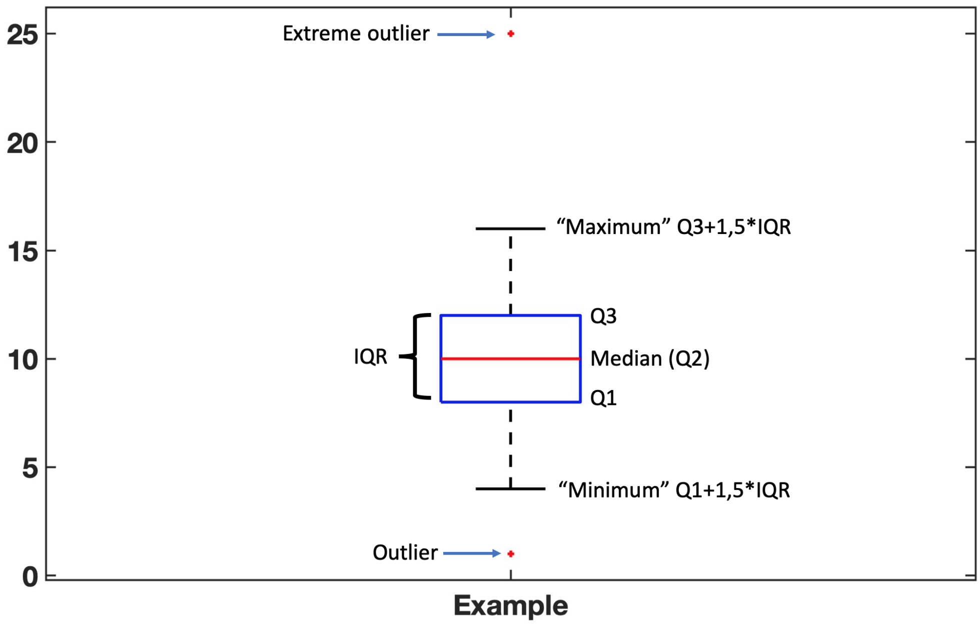

Figure 2.9: Example over a boxplot (Galarnyk, 2018).

The first thing to identify in a boxplot is the median (Q2) which is the number in the middle of the data sheet. After the median is found two interquartiles are identified. These interquartiles are in the middle of each half so the first quartile (Q1) is in 25% of the data sheet and the third quartile (Q3) is in 75% of the data sheet (Galarnyk, 2018). The interquartile range (IQR) is the range between these two interquartiles. The observations that fall outside of 1,5*IQR below the first quartile or above the third quartile are considered outliers and the once that fall farther than 3*IQR are considered as extreme outliers (Portela et al., 2019). The formula for extreme outliers can be seen in equation 2.1.

$$\text{Extreme outliers} = Q1 - 3 * IQR \text{ or } Q3 + 3 * IQR \tag{2.1}$$

2.6.2 Paired z-test

One popular test used by researchers is the z-test and it is best used when the sample size is larger than 30 (J. Chen, 2019). The paired z-test is used to analyze if the difference between two population means is lower, greater or not equal to zero (NCSS, 2019). This gives three possible hypotheses.

(1) - The two tailed hypothesis test is defined as:

Null hypothesis	Alternative hypothesis
$H_0 = 0$	$H_A \neq 0$

Rejecting the null hypothesis indicates that the mean paired difference is not equal to zero (NCSS, 2019).

(2) - The other two are one-sided tests. The hypothesis for the lower-tailed test are:

Null hypothesis	Alternative hypothesis
$H_0 \geq 0$	$H_A < 0$

By rejecting the null hypothesis, the mean paired difference is less than zero, hence the difference between the sample means is less than zero (NCSS, 2019).

(3) - Vice versa applies for the upper-tailed test:

Null hypothesis	Alternative hypothesis
$H_0 \leq 0$	$H_A > 0$

Rejecting the null hypothesis implies that the mean paired difference is greater than zero (NCSS, 2019).

The random sample points are defined as x_i and a paired z-test assumes that these random sample points are from a normally-distributed population and all of them has the same mean and variance. The equation used when calculating the paired z-test is given in equation 2.2 (NCSS, 2019).

$$Z = \frac{\sqrt{n} * (\overline{x})}{\sigma} \tag{2.2}$$

n - is the sample size.

$\overline{x}$ - is the average value of the paired differences.

σ - is the standard deviation of the paired differences (NCSS, 2019). According to Hargrave (2019), standard deviation measures the dispersion of a set of data relative to the its average value. If the sample points are closer to the mean the deviation is lower, hence the denser data the lower is the standard deviation (Hargrave, 2019).

To be able to reject the null hypothesis at a significance level of 5%, the z-value has to be higher than 1.96 or lower than -1.96 for a two tailed hypothesis test. For a lower-tailed test the z-value has to be less than -1.645 and for an upper-tailed test the z-value has to be greater than 1.645 for the null hypothesis to be rejected at a significance level of 5% (Sullivan, 2017).

3

Methodology

In this section the method that is used to fulfill purpose and research questions of this thesis will be described. The methodology includes data collection methods, workflows and design of experiments.

3.1 Research approach

According to Spens and Kovács (2006), there are three different research approaches: inductive, deductive and abductive which can be seen in figure 3.1. Inductive and deductive are two general approaches, the inductive approach starts with observations and then develops theory about the investigated phenomena. The deductive approach test theory by first establishing a theoretical framework and then see if it works in reality. The third approach is the abductive research approach, it starts with an observation of a real phenomenon but at the same time the theoretical framework plays an important role. The researcher uses a creative repetitive method of matching theory to the observation (Spens & Kovács, 2006). Abductive approach is when researchers goes back and forth between theory and observations and consequently increase their understanding of the phenomena (A. Dubois & Gadde, 2002).

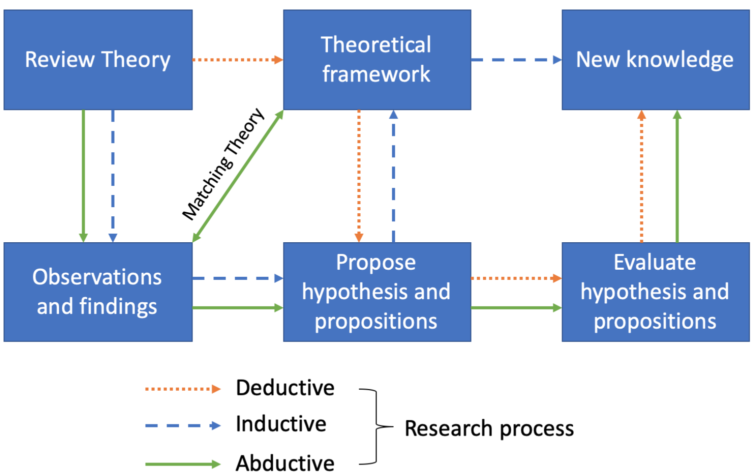

Figure 3.1: Deductive, inductive and abductive approach (Spens & Kovács, 2006)

In this thesis an abductive approach was used, it was best suited for this research since both theoretical framework and observations contributed to the analysis and conclusions of this project. First an observation that the straddle carrier operators had insufficient information was made by the authors. The observation was then matched with theory about the problem. During the thesis, observations and interviews were made simultaneously with and confirmed by the theoretical framework. After the observations and theoretical framework was made, a hypothesis was proposed and later evaluated.

3.2 Literature review

Literature reviews are performed in academic studies to get a deeper understanding of certain topics (Maxwell, 2012). In this thesis a literature review of studies and theories that were particularly relevant to the research has been investigated. Several articles, books and scientific research were studied during the process of this thesis. The literature that was examined in the review was mainly gathered from Chalmers library database, ScienceDirect and Google Scholar. Some articles which were used in the review were also recommended by the supervisor for this thesis. Important literature areas were yard management, transportation management, information sharing, lean, physical distribution management and statistical tests. The aim of the literature review was to increase the knowledge and to find a base for both author and reader.

Most of the searches for important literature were made in English but some Swedish articles and books were also used in the research. Bell (2011) state in her book that it is important to eliminate irrelevant material in the literature study. Therefore, the authors were restrictive with using literature that was older than 20 years since it seldom applied to the current terminal and were outdated when it came to potential information improvements. However, one exception was the lean concept since most of the fundamental articles and books about lean were older than 20 years.

3.3 Research process

This thesis was divided into three phases, one phase for each research question. In every phase a literature review was performed to increase the authors knowledge about the topic around the issues. Whenever an observation was made during a phase it was checked with theory to increase the understanding of the phenomena.

In the initial phase, the first research question was evaluated. Here the goal was to clarify the flows in a container terminal to support the other research questions. To answer this question, observations, literature studies and interviews were used. The ARA model, as mentioned earlier in section 2.4, was used as a tool to facilitate the mapping of the processes. The mapping was assisted by the fact that the authors already had basic knowledge of terminal equipment through their studies within supply chain management and previous work in the case terminal.

During the second phase, improvements for straddle carriers through increased information sharing was evaluated. In order to find possible improvements, the authors' previous knowledge was used together with observations, literature studies and interviews in the case terminal. The interviewees' long work experience as straddle carrier operators was the main key when solving this research question. Several ideas were discussed with the operators who also came with suggestions on how their work situation could be improved by increased information.

In the third phase, measurements were made in the case terminal. The measurements evaluated the information sharing's impact on the operations in the terminal. To analyze the effect of the shared information, a hypothesis test was. Discussions were also held with the straddle carrier operators who participated during the tests to find out what they thought about the shared information.

3.4 Data Collection

Several data collection methods were used to get an understanding of the case terminal, knowledge about terminal systems and to evaluate potential improvements etc. The primary data that were used to support the thesis were measurements, observations and interviews.

3.4.1 Observations and interviews

Observations and interviews were conducted to analyze how straddle carriers and STS cranes operates and how straddle carriers assist the STS cranes in terminals. Before any observations were made at the case terminal, the case terminals website and other articles about the terminal was studied to get an understanding of the terminals function and what it handles. Since one of the authors worked at the case terminal before the thesis, basic knowledge about the terminal already existed. During the thesis, several observations were made by accompanying STS crane and straddle carrier operators. Dispatchers at the case terminal were also observed and discussions were held with them to get a deeper understanding of the movement of straddle carriers and the structure at the terminal. A table of all the performed observations can be seen in table 3.1.

Table 3.1: All observations during the project.

Organization	Approach	Aim
Case Terminal	Worked as a straddle carrier operator.	Before and during the time of the thesis one of the authors worked as a straddle carrier operator.
	Ride with a straddle carrier operator.	Get a view of the activities for straddle carrier who serves the STS crane.
	Ride with an STS crane operator.	Get an understanding of how vessels are loaded and how straddle carriers are affecting STS cranes.
	Study the dispatcher.	Get an understanding of dispatcher's role in the terminal.
	Ride with an STS crane operator.	Get an understanding of how vessels are unloaded and how straddle carriers affect STS cranes.

Interviews were conducted with straddle carrier operators, STS crane operators and managers at the case terminal. The interviewed managers had experience of the current software system and earlier software system used in straddle carriers. The interviews were done face to face and provided an insight in and understanding of the current situation for the operators. All the conducted interviews can be seen in table 3.2. The length of the interviews were around 30 minutes to one hour, notes were taken during the interviews and all of them were recorded so that they could be examined again if something was forgotten or if anything else was needed. Bell (2011) state in her book that when interviewing respondents one at a time it is beneficial to record the interview. This allows the interviewer to pay full attention at what the respondent is saying and afterwards ensure that the notes are correct.

Table 3.2: All interviews during the project.

Organization	Role	Aim
Case Terminal	SC operator 1	Understand the terminal and see what information the operators need.
	SC operator 2	
	SC operator 3	
	STS crane operator 1	Understand the terminal and find out how SCs affect the STS crane.
	STS crane operator 2	
	STS crane operator 3	
	Management 1	Find out reasons for current software and what the plans are for the future.
	Management 2	See which kind of data that can be gathered and the plans for the future.

Saunders, Lewis, and Thornhill (2016) describe three ways in which an interview can be constructed and those are: structured, semi-structured and unstructured.

All of the interviews in this thesis were conducted in a semi-structured manner. A general guideline was used for the interviews which can be seen in appendix A, this allowed that focus could be kept on the topic of the research. By conducting semi-structured interviewees, the possibilities increased to learn more about opinions and experiences from the interviewee through asking questions that depended on the answers from the participants.

The participants for the interviews were chosen due to their working experience and identified by both the authors and other involved actors at the case terminal. The interviewee agreed on that their names were not be mentioned in the thesis, this minimized the risk that any personal information would become public which could have hurt the participants. This also decreased the risk that the interviewee would restrain themselves during the interviews. Before the interview took place, the participants were informed about the reason for performing the interviews. This was done to motivate the interviewee since they sometimes do not see the benefit of answering the questions (Patel & Davidson, 2011). The result from the interviews were used in the findings and the analysis in this thesis. The interviews supported the work with the knowledge and expertise that the operators and managers possess.

3.4.2 Measurements

Two different tests were performed in this project. The first test analyzed whether extra shared information could improve the container handling in the case terminal. The second test was established to see if anything else impacted the test results in the first test. The two different tests can be seen in table 3.3.

Table 3.3: Table of the two different tests which were performed during the project.

	First half hour	**Second half hour**
First test	Without information	With information
Second test	Without information	Without information

To measure the difference between additional shared information and normal operations, a data collection software for smartphones called StarDriver was used. The software was possible to program depending on which activities that were being measured. The software is developed by Prockl and Sternberg and originally used to measure activities of truck drivers. With few alterations it was adjusted to measure activities of STS cranes and provide data of the crane operations. An image of how the app looked when used during the measurements is presented in figure 3.2.

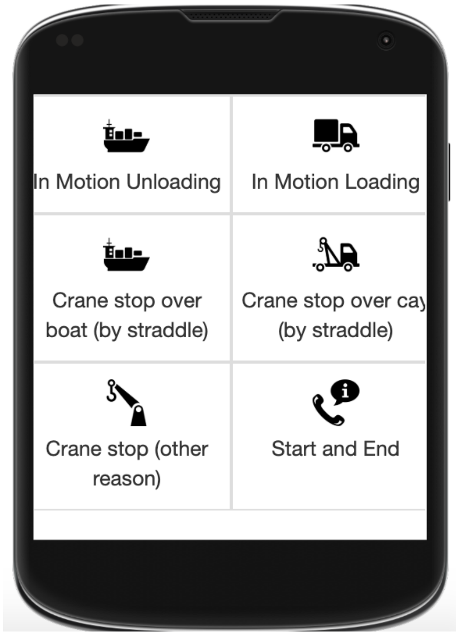

Figure 3.2: A view of the StarDrvier interface used during the measurements.

When pushing a button, StarDriver started to record the time for that activity. An example of data which was gathered from StarDriver by pushing these buttons can be seen in appendix B. N.B. the duration for each motion in the example is randomized between 40 to 60 seconds.

The key performance indicators (KPIs) that were measured during the tests can be seen below:

- The time for each loading cycle performed by the STS crane.
- The time which STS cranes are disturbed by straddle carriers.
- The distance traveled for the straddle carriers serving the crane.

The KPIs were used when measuring the difference between the potential improvements and the regular system during the two tests. The tests were performed at four big port calls during the spring of 2019. The capacity of the vessels was around 21 000 TEUs and each port call lasted for about 72 hours. Both tests in table 3.3 consisted of smaller samples, each sample took 50 minutes and to have as similar circumstances as possible the measurements were split into parts of 25 minutes each. In the first test the straddle carrier operators worked as usual during the first 25 minutes and during the second 25 minutes they had access to additional information. In the second test the straddle carriers drove as usual during the full 50 minutes. The first 25 minutes are referred to as the first half hour and the second 25 minutes are referred to as the second half hour in this thesis.

The reason for only measuring for 50 minutes was because the workers at the case terminal were following two-hour rotations and every hour operators were relieved to go on brake. The change took around five minutes and was performed each hour. To minimize the risk that the machine change impacted the tests the time for measuring was reduced to 50 minutes instead of one hour. This ensured that the same STS crane and straddle carrier operators were operative during the full 50 minutes. Another requirement for the tests was that it had to be enough volume of containers so that the STS crane could operate continuously for 50 minutes without having to switch to another bay or be disturbed in any other way. It also had to be three straddle carriers that served the crane for the entire 50 minutes. The dispatches could regulate this depending on demand and if there were not three straddle carriers at the crane throughout the test period, that period was excluded from the data.

Before the tests began, the information sharing system was tested. One of the authors drove around in a straddle carrier and the other author sent out messages to this straddle carrier. By doing this, the authors ensured that the information sharing system would work and that it could be applied in the case terminal. In addition, the minor test included sending messages both during discharge and loading. The container's location in the terminal could only be foreseen during loading and not during discharge. During discharge the container location was calculated first when the container was picked up by the straddle carrier. Therefore, the tests were made when the STS crane was loading the vessels.

During the first test one of the authors accompanied an STS crane operator and measured the crane operation times with StarDriver. At the same time, the other author sat in the dispatcher's office and sent out messages through a computer to the straddle carrier operators who were serving the STS crane. The straddle carrier had a screen where they received their job orders. This screen had the feature to receive messages from the dispatcher with maximum 38 characters. This message function was used when sending out additional information during the first test. The information presented to the operators was carefully selected according to what had been said during the interviews. Discussions were held afterwards with operators who participated during to evaluate the additional information.

The second test was made to clarify that nothing else could have affected the first test. During this test, the authors accompanied one crane operator each and measured every operation for 50 minutes to see if there was any difference between the first 25 minutes and the second 25 minutes. During these samples, the crane also loaded under deck to obtain similar conditions as during the first test.

The time for each loading cycle was used to see if there was a difference between the first and second half hour. All the data was adjusted to only show percentage since the case terminal did not want to share real data. For the loading cycle data, the median of the measurements during the first half hour was set to one in both tests and then all the other data points in that test was adjusted to that number.

Another part that was consider during the tests was the last KPI which was the distance that the straddle carriers traveled during the samples. This data was also modified so it did not mirror the reality. The average distance traveled for each straddle carrier during the whole test was reflected upon. This data was gathered directly from the case terminal's operating system (Navis). Origin of the data measured in the thesis can be seen in table 3.4.

Table 3.4: Data origin of the measured KPI's in the thesis

KPI	**Data origin**
Time for each STS crane cycle	StarDriver
Disturbance caused by straddle carrier	StarDriver
Distance for straddle carriers	Navis

The data which was collected with StarDriver was stored in Excel-sheets. Excel is a spreadsheet program which can organize and manipulate data, it is created by Microsoft Corporation (Rouse, 2007). An example of data that was gathered from StarDriver can be seen in appendix B.

3.5 Statistical test

Statistical tests were made to investigate whether the result obtained was due to chance or not. A programming software called Matlab was used when performing the statistical tests. Matlab is a programming language and numerical analysis environment Rouse (2015). The code which was written to analyze the data from the measurements can be seen in appendix C. The data for each crane cycle in the Excel-sheets were loaded into Matlab. After that, boxplots were made by performing the boxplot-command in Matlab on the loaded data. The boxplots were used to visualize the spread of the data. The quartiles and IQR which are used when defining the extreme outliers were calculated in the Matlab-code. The max values for each half hour was calculated in Matlab and if these max values were greater than the value for the extreme outliers that data point was manually removed in the Excel-sheet from StarDriver. This process continued till the max value was lower than the value for extreme outliers. By excluding the outliers, the risk that rare occasions would impact the result was decreased. Only extreme outliers above the upper limit was considered since there was no possibility that there would have been any extreme outliers in the lower end, assuming that no mistakes were made during the measurements.

One important thing to notice is that when one extreme outlier was removed the corresponding value during the other half hour was also removed since there had to be the same number of measurement points for both half hours during every full hour. Otherwise, some of the measurement's points might have been compared to points that were collected during a different time with other crane- and straddle carrier operators.

After the extreme outliers were excluded a z-test was used if the data contained more than 30 data points. To perform a statistical test on the measurements they were subtracted with each other. The data for the second half hour was subtracted with the data for the first half hour for both tests. This gave one series of data for each test. The statistical test was then performed on these two subtracted data series, the one when comparing the extra information and the one comparing the difference between the first and second hour.

When performing the statistical test, the z-value is calculated. As stated in equation 2.2, there are three things that are needed to calculate the z-value. Those three things are: the sample size (n), the mean value ($\overline{x}$) and the standard deviation (σ). All three values were calculated in Matlab which can be seen on row 77 to 79 in appendix C. The mean value was calculated by using the mean-function on the collected data, the standard deviation by using the standard deviation-function and the sample size was calculated with the length-function.

The z-test was used to analyze if there was a statistical significance between the first and second half hour for both tests. Before performing the z-test a hypothesis was stated with a null hypothesis (H_0) and alternative hypothesis (H_A). The objective was to see if the loading time for each container decreased between the first and second half hour. Therefore, the null hypothesis stated that the average time for a loading cycle was the same or greater during the second half hour. The alternative hypothesis stated that the average time for a loading cycle was less during the second half hour. The stated hypothesis can be seen below were $\overline{y}_1$ was the average time for a loading cycle during the first half hour and $\overline{y}_2$ for the second half hour.

Hypothesis:

$$H_0 : \overline{y}_2 - \overline{y}_1 \geq 0$$
$$H_A : \overline{y}_2 - \overline{y}_1 < 0$$

This hypothesis is called a lower-tailed test which is described in section 2.6.2. If the z-value was lower than -1.645, which is the z-value at a 5% significance level for a lower-tailed test (Sullivan, 2017), the null hypothesis was rejected and the alternative hypothesis accepted. This implied that there was a difference between the two half hours and that the STS crane performed better during the second half hour, hence an improvement in the case terminal. If the z-value was greater than -1.645 the null hypothesis was accepted, hence no improvement in the case terminal.

3.5.1 Example of the calculation procedure

To show the statistical test procedure, an example with 30 data point for each half hour was made. The data for the example is given in appendix B, it was collected from StarDriver and the duration for each motion was randomized between 40 and 60 seconds. The hypotheses used for this example test was the same as the one used in this thesis. The example data was put into one Excel document and split up into two different Excel-sheets. The data for the first half hours was put into the first sheet and the data for the second half hours was put into the second sheet. The values in the excel document worked as an input in the Matlab program. The data was divided by the median for the first half hour to mirror the procedure for the tests in this thesis. Matlab calculates the boxplot which is visualized in 3.3.

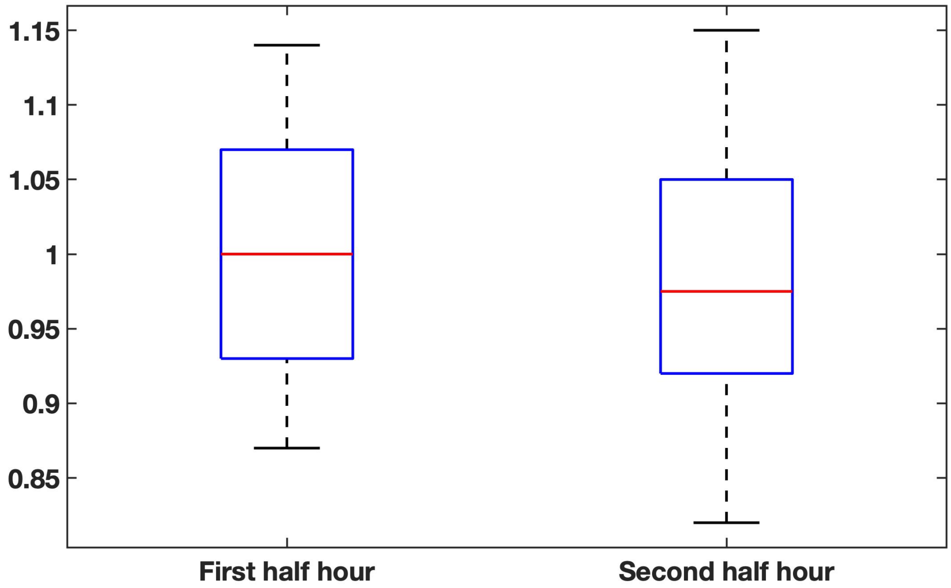

Figure 3.3: Boxplot over the example data from appendix B.

The extreme values for the upper-limit was calculated in Matlab and for the first half hour the extreme upper-limit was 1,49 and for the second half hour it was 1,44. The max values were also calculated in Matlab and they were 1,14 and 1,15 respectively. Since none of the max values were greater than the upper-limit for the extreme outliers no data points were excluded.

The difference between these two tests are calculated by subtracting the second half hour with the first half hour which is performed on row 75 in the code in appendix C. The number of measurements (n), mean value ($\overline{x}$) and standard deviation (σ) were calculated in Matlab and they are given in table 3.5.

Table 3.5: Results from the example provided in appendix B.

Mean value	$\overline{x}_1$	-0,018
Standard deviation	σ_1	0,138
Number of measurements	n_1	30

Since the number of measurements (n) are 30 or above, a z-test could be performed. With the numbers in table 3.5 the z-value was calculated in Matlab. The equation used for calculating the z-value is given in equation 2.2 and used in equation 3.1.

$$Z = \frac{\sqrt{n} * (\overline{x})}{\sigma} = \frac{\sqrt{30} * (-0,018)}{0,138} = -0,727 \tag{3.1}$$

Since the z-value was greater than -1.645, which was the z-value at a 5% significance level for a lower-tailed test (Sullivan, 2017), the null hypothesis could not be rejected. Therefore, it was not statistically significant at a 5% significance level that the mean for the second half hour was lower than the mean for the first half hour. The p-value was also calculated in the Matlab code and it was equal to 0,766. This gave that there was a 76,6% chance that mean loading cycle in the second half hour was lower than the mean loading cycle in the first half hour. Since the p-value was lower than 95% it was not significant at a 5% significance level.

3.6 Reliability and validity

It is the credibility and feasibility of a project that determines if others accept it (Bryman, 2012). One recommended technique to ensure feasibility and credibility is triangulation, triangulation requires that more than one source of data is used during the study. The term refers to a method that uses various source of data, theoretical perspectives and observations. In this thesis, multiple sources of data were used to increase the trustworthiness and validity.

According to Bell (2011) interviews usually takes quite some time and during a project there might not always be room for more than a few interviews. Therefore, the risk of bias could be large. The interviews in this thesis were always done anonymously to minimize the risk that the interviewed person would be restrained. There was also more than one interview for each competence to reduce the impact of one individual interviewee.

One of the most obvious main elements for the reliability of measurements is that the same answer should be obtained even if measurements are carried out during two different occasions (Bryman, 2012). In this project a statistical hypothesis test was used to ensure the reliability of the measurements. The z-test gave the probability that the same result would be obtained if measurements would be done on the exact same thing again. If the probability is high, the reliability of the measurement should be considered large.

Another thing is the validity of the measurements. It is important that the test really measure the stated concept (Bryman, 2012). To guarantee the validity of the measurements the tests were carried out in two versions. The second version was made to see so that nothing else than the shared information impacted the result for the first test.

3.7 Earlier experience from seaports

As already mentioned, one of the authors previously worked in the case terminal. This meant that the terminal processes and seaport functions were already well known. The knowledge in the area was useful when writing interview questions and when performing observations, interviews and measurements. In addition, the interviewed workers at the terminal had easier to relate when the authors where known since before. Also, for them to understand and embrace when the authors had deeper understanding, used proper terminology and could further explain the aim of measurements and interviews etc.

Being employed at the case terminal could imply bias, trying to mend or enhance findings and results. When the case terminal abstained to be mentioned in the report, the authors had an increased freedom to discuss findings and conclude what otherwise could be considered. This also meant that the authors could keep a more neutral position and be seen as researchers from a University instead of representatives from the case terminal.

During interviews and measurements, the authors clarified that this was a project that was designed by the authors with intentions to pass an examination. This was clarified so that the interviewees understood that the authors represented a university and not the case terminal. The project itself was not ordered by the case terminal but instead an initiative from the authors. The project was accepted by the case terminal, but they insisted that it where to include something measurable and the lean philosophy.

4

Results

In this chapter, a case terminal is explored to investigate how shared information could potentially increase the efficiency of STS cranes. The operations in the terminal are identified and a research on which information that can improve the performance is conducted together with measurements of the potential improvements.

4.1 Mapping of terminal operations

The case terminal contains of four main departments or flows; 'Export/Import grid', 'railway', 'empty-depot' and 'ship-side'. These different flows intertwine with each other, sharing storage areas, driveways and equipment, and together provides services to the terminal customers. This section is an elaboration on research question 1; *"How are STS cranes and straddle carriers operated in container terminals?"*.

4.1.1 Actors

Individuals or actors are the ones that uphold the relations in between companies. With layers of soft and abstract values, actors are associated through different impressions and the experience will set a tone for the actual relationship. Actors that are connected to the case terminals operations are detected and explained in this section. Some of the actors might not directly impact the STS cranes and straddle carriers. But all of them have an influence on the decisions taken in the terminal and around the STS crane.

- Dispatcher
- Yard planner
- Vessel planner
- Berth planner
- Tally worker
- Manual worker
- STS crane operator
- Machine operator
- Supervisor
- Lashing
- Deck men/seaman
- Machine/crane tech
- Shipping company
- Captain
- Pilot
- Tug company
- Mooring company
- Trucking company

Dispatcher, each department got their own dispatchers. Depending on expected workload they vary between one or two for each department and shift. Many of them share the knowledge and are able to relieve each other or help out during peak hours. The dispatcher role is to support the departments work force. Much of information is limited for the workers and when problems occur, they contact the dispatcher for help. The dispatcher is a super user in the system, and they are able to reach all information, not only as a support but they direct the work force and daily tasks. They can focus the work force on certain flows, cranes, yard block alterations or other tasks that is prioritized. Dispatchers are available through phone and a dedicated dispatcher radio channel for each department.

The ship-side dispatcher prepares the calls and plan the crane moves, especially on the large calls that are served by 5 cranes. Having crane teams end at almost the same time helps reduce costs. In addition, being able to communicate expected time for the vessel to be ready for departure are in the interest of the shipping company. To be able to order pilot, tugs and mooring and depart on a predicted time is appreciated. Being done and awaiting the time of these service companies to arrive is considered as waste, which in some cases means that the vessel loses the ability to slow-steam to the next port.

Yard planner, every terminal got their own yard planner, having expertise that creates a strategy for the yard are crucial to run a proper container operation. The yard planners work is in direct connection to the operations that are performed by the straddle carrier operators. Storage suggestions are proposed to the operators through the operating system, Navis, which is further explained in section 4.1.1 under *"Navis"*. Navis follows a strategy by evaluating conditions entered in the system. Depending on available positions, exporting containers are placed as near the berth site as possible. There are ways to reduce unnecessary moves to match containers with earlier arrivals with similar weight and same destination or to locate a bottom layer position for the new arrival. The operating system within itself follows the preset conditions that are set according to the long-term yard strategy.

Vessel planner, the vessel planner is responsible for matching containers that are booked with the available positions on the vessel. This is done considering the best possible sequence in regard of the actual yard stowage. The stowage plan provided by the shipping company is the preset plan to follow. Minor alterations are accepted, and others must be cleared with the shipping company e.g. moving dangerous contents. The matching of containers is done hours before arrival and are dependent on the long-term strategy set by the yard planner. The ability to alter current situation in the yard are mainly with help from dispatchers and available straddle carriers.

Berth Planner, berth planner is responsible for booking vessels along the quay. Considering; arrivals, departures, vessel sizes, quay side depths and the ability to accommodate vessels by the available cranes. Bookings of time windows at quay are often made long time ahead when vessels tend to operate on a long route with several other vessels or sister ships. Normally during these conditions there are a dedicated number of containers to and from the terminal, with minor variations during the year. Both to ensure the terminal of the workload and to be able to plan the shipping lane and dedicated volumes. There are also changes and exceptions to these long-term plans leading to last minute changes due to a variety of reasons. In each and every of these cases there is a discussion between the shipping company and the terminal. First question is if the berth planner can find a window to accommodate the vessel. Then further discussions will follow. Changes like these might have an impact on the yard plan and the vessel planner, but not necessarily. The vessel plan is not done before the vessel is on the way to the terminal.

Tally worker, tally worker handles the computer in the crane team, located beneath the crane. They overlook the scheduled discharge, loading, dual and hatch lifts among many processes. By logging what containers are discharged and what containers to load and the sequence, they are responsible for the positions of the containers on the vessels. The stowage plan is illustrated in figure 2.2. The tally worker visually oversees the vessels stowage plan and current progress to manage the situation. Depending on dangerous contents, there are strict regulations of where to place containers, also due to weigh distribution, especially on smaller vessels. To keep in mind, a miss-placement can lead to unnecessary moves of several containers or in the end a mistake that can lead to containers being left on board and later unloaded in the wrong port. The tally worker communicates on an intercom with the crane operator and through communication radio with the whole crane team. In addition, all tally offices got phones for contact with dispatchers or supervisors.

Manual worker, tally worker and manual worker are in the same team, first hour in the tally office and the second hour as manual worker. The manual worker handles cones beneath the STS crane or as an extended pair of eyes guiding the crane operator on board the vessel. To ensure containers being positioned right and reduce the risk of damages when guiding the operations. Manual worker is equipped with communication radio and follows a certain movement pattern due to health and safety regulations to avoid the heavy machines that operates in the shared work area.

STS crane operator, there are at least two people in every crane team. They operate under two hours and are relieved at the point of work by their colleague. They take an elevator that is within the crane structure and walk on a walk path that is aligned by the operator to change place. These changes take a few minutes and are often matched when the straddle carriers do their break changes. The crane operator is guided by the tally worker that follows a discharge or load schedule. Normally they operate by engaging in certain cells on board or layer by layer. Communication with the tally is performed via an intercom system or the radio communications which also is used to communicate with others, often team members. The crane operator is restricted by certain rules of how to handle containers.

Machine operator are the ones that operates straddle carriers, reach stackers and terminal trucks. This is done in teams of three workers on two machines during normal conditions. They change operator once every hour, driving two hours with a one hour break every third hour. They operate out of on-screen information and communicate through multi-channel communication radios. When the machines change team, they change radio channel to be available for communication within the right team.

Supervisor, the different departments are also managed by supervisors, normally ship-side have two supervisors per shift. The Export/Import grid, empty-depot and rail-way got their own supervisors, mainly one per shift. Supervisors or foremen are responsible for the running operations at each department. They focus on production and they are responsible for handling all sorts of situations, especially extraordinary situations. They are problem solvers that can allocate personnel and machines in collaboration with dispatchers.

Lashing, some vessels, often larger ones, require terminal workers to prepare the vessel for discharge and departure. Workers then follows a blueprint that shows the different bays and what containers and additional lashing equipment that is affected. These schedules are provided by the ship-side supervisor and priorities depends on how the dispatchers scheduled the cranes. The supervisor is part of managing the operations on board to ensure that the crane teams can operate loading and discharge without interruptions.

Deck men/seaman, the deck men are working on the vessel and are part of the daily routines on board. They can provide mooring lines when docking, mending lashing equipment or overlooking the container handling progress. They can help the crane operator and mediates requests. When they point out mistakes the team has to amend among the loaded containers etc. They also handle special tasks e.g. to connect and disconnect reefers, lift hydraulic hatches and do checkups on the performed lashing to approve the terminal workers job before departure. Much of their contribution is voluntary on the vessel's behalf, to ease the process, but their progress helps the terminal, and, in the end, it helps the vessel to depart on time.

Machine/crane tech, the terminal got their own mechanical division, with electricians, machine and crane mechanics. They are always on call via their own radio channels; machine tech, crane tech and electric tech channel. They are available on the terminal whenever there is a shift working, day, night or weekend. In addition, they perform reoccurring maintenance, they are mobile, and perform everything from spreader change on a crane to mounting a screen in the crane cabin. Tire change on a straddle carrier to whole builds of new straddle carriers from kits. Electrical alterations to save energy on the crane, to monitoring heavy lifts and guiding the crane operator to be able to maneuver the crane close to its electrical safety limitations and more.

Shipping company, many large shipping companies amend their lines yearly, making the companies change time windows in different ports and the calculated volumes that can be handled during that time period is limited to the terminal operators invested infrastructure and machines. A change of adding a stop at a terminal can imply a change to the volumes available for other terminals along the way, and a need to add extra vessels to the lines to keep recurring calls. Having long collaborations or close ties to terminal operators are of importance to be able to invest and grow where the volume of goods are growing.

Captain, captain is in charge of the vessel, not only being the shipping company's ambassador, but the commander on board. When the vessel is moored at the berth place, they rarely interact. But if there are problems during docking, they are able to turn a vessel around and leave. The captain can also command the decks men to not allow terminal workers to enter the vessel before he gives the final order that the vessel is docked and fully prepared for discharge and loading of containers. The captain is utterly accountable for the vessel and even the shipping company can just advice the captain in situations that occur. The captain has the responsibility over the vessel, but the command on deck can be shared between different officers by certain regulations with few exceptions e.g. special situations can be when a pilot is guiding the vessel to the harbor.

Pilot, the pilot is a local navigator that helps commanding the vessel during the transition into the port. This is common in areas where the conditions of the surrounding environment e.g. archipelago or the harbor inlets are hard to maneuver, and the vessels features as depth, size and maneuverability exceeds certain numbers or criteria. The pilot is transported to the vessel outside the restricted area to ensure a safe transition to the berth place. The pilot can refuse/deny attempts to begin the transition due to weather or other conditions, delaying the call to the port. The pilot can call for tugs that pulls or pushes the vessel to ensures the vessels position, they can turn, brake and hold the vessel when approaching the dock. On the departure of the port, the pilot follows the vessel out of the zone and embarks the small pilot boat to return to port. The pilot service is ordered hours before arrival or departure.

Tug company, tugs are used all over the world supporting vessels during the approach, departure to ports and other critical navigation maneuvers. The tug is designed to act like a floating anchor or extra impulsion, both able to pull towing/-mooring lines and push on certain reinforced spots on the vessel. For certain vessels, tugs can be mandatory to use, and the companies are using them as a support to ensure their own vessels. This service is needed to be ordered hours before arrival and departure.

Mooring company, when the vessel is on its way in to the dock, there is a company that meet up at the dock and secures the mooring lines to the quay. When mooring large vessels, they have a small boat in the water that fetches the lines and provide them to the dock. Their cars are equipped with special tools to pull the mooring lines. During daytime they position themselves close by the mooring positions to communicate where the vessel should dock. At night they mark the points where the vessel is going to dock with special lights in the fore and aft positions, to help them navigate to the intended berth place. This service is ordered hours before arrival or departure of the vessel.

Trucking company, trucking companies are important actors in container terminals since they connect other companies that cannot use rail to the seaport. There are many different trucking companies with multiple drivers arriving and departing at the case terminal every day. The trucking companies gather containers at different companies and transport them to the terminal where the containers are later loaded on vessels. They also pick up containers in the terminal and drive them to different companies that are located both close to the terminal and far away.

4.1.2 Resources

The terminal uses a verity of different resources, from invested infrastructure and heavy machines to advanced software and skilled personnel whom interact with each other. These resources are part of a continuous development that forms the terminals production and ability to serve their customers. Resources that are important for the case terminal direct operations are gathered and explained in this section.

- Navis
- Yard planner competence
- Vessel planner competence
- Dispatcher competence
- Tally competence
- Tally office
- STS crane operator competence
- STS Cranes
- Communication radios
- Vessels
- Straddle carriers
- Straddle carrier competence
- Supervisor competence
- Platform
- Storage area
- Other machines
- Other machine competences
- RMG cranes
- RMG crane competence
- Gate

Navis is an operating system that many port operators are using to log and keep track of containers in their flows. It is well known for optimization, automation of management and in many cases planning of complex terminal operations. The terminal stores containers and there are always containers stacked and awaiting the arrival of their next leg in that transportation network. Even if the majority of the containers are transshipped within a few days. Navis is a system that can be tailored for the terminal operator to suite their unique setups of infrastructure. In the case terminal there is a long-term goal to implement more advanced parts of Navis different features to make the production system further integrated and improve the system on preset calculations.

Navis is operated by dispatchers, tally workers, straddle carrier operators, terminal truck operators and RMG crane operators whom are in direct connection to the production. The dispatcher operates as a super user, able to reach all possible information. The tally worker got a level of increased information, where they can see the progress, a simple overview of the vessel and all bays graphically to see the sequences and the scheduled plan. All operators have a simplified view where they only see the step, they are executing next e.g. "Carry container # to crane K1", "place container # under K1" or "drive to row PP07" etc. An exception is the railway grid, they utilize lists on their screens, both in the straddle carrier and the RMG cranes, where they can choose the closest container to move. The dispatcher is able to see everything in the system, even see a double of the screen of any machine at any time. The dispatcher even proceeds pressing "next step" on their screen overriding the machine operator. They can switch jobs that is assigned from one machine to another and much more. Many of these features are done when the machine operator is on radio link with the dispatcher. This is just small parts of the features that the Navis operating system can offer to a terminal operator.

Many of the features are connected to the benefit of other terminals or shipping companies that uses the same or similar systems that are compatible. This makes transfer of where containers are on the vessels easier. Having other terminals in their network that can share information of vessels with prepared graphics and other useful information, a positive impact in the daily work. Navis is a well-established operation system that provides complex features and building blocks for different terminal settings. There are possibilities to tailor features, but there is often a need to share the development costs, due to the complexity within the operation system.

The system has a digital map over the terminal and uses a matrix to calculate optimal driving patterns. This dedicates work from various work lists that are devoted to the different grids. This tool is called prime route and it calculate and dedicate machines to different assignments. Within the system there can be set priorities and the ability to assign work in the closest surrounding. Reducing driving without carrying load or allowing the opposite, to roam the whole yard etc. Making the machines to either be busy driving to the next assignment further away or standing idle waiting for a dedicated assignment close to the last position where last task ended. This function is primarily used in the export/import grid with the aim to expand to other departments.

Yard planner competence, in the case terminal, key knowledge for a yard planner is to understand the operating system, in this case Navis, to know the physical impact on the production. There are layers of set stipulations to how an inbound container will reach the best position possible in the yard. Whether that is an export or import the goal is to minimize driving distance, keep it at a location that is accessible and aim to avoid any type of re-handle. To keep targeted goals, containers are paired together. Either two and two, or whole rows of up to 27 containers that are matched together. The terminal aims to keep containers stored together with the same destination, weights and heights. Making the planners job easier, and in the end the production run smoother.

Vessel planner competence, before every call, there is a terminal vessel planner that matches the available positions on the vessel with suitable targets in the yard. All goods in the terminal are not always booked on vessels and might therefore be stored and matched with other goods due to destinations. In some cases, larger bookings of several units that are booked together get changed to other departures, meaning they are planned on other vessels. These changes lead to additional moves if vessels are planned at other berth sites or if the containers interfere with the loading sequence e.g. if rescheduled containers are stored above sequenced containers. The load order is decided by the planner in detail. Having containers placed in three locations, depending on the order they are marked they are going to be sequenced differently. Just marking a full row with 27 containers, depending on how the marking is done. Clicking pulling down and then right gives one load sequence emptying each stack in order from top down and clicking pulling right and then down gives another order, emptying layer by layer, reducing the number of straddle carrier lifts to the 3rd layer when entering the row 17 times. This also means if done in worst way the operators would be forced to lift 24 times to the 4th layer to pass all other positions with three high in the row, lifting the first position last. This implies, having great knowledge of the differences saves time in the yard.

Dispatcher competence, the dispatcher competence takes time to embrace fully, a lot of the different tasks are performed through Navis and small adjustments and functions can alter the production. The level of knowledge on this position is often shown as a result in the operations. Gained knowledge from the operations, both tally and straddle carriers could affect the ability to understand problems and difficulties for other users. Consequently, the ability to amend these before the affected personnel even notice the issue. Some problems are issues within Navis that today are amended by dispatchers. Often the system functions right, and there are no radio calls to the dispatcher. But when there are, either misplacement in the park or other uncertainties, the machine operators are obligated to call it in. Sometimes that is not done, which can lead to containers that disappear and are lost, only appearing as a number in the system. The dispatcher can reach all straddle carrier operators at once, using a message function, writing text that shows up on screen. This text can be used, sending out warnings of machine breakdowns and positions to avoid or special vehicles that are in the work area or other reasons. The operator can choose to keep the message or close it. Information that is shared can for example be missing containers, workers present in the yard, accidents, oil spills etc. The text message itself is restricted to 38 characters. The dispatcher is also in charge of the operations, able to let people park their machines or let them on break to start up later if there are gaps in between vessels that depart and arrive or by other reasons.

Dispatchers on ship-side and export/import grid work together preparing for housekeeping and yard moves due to rescheduling or other changes. This procedure follows the same procedure as when the vessel planner matches stored containers with the vessel plan which is explained in section 4.1.2 under *"Vessel planner competence"*. Depending on how the units are marked it will affect the straddle carrier efficiency in the end.

Tally competence, the tally competence is reached through a three-week education and takes months to handle flawlessly, and years to master. The competence in itself seems quite easy, but the whole team's performance is in the hands of the operator of this position. A lot of the communication to the team members are spotted here. Senior tally workers share this information through communication before being questioned, which saves unnecessary time waste. When questions in general are asked, they appear in later stages or in worse cases they are never brought up before it is too late. A well working team with an experienced tally worker often runs in total radio silence. Where information gets shared from the tally, with few questions asked. The knowledge and experience on this position are crucial when communicating. Typical can be asking a crane operator if the layers are even, this can be confusing when reality differ from stowage plan depending on container heights, DV or HC, in relation to the illustrated stowage seen in figure 2.2. Those issues often occur when loading large vessels below deck, at certain levels.

Tally office, the tally office is located below the crane within the land side leg with an overview of the area between the crane legs. The tally is an office spot that performs the logging of containers that are being loaded or discharged. In addition, the tally is equipped with cameras that can be directed towards the deck or give an overview of the containers below the crane. Stationary radio equipment is used to communicate with the team members and an intercom system with direct link to the crane operator. All tallies are equipped with phones to directly reach dispatchers.

Crane operator competence begins with a five-week education, which many of the first hours are performed in an advanced STS crane simulator. It is able to simulate everything from weather conditions with wind, fog and time of day to movements of the cabin. It takes towards a year to become a decent operator. On this competence lies large obligations and responsibilities, many in the line of health and safety, but also towards risk. A goal is to move a certain number of units every hour, and it takes time to reach that target. Many of the crane operators are well above that target, lifting the production every day, but letting new operators grow and be part of the production rate is also of importance. The number of crane operators need to continually be educated to keep the production level and being able to deliver over time. Reducing the risk of having large numbers of retirees, loosing large number of workers at the same time. In the same way ensure a growing and well distributed work force with experience and a system where both teachers and the education evolve.

Ship-to-shore cranes, the case terminal is equipped with several STS cranes, the latest installed a few years back, able to accommodate the largest container vessels in the world. The older ones are quite moderated making them quite complex when in need of repairs or service. But still the oldest ones are the ones with least need of repairs, built in the time when they were intended to last a life time. there are two different track width and two main types of cranes. This project has only been performed in the larger versions with the widest track features, where the straddle carrier operates between the crane legs also known as beneath the crane. The smaller cranes have their straddle carrier traffic behind the crane. The larger cranes are equipped with a light function that shows when the machines are placing the container aligned with the cranes spreader. The light can be calibrated from the tally office, normally in during communication with the crane operator and the straddle carrier operator. The positioning device is a row of five lights. The device shows one or two lights at a time from in total five lights. They start shining from one end and ends up with one red light in the other end, showing the progress of the machine up to the stopping position. When the final red light shows, the container is at the right position which means that the straddle carrier can place its container.

The spreader, also known as yoke, is the mechanical connector that is able to connect and lift containers. The spreader is hanging in cables and are maneuvered on top of the container to connect in all top corner fittings to be able to lift the container. Often single 20’, 40’ or 45’ containers. The spreader is also able to adapt and lift twin 20’ containers. By lowering twin boxes to hook into the 4 additional center corner fittings when two containers are aligned and placed close together. The spreader is able to extend from a 20’ position to both 40’ and 45’. The spreader is also equipped with flipper arms that acts like guiding funnels around the corners of the container. The flipper arms guide the spreaders mechanical twist locks in to the corner fittings of containers. The spreader indicates when all twist locks are in contact with the corner fittings and the operator manually lock them with a switch, before every lift. When placed the operator also unlocks the spreader with the same switch. Which only can be achieved with the spreader in contact with all container corners meaning that its relived from any tension in the cables.

The beam stretches from the extended back reach to the end of the outreach. The outreach is able to either retract or be lifted. STS cranes with a high profile got a beam with hinges that can fold and be hoisted up towards the sky. To lift or lower the beam from the parking position, an operator can execute this from an operation panel from the ground or from the operator’s cabin below the beam. The crane is able to move alongside the vessel in both positions. The hoisted position is used when in need of clearance from high obstacles e.g. the superstructure where the bridge is located or the smoke stack (depending on vessel design these can be either one unit or separated). Normally the cranes are parked with the beam hoisted and the crane in storm locks in certain positions along the quay. Hoisted position is also preferred when the crane is awaiting incoming calls. When vessels are on their way to depart or arrive, the cranes have to stand idle. First after complete mooring procedure, they are allowed to align to their prospective bay that is planned to be loaded or discharged according to the crane schedule.

The crane is operated from a cabin that rides below the beam, facing the vessel with the spreader and its cables positioned close in front. The control cabin is reached via an elevator inside one of the legs and a small walk path that is aligned with the cabin when the operator maneuvers to the parking position. The distance between the cabin and the hanging spreader creates an angle that makes it possible for the operator to assess how to align the spreader or position containers correct. Instruments within the crane can indicate height, spreader contact, spreader settings and weight information e.g. total weight, weight distribution, weight straining when hoisted etc. During normal operations some of these instruments are in need of calibration due to inaccurate readings, which is done with ease by the operator.

Depending on how STS cranes are operated, each terminal tailor and install different systems. Whether its related to operations or health and safety, these options are in some cases individually developed or retrofitted. Examples on systems could be cameras allowing loading and discharge behind stack and close to land in the hold, or an overview of the traffic below the crane. In addition different installations of safety zones where the spreader needs to be lifted over or can't operate through, to avoid knocking a straddle carrier over or as a safe zone for the manual worker.

In the land side leg, there is a small office place for a local administrator referred to as 'tally worker'. All information from the system is communicated to the crane operator and the 'fed delivery service'. The administrator registers which containers are unloaded and the positions they are loaded at. Positions are of importance regarding destination, weight and registered content among others.

Communication radios, communication between the operators in the team are utterly important. If the radio is not working properly a machine operator drives the straddle carrier to machine tech. All changes within the team are communicated via radio, one member speaks at a time. As an example, in the straddle carrier the radio is integrated in the joystick that operates the machine, making communication accessible with ease. Everything from routine messages, questions and answers to praises and reprimands are commonly shared within the team. All to make the work flow better and incubate the team members.

Vessels, when servicing a vessel, the terminal is able to produce averages when loading and unloading, measured in moves per hour. Depending on size and design of the vessel there are differences. Smaller vessels got shorter distances for the crane to lift and can vary in the way they are designed and aligned from above to below deck etc. Larger vessels are stable in the water and not affected of containers being placed. Having several cranes loading whole compartments at the same time on one side of the vessel will have the crew on board contact the terminal operator to change the loading sequence. The shipping companies that order these gigantic vessels are keen on equipping them with all helping features to ensure a fast turnaround at the berth sight. A small rocking vessel that is used as a feeder might be old and the equipment is timeworn, making the terminal production rate suffer. Vessel designs and differences between unique vessels are a compromise of ageing fleets and the need of keeping them during the time of depreciation. The container shipping industry are to be considered quite new and in comparison, during 15 years in the beginning of the millennium, the largest container vessels measured in TEUs almost doubled in size, from 12 000 to 22 000 TEUs.

Each bay in the vessel got their own characteristics, in the fore of the vessel the holds are more V-shaped with a reduced depth due to the hull. In the center of the vessel the holds are large and squared and typically in the aft of the vessel, they are limited by chimney, engine and propeller shafts, which can be seen in figure 2.2. Providing the ability to transport increased amount of goods below and above deck. The terminal operators planning program showed that in the largest bays on board, the vessel was able to carry around 250, 40' containers with a weight limitation around 6 500 metric tons below deck. It also showed that it could load 230, 40' containers above deck, with a limit of around 1 900 metric tons. Filling the bay below deck with empty containers would still be weighing around 1 000 metric tons.

The terminal operator's goal is to attract as many direct calls as possible. Larger vessels calling the port/terminal will decrease the transportation times with a week according to the case terminals calculations. Having feeder vessels carrying the goods to other ports with additional waiting times etc. To be able to attract and retain larger calls with more frequent intervals will in the end affect the whole industry in the region that are dependent on different terminals services.

Straddle carriers, straddle carriers are utilized to store and move containers in the primary yard. The terminal uses two types, one higher and one lower. The higher machine consumes above 12 liter diesel per hour and the older, lower machine consumes almost double according to the case terminal. Both able to stack containers three high and the newer version can also move containers in the fourth layer, having easier access to any container in the primary yard within a couple of extra moves. They utilize a low-cost alternative for terminals within a range of 100 000 to 3 000 000 TEUs per year. With an average of 10 moves per hour. The terminal experience individuals with years of practice moving towards double the average, serving in certain departments and flows.

Straddle carrier competence, to be able to operate straddle carriers, there is an education of three weeks. The terminal themselves educate and examines operators. Depending on the workers prior knowledge base and educations within the terminal, there are different departments the operator is able to be part of. Normally everyone is able to operate in the export/import grid after three weeks. Later on, the operator is able to be educated within ship-side or railway grid. If the worker had experience from the tally and manual worker, the three-week education could contain the ship-side competence. Much due to the health and safety regulations and the basic knowledge of how to operate under the crane. The manual workers movement pattern is the reason and to avoid people being injured or worse.

To learn how the machine works, knowing all the functions by heart and operate the straddle carrier in full speed in the rows. In the end being able to minimize the time beneath the crane. In addition, being able to navigate around all other straddle carriers that operates in the surrounding production, takes time to learn and later master. To learn the basics of the machine itself when operating in the export/import grid is a preferred level to start at. In that way it is easier to add a machine to the department without delaying others in the same extent as in a sequenced crane operation. Where three straddle carrier runs in a loop around the crane, often in need of being in a certain order.

The straddle carrier competence differs between different departments. Many departments follow strict storage areas and positions, mainly at the export/import grid and in the storage area, where all container places are marked. There are several areas at ship-side and the railway grid, that are complex and needs years of experience to master. Many of the railways import containers need to be placed on a know how basis. Looking at the train set wagons to evaluate where to place a container to reduce the move for the RMG crane, due to the unknown train setup before arrival to the terminal.

Supervisor competence, to handle and know what knowledge the different workers possess are key to handle unique situation. Being able to top teams and perform high numbers in situations when short on time are essential.

The supervisor competence implies being able to lead and support during special occasions e.g. heavy lifts, loading oversized goods and other unique situations. The supervisor has the ability to appraise situations and assess how to handle them. Damaged containers are recurrent, not necessarily to be damaged inside, but making the container impossible to lift with the ordinary equipment. Often a team effort with well experienced workers both instruct and carry out the task.

Platform, platforms are used to handle cones when containers are loaded or discharged from the vessel by the STS crane. All cones are part of the vessel's equipment, further explained in section 2.1.5, and needs to be removed when discharged and attached when loaded. This is performed depending on where the different containers are placed. Cones can be placed in all corner fittings or some depending on what is needed. The platform is designed to have space for the manual worker to reach and freely remove all possible cones under all corner fittings on both twin 20' and 40' containers. The platform is in the same height as a truck chassis and makes a safe work area for the manual worker. In general, one platform is used per crane when there is a need for cone handling. In these cases, the fed delivery service is restricted to one lane under the crane to avoid unnecessary cone mounting when containers hang from the STS crane. Cone handling when containers are already lifted are used in special occasions.

Storage area, the case terminal consists of different storage areas, some dedicated to export containers and some to import containers closer to flows going inland. The terminal is operated by two types of straddle carriers, one that can lift and stack three high and a taller one that also stacks containers three high but in addition can handle containers in a fourth layer. This ability opens up the possibility to increase the storage all over the terminal and increase the ability to re-handle containers that are sequenced. Normally the rows are considered filled when stacked in two tiers, but sequenced loading order utilizes the third tier showed in figure 4.1 as (b).

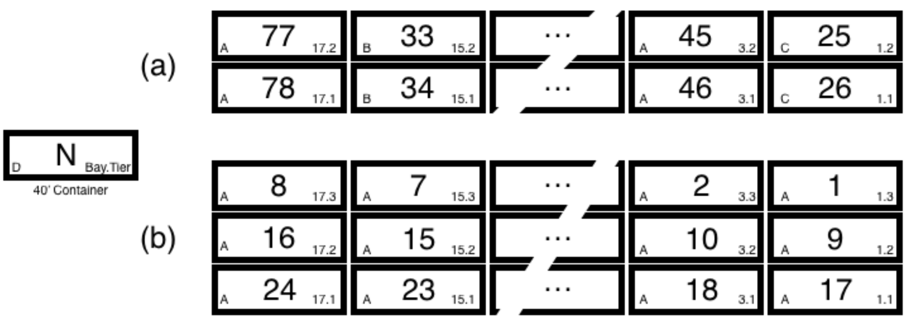

Figure 4.1: Illustrated sequencing options in container storage rows

All storage areas got marked lines on the tarmac in a grid pattern to accommodate 20' containers, the rows are prepared for in between 12-19 places, depending on the specific storage areas layout. In the figure 4.1, 40' containers cover both odd and even bays, making the fore bay number the containers storage place. Normally the rows are filled in two tiers as shown in example (a) of figure 4.1. The sequence number 'N' illustrates in what order they are going to be loaded or driven to the STS crane. If a storage area is named PP the information to the straddle carrier operator shows as follows; 'PP0517.2' (storage area PP, Row 05, Bay 17 and Tier 2). If example (a) would be 'PP05', then 'PP0517.2' got sequence number 77 and the destination (D) = 'A'. Often the sequenced containers that are stacked on top of each other got 2 sequences or more in between them, making the three straddle carriers that normally operates at one crane to be spread out in different rows. This reduces the risk of blocking each other in the rows and delaying the loading sequence. Note that the containers stacked on top of each other are headed to the same destination and in addition they got similar weight, the later does not show in the figure.

Other machines, another machine which is used in the terminal is the reach stacker. The reach stacker is mainly used in the empty depot and when handling special oversized goods. It is ideal for a low-cost production in a secondary flow, where containers can be stacked tight in a deep storage, not being able or in need of a direct reach of any specific container within the storage. Containers from the same company or alliance with equal features are stored in the same locations. And often two identical storage points are filled and cleared out in turns to follow a FIFO strategy. This is partially a request from the shipping companies, who in general owns the containers, to ensure that all containers are moved and used continuously.

Terminal trucks are also used in different flows within the terminal. Empty containers are loaded by reach stackers that are pulled on trailers to neighboring companies that fills containers. These are later pulled back to be driven by straddle carriers and placed in the storage areas. Terminal trucks are also used when crane teams are loading oversized goods, mainly flat racks and vehicle racks that carry goods, making the straddle carrier unable to straddle or without risk of damaging the goods. These are used both at loading and during discharge. In extreme cases trucking companies under escort, carry the goods under the crane, often placed on several flat racks already loaded empty, to later be strapped and secured on board.

Other Machine competences, educating personnel for the reach stacker competence takes three weeks and is done within the terminal through their own department of education. After three weeks they are part of the team managing the different volumes that passes through. Building the skill take time and being able to understand the issues that are sent forward if containers are misaligned can affect other departments. When preparing for empty containers aimed for vessels, especially 20' containers to be lifted as twin, the difference of two aligned containers and two that are not can be a minute or more. To understand when to just place a container and when to do it with precision is crucial for the terminal.

Terminal truck competence is educated over a few days within the terminal. Being able to perform within different flows takes additional education. Many of the tally/manual workers are educated on the terminal truck and are part of bringing special goods to the crane when its sequenced to be loaded or discharged. Being able to align the vehicle takes time and are up to each crane team to perform. Also, special goods that need to be aligned perpendicular to the normal containers are prepared and placed, increasing the difficulty of the maneuvering of the goods, especially if its oversized in several directions. A skilled operator can considerably reduce the time used during these conditions.

RMG cranes, within this terminal, the railway grid handles the train sets with two rail mounted gantry cranes (RMG cranes). These cranes span six train tracks and are able to turnover a train set within a few hours. The cranes move fast and handles large volumes of environmentally friendly transports daily. Together they handle one end each and often moves with a far distance between them. One starting in the middle and one at the end position of the train, following each other when unloading and then loading the train again going back to the starting position. Dual could also be performed, but due to shift brakes, and the risk of mixing containers, they try to discharge before starting to load.

RMG crane competence, the operation is quite complex, the RMG operator needs to know both the operating system, Navis. Knowledge about the different train destinations and the characteristics of the train wagons. Some train wagons are limited by weight restrictions, fairly being budget wagons, capable of carrying considerably less then robust wagons. The trains are planned and prepared to be loaded and knowledge from the crane operator are crucial to correct mistakes and sending trains that are safe and secure, within the weigh limitations. The crane operator has the responsibility of knowing when straddle carriers and reach stackers are moving in the RMG cranes work area. In addition, there is a need to notify the other crane when working close to each other. During normal work, other manual workers are down on the ground verifying outgoing and incoming train carts and containers, making the movement below as an additional risk to handle. The crane itself is easier than an STS crane to operate, due to stabilization cables that are in an angle to the spreader. Radio contact is mandatory within the team and ensures the safety around the complex work flow.

Gate, the gate that receive trucks have been a manual operated system and are turned in to an automated gate. Having the truck drivers log pick-ups and when dropping of containers, the automatic gate registers the truck and container. When the truck is parked in the transfer area, the truck driver blips a card registered to the truck which initiates the pickup or the delivery by the straddle carriers. By letting the truck driver be responsible for some easy steps, the automated system will reduce extra interactions. The system is already running in the empty depot and is proven to reduce the queues and turnover times of trucks delivering and picking up containers for customers.

4.1.3 Activities

Within this section, the terminal activities are explained. There are many actors in a terminal which all carry out different activities. The way in which these activities are accomplished and by whom is brought up in this section.

- Export/Import grid
  - Receive
  - Delivery
  - Housekeeping
- Railway grid
- Empty depot
- Ship-side
  - Lashing
  - Loading
  - Discharge
  - Dual
  - Cone handling

Export/import grid provides the service of handling containers with direct lifts, to and from truck and trailer frames by straddle carriers. Export containers that arrives to the terminal by truck are moved to yard blocks close to the berth area and the import containers from the vessels are brought closer to the trucks. This is to prepare the area near the berth site before the call. It is done daily to handle exports and import faster around the cranes and to serve trucks faster when they either picking up departures or delivering containers. At high peaks, containers are placed at locations close by to reduce driving distances and increase certain productivity goals. These containers are later on moved to intended storage locations when the terminal experience a lower work load. As a service for companies the terminal weighs containers, both to ensure the load distribution of the vessel and to complete the final transportation documents. Compared to the railway grid, there is a higher difference in work load due to unscheduled deliveries and pickups.

Closer to the call of the vessel, planned container sequence of how the vessel is going to be loaded can change. These changes can force the yard manager to rearrange containers in the yard. This is a task that belongs to the 'export/import grid', making them stack and prepare for the upcoming days. This saves time during the short time window the vessel is at the berth and are commonly known as re-marshalling or housekeeping. Depending on workload in the different departments machine operators can be pooled in to take part in the housekeeping operations. Housekeeping are also part in finishing moves that were placed temporarily during peak hours.

Railway grid is a lot like the 'export/import grid'. They are operated by straddle carriers that lift 3 high and the trains are unloaded by two 'rail mounted gantry' (RMG) cranes. The straddle carriers provide the RMG crane with loaded import containers and moves loaded export containers to the yard. Empty containers that are incoming and outgoing are lifted by the RMG cranes and handled directly by the empty-depot with reach stackers. Each crane is supported by 1-3 straddle carriers.

The two RMG cranes can handle 3 train sets at a time, divided on six rail tracks. Normally two out of six tracks are empty to allow the rail contractor to deliver one train set and pick up a set that is ready to depart. The terminal aims to schedule arrival and departure of different train sets in order to reduce transport costs. On an ordinary day, the train schedule allows the terminal to have a constant flow of containers, in- and out-bound, evenly distributed over the day. The railway grid is open longer hours than the export/import grid and in addition it operates partially on weekends.

Empty-depot provides customers and companies in the region with empty containers for their transports. Trucks and trailers arrive with either empty containers from the region or to collect containers to be sent to them. They pass the auto-gate that registers their entry and processes their information. The truck enters a parking or delivery pocket to get served by a reach stacker. Next, the container is lifted to a high stacking area where different brands or container alliances have separated assigned storage areas. They try to follow a first in first out (FIFO) order, which eliminates containers being stored long periods. Even when it is a high storage with a depth, they alter it by filling one stack and emptying another. The empty depot also balances the demand from different terminals by sending and receiving hundreds of containers a week.

The empty depot serves two areas where straddle carriers arrive to pick up or deliver containers to and from the STS cranes. This area is designed for manual inspections of containers and are shut down for traffic when inspections are carried out. Having two areas makes it possible to always have a steady flow of containers entering the empty depot and have the inside of the terminal running smoothly. Inspections of incoming containers from the railway is done beneath the RMG cranes outer area. These containers are later placed in the high storage by reach stackers. This flow works in two ways, the same area is refilled with ordered empty containers that are loaded by the RMG crane and sent to different dry ports by train. This collaboration between the departments saves hundreds of straddle carrier lifts every day within the terminal.

Ship-side is the heartbeat of the terminal. Servicing one large vessel or several small ones, the terminal is often running with several STS cranes. Depending on priority and ability every STS crane needs at least three straddle carriers to be able to run without any major interruptions. In extreme cases the cranes fed delivery service alter between one to five straddle carriers. Normally the terminal runs with three straddle carriers per STS crane, two straddle carriers per 'crane team' and one additional that can be moved around if needed.

Every STS crane is manned with one crane operator, a tally worker that registers what is loaded and discharged, and a manual worker handling cones. The later also takes part on deck as additional eyes to help guide the crane operator, via radio and by hand signals e.g. mainly when the first layer is placed, but also when loading behind stack when the spreader is out of sight.

During the session of servicing a vessel, there are communication with the deck-men aboard. This is done by the tally worker and manual worker via radio in the crane team. Among things that is communicated could be (1) ’folding hatch covers’ if they are hydraulic and maneuvered aboard. Otherwise they are ’lift-away hatch covers’ that are placed close to the STS crane and lifted away from the vessel by the STS crane. (2) The deck-men handles refrigerated containers (reefers) and know what direction the cooling unit is going to be placed in order to run electrical connections, and if discharged, the deck-man disconnect reefers. In the terminal there is a dedicated three high storage area with a rack where terminal operators can connect and disconnect reefers. This can include specific tank units that needs specific temperatures to preserve its content in a desired state. These containers cooling system runs by petroleum and electricity when stored in the terminal or aboard the vessel to ensure that they don’t run out of fuel. In the terminal, orders to connect or unplug reefers are managed by the software. A move order, to the straddle carrier operator, pops up first after the reefer has been disconnected or the opposite, when it has been placed at storage. A work order is sent to the person on call, to connect or disconnect electric power to the unit.

From interviews with the management at the case terminal the authors learned that terminal is planning on implementing pooling at the STS cranes. By using pooling the straddle carriers will not be allocated to one single crane as they are today. Instead, they will be allocated to the whole vessel, or even further, allocated to all terminal departments at the same time in the future. By allocating the straddle carrier to the vessel it will enable the possibility for one straddle carrier to bring load to one crane and then drive to another crane and pick up a discharged container. By doing this the need for straddle carriers will reduce since potentially one straddle carrier used in pooling could almost count as two straddle carriers in today’s system or at least as one and a half straddle carrier.

Lashing, when vessels arrive to the terminal, there is a need to prepare the load to be discharged. There are a few different systems that keeps the containers strapped to the deck and other systems that secure containers to each other in each stack. Before discharging this lashing needs to be undone. In general, there are cones in the bottom ’corner fittings’ of every container stacked above deck. Connecting and utilizing the structural container strength and ability of high stacking when fixed to each other. Cones in combination with ’lashing rods’ and ’turnbuckles’ keeps containers strapped to the vessel during transition. This ensures that the load reaches its destination without risk of movement or being lost at sea. Smaller vessels will manage the lashing procedure with their own deck men. Larger vessels often buy that service from the terminal operator when their own resources can’t handle that amount of work during that short period of time. Larger vessels often operated by 5-7 cranes are in need of fast container unlocking after being docked at the berthing location and a large number of workers during a short period of time. Some cranes might be able to work below deck and some awaits the lashing team to unlock enough to stay ahead of the STS cranes scheduled operations.

Larger vessels tend to use ‘wire cones’ above deck, where the wire needs to be pulled to be unlocked. The locking mechanism are strong enough to lift the container below if it’s not unleashed. Single cones that are stuck can be pulled a part by the crane operator, but not without any additional risk of unwanted damage. Due to ware and tare, ‘wire cones’ can lock themselves, or fail. Reasons to this could be (1) the spreader from the STS crane hits the stack of containers making the wire pop back due to vibrations. (2) The mechanism can be broken making the cone to be stuck or drop out, staying in the top corner of the container below, forcing the crane team to remove it by hand, or (3) the lashing team just missed pulling one/some wires. All these reasons cause extra work and sometimes full stop to the STS cranes planned work if it happens in the wrong sequence. When loading, these ‘wire cones’ automatically lock to the container below when stacked. Still the lashing team needs to prepare the vessel for departure using ’lashing rods’ and ’turnbuckles’ to secure the stacks that reaches above certain levels. Either securing the containers to the deck or the ‘lashing bridges’ that are present between the ’bays’.

Discharge and Loading, the tally worker runs the planned crane operation and talks to the crane operator via intercom or radio. Information is shared of where to load and what units to discharge, specific cells/stacks or sections, layer by layer if the blocks are big enough or ideally the whole bay is targeted. To make it easy for all parts, most common is to operate layer by layer to ensure the stability of the vessel, especially small ones. The tally worker got the total overview of what is going to be processed and the straddle carrier operators get on screen information on the current process they are handling. Either vessel load from storage area or vessel discharge to dedicated STS crane. In addition, the bay number with information if the targeted containers are going to be above or below deck are shown in some of the steps.

When loading twin 20’ containers and driving them as singles with the straddle carrier, information shows only the fore or aft position of the ’bay’ as an uneven number. The information of which machine that is going to place the first (fore) container is shared by the tally worker through the communication radio. This handling is done when (1) the planned twins exceeds 50 metric tons combined, (2) the planned containers consist of either one tank or dangerous goods in combination with any other 20’ container, (3) if the containers have too large difference in weight or, (4) if the containers that are planned as twin are spread out in separated yards.

Straddle carrier on screen information can show if the unit that is going to be moved is oversized, either higher or broader than a normal container. Information urges the operator to contact dispatcher, who then informs detailed information if needed e.g. if ‘extension rig’ is needed or not and where to find it, if not already placed on top of designated target. These oversized units are either placed on deck, on top of stacks or just below deck in the weather proof space on top of other containers. These containers take up extra space and depending whether they are higher or broader than a container they need between two and six normal units’ spaces on board, if not more. These units can be combined with other oversized goods to further use the additional space. Some of these can be moved with straddle carriers, but if they are too broad, they are moved with terminal tractors and flatbeds. Those flatbeds are loaded with a ‘heavy reach stacker’ that can lift and move heavy containers and are then driven to the STS crane to be loaded. Same procedure but reversed if the oversized goods is discharged from an arriving vessel. Oversized handling is time consuming, much due to extra lifts and logistics of the ‘extension rig’ that is used. A reduced top speed of the straddle carrier moving the goods with ‘extension rig’ and spreader lifted above normal driving height are time consuming. Also, when a team member leaves to get the terminal tractor and maneuver the oversized goods to the STS crane. This process often contains passing other operations along the way with additional waiting due to restricted driving paths in line with health and safety regulations.

Dual, when planned the terminal performs dual-cycling, loading and discharge at the same time from one STS crane. This increases the performance when STS cranes carries containers both to and from the vessel. In the same way, the straddle carrier’s performance increases when they carry containers both to and from the storage area. When a ’bay’ volume exceeds a certain number of turn over, meaning discharge of imports and refill of exports. The discharge and loading will be done simultaneously, which is referred to as dual-cycling. Dual will increase performance by both (1) reducing the fill rate at the storage area, zeroing the effect of the load unit against the discharge unit by using the vessel as storage, and (2) utilize both the STS crane and the fed delivery service performance to the fullest. This is done by emptying stack by stack, eventually with a gap large enough to refill the bay at the same time.

Cone handling, container vessels got their own preferred type of cones, stored in ’cone bins’. These are bins mounted on either 20’ or 40’ container frames that can be moved as any other container. Depending on the size of the vessel, the ’cone bins’ differ in size (20’ or 40’) and number. There are many different types of cones with various characteristics with the common function to keep containers in place. When loading on deck the crane targets the container on cones prepared on deck. This cone handling is done on board with special deck cones. It is crucial that they are locked and correctly placed when the bottom layer affect all containers above in the stack. This sequence is communicated via radio and by hand signals. The manual workers ensure that the containers are locked in position and unable to move under normal weather conditions. The main task of the manual worker is to mount or dismount different locking mechanisms to/from the bottom ’corner fittings’ on containers, called twist locks or cones. This is done when the containers need to either be held in place to avoid sliding (normally below deck) or to lock them to each other above deck. In both cases aligning ’corner fittings’ below or above deck to interconnect the container to the container below and the rest of the stack.

There are a few ways to mount the cones. Either when the container is lifted by the STS crane or when placed on a platform that is provided by the straddle carriers and placed in position. This platform reveals the lower ’corner fittings’ on both 40’ containers and two 20’ containers placed to be lifter as twin. This type of handling provides a safe place to mount and dismount cones for the manual worker.

The platform is moved around the terminal in 30' joke position, making it close to impossible to be hooked by container twist locks by mistake. When placed under the STS crane, the straddle carrier operator is guided by lights mounted on the STS cranes structure. These lights show how to place a 40' container and also the fore 20' container in a twin in alignment with the spreader of the STS crane to ensure a smooth transition. When the platform is aligned it temporary stores cones between discharge and loading. Depending on how many containers that are discharged, there are a need of having a 'cone bin' close by to move excessive cones.

4.2 Interviews - Operators on information sharing

In this section, various information is presented which the straddle carrier operators are lacking in the operating system. The result comes from both interviews and observations in the case terminal. These results are part of the elaboration on research question 2; *"What information is required to be shared to improve the performance of straddle carriers?"*.

4.2.1 Sequence order

All straddle carrier operators who were interviewed in this thesis mentioned that they, during loading, lacked sequence order into the STS crane. If they did not remember which straddle carrier that was before them the last time, they had no idea if it was their turn to proceed in beneath the crane or not. They had two ways to solve this either they gambled, or they called on the radio and asked the tally worker who's turn it was. Especially when operators started their shifts, they had to ask the tally worker who was next, since they had no clue after being on break.

During loading, the straddle carrier operators also wanted to access which container they would pick next. Today they received that information after placing their container under the STS crane and confirmed on the screen that they finished that job. Due to lag in the system, it sometimes took several seconds before they received their next job and knew where to go next. A list of, for example, the next six containers would have helped them to plan better and also give them the possibility to pick up a container that was far away when they had extra time over.

4.2.2 Visibility when loading and unloading large vessels

One difficulty when loading and discharging the large vessels, mentioned by one of the straddle carrier operators, was the sight. It was hard for the straddle carrier operators to see where the crane was. Often the straddle carrier operator had to gamble that the STS crane was busy, and that there was enough time to proceed in under the crane and pick up or place the container. Since the straddle carrier operator was not able to see where the crane cabin was, there was a risk that the crane operator had to stop due to that the straddle carrier was in the way. The disturbance was larger during unloading since the crane was not allowed to operate over straddle carriers when lifting containers due to health and safety regulations.

4.2.3 Weight information unloading twins

The machines were sensitive to weight distributions which is mentioned in section 4.1.3. When unequally loaded twins were driven, the machines gave a warning sound, displayed a blinking light and reduced the top speed down to a few km per hour. SC operator 3 mentioned that the late information within the systems force the operator to either continue with low speed or to select one of them (which was an option on screen). But in addition, the operator needs to lift twin boxes, and retract the spreader to 20’ from the earlier 40’ position. Not being able to realize this information and on forehand retract the spreader would result in being parked beneath the STS crane. The additional time spent was estimated to more than 30 seconds which could be considered as pure waste in direct line with lean philosophy.

4.2.4 Turn back to previous step

When wrong input or early next step were completed in the system, the operators were unable to amend or turn back according to three of the interviewed straddle carrier and crane operators. The only way to correct this was to contact the dispatcher. The least mistake forced the operator to contact the dispatcher, in many cases standing still in the rows blocking other machines. In worse case there were more machine operators contacting the dispatcher, making the wait longer than already needed. A system where a turn back feature would be possible for a few seconds, not fully locking the next job, keeping it on hold during the expiration time on the last task were mentioned. To be able to share the administration with those who are the ears and eyes in the yard, would help the dispatcher and terminal in critical situations by delegating routine work to the machine operators.

4.2.5 Automatic sequence changes loading empty containers

When empty containers were loaded, awaiting straddle carriers that were to deliver containers were planned in a certain sequence. When arrived at the crane or rather when the operator progressed to the final stage in the operating system to place the container. The system swapped that operator to be first in sequence, if all the empty containers had the same destination. When the system by itself changed the sequence, right before the machine that was first in line placed the container, the output was confusion and added work for the tally worker. When this happened, it was up to the tally workers knowledge and experience. The response could have been a change back to the original or to bring in the next one. In both ways the workload for the team was increased. In many cases the system did not need to micro manage the situation when several machines were in the same step.

4.2.6 Break changes and dual

Operators experienced issues during dual, specially right after break shifts, where Navis directed the machine to the crane in wrong sequence according to crane operator 2. Carrying too many loaded units to the STS crane when there was a need of discharge. This issue was either within the operating system or the operators. Either within the tally position logging the progress during shift change or the straddle carrier operator when logging out. This issue led to increased handling times when having one or several machines standing still. According to the operator one way to solve it was to let the crane operator arrange containers making a flow possible. The other solution was to let one straddle carrier drop off a container and then carry a load away from the crane. If possible, drop the container above a discharged container which reduced the re-handle.

There were also errors when leaving two straddle carriers waiting for discharge, making the production perform as if they were operating with one machine less according to crane operator 1. In case of being two straddle carriers waiting, the solution aimed for would preferable be to ask the crane operator to discharge one extra unit to get in to the ordinary sequence. This kept the straddle carriers moving in the park instead of a total waste standing idle behind the STS crane.

4.3 Information sharing - Test messages

These results are part of answering research question 2; *"- What information is required to be shared to improve the performance of straddle carriers in container terminals?"*. Elaborations are made on previous section, where several ideas and issues within the system were shared in regard of information sharing to the straddle carrier operator.

4.3.1 Evaluating information

When evaluating the interviews and the authors point of view, all inputs were weighted in relation to the ability to share them as information. Regarding that Navis got a 38 character restriction in its message function, discussions and initial trials where done to evaluate the possible impact on sent text lines. Evaluations regarding how to perform tests during the processes of; loading, discharge and dual. In addition, evaluate the accuracy the human interaction could have when Navis performs different during the various processes, making it more predictable in certain settings compared to other.

4.3.2 Information configuration

The sequence was a big issue that all of the interviewed straddle carrier operators felt they were missing; therefore, the first part of the message contained the sequence number to the STS crane. The straddle carrier operators also found it hard to plan where to go to next since they did not know where their next container was located. Therefore, the second part of the message consisted of the location for the next container. An example of a message can be seen below:

- SC1 SC2 SC3 Next container PP15
- SC2 SC3 SC1 Next container TT17
- SC3 SC1 SC2 Next container PP07

In the first case above, SC1 is the next straddle carrier that has to place its container underneath the STS crane, after that it is SC2s turn and the last one in sequence is SC3. The location of the next container for the first straddle carrier in sequence (in this case SC1) is at PP15. PP stands for which yard block the straddle carrier should drive to and 15 represent the row in that block. In the second case SC2 is the next straddle carrier in sequence and after it has placed its container at the STS crane it will drive to TT17. Finally, in the third case, SC3 is the straddle carrier who is next in sequence and after placing the container at the crane the next container is located at PP07.

4.4 Operational effects of information sharing

In this section the result from the two tests are presented. The first test measured if additional information during the second half hour improved the container handling at the terminal compared to the first half hour. The second test examined if there was any difference between the first and second half hour. The collected data was divided with the median for the first half hour in both tests since the company did not want to reveal any data. The hypothesis stated in section 3.5 was used together with the Matlab-code provided in appendix C to calculate the results provided in this section. These results are part of the elaboration on research question 3; *"-What are the operational effects of information sharing in container terminals?"*.

Several measurements were made during the project to see if additional information impacted the production at the case terminal. Around 800 container lifts were measured but some of the measurements were deliberately removed because the cranes often stopped due to different problems. However, around 400 measurements points were successful when measuring the difference between driving with and without additional information.

4.4.1 First test

The data collected with StarDriver for each crane loading sequence during the first test is visualized in the boxplot in figure 4.2. The boxplot was made with the Matlab software defined in section 3.5. Note that the data has been divided with the median for the first half hour (without information) since the company did not want to share any crucial data.

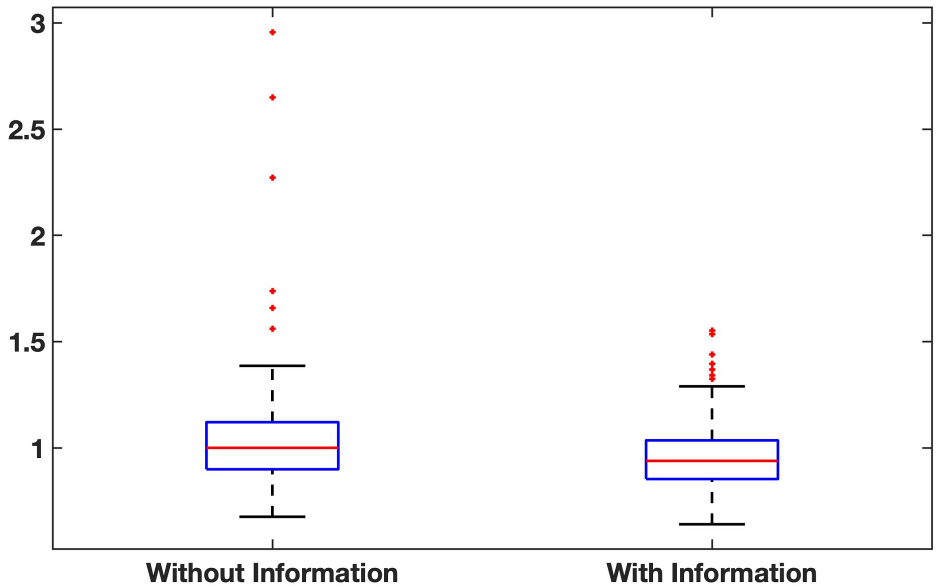

Figure 4.2: Boxplot over the first test with and without information.

The Matlab program gave the upper quartile (Q3) for the data series without information which was 1,1228 and the IQR which was 0,2215. Together with equation 2.1 the upper limit for the extreme outliers was calculated with Matlab:

$$\text{Extreme outliers} = Q3 + 3 * IQR = 1.1228 + 3 * 0.2215 \approx 1.89 \tag{4.1}$$

Matlab calculated the four data points that were furthest from the median and they were 2.96, 2.65, 2.27 and 1.74. Since the three largest data points were bigger than 1.89, they were considered as extreme outliers, hence excluded from the data series. Note that the corresponding value in the data series with information were excluded so that the number of measurements were same for each sample in the test.

The extreme outliers were also calculated in the Matlab code for the measurements with information. The upper quartile (Q3) for these data points was 1.0351 and the IQR was 0.1820. Together with equation 2.1 this gave the upper limit for the extreme outliers:

$$\text{Extreme outliers} = Q3 + 3 * IQR = 1.0351 + 3 * 0.1820 \approx 1.58 \tag{4.2}$$

The largest data point for the data series with shared information was calculated with Matlab and it was equal to 1.57. Since it was lower than the upper limit for extreme outliers (1.58) it was not considered as an extreme outlier.

With the three largest data points excluded from the data series without information and their corresponding values excluded in the data series with information, a new boxplot was made in Matlab which can be seen in figure 4.3.

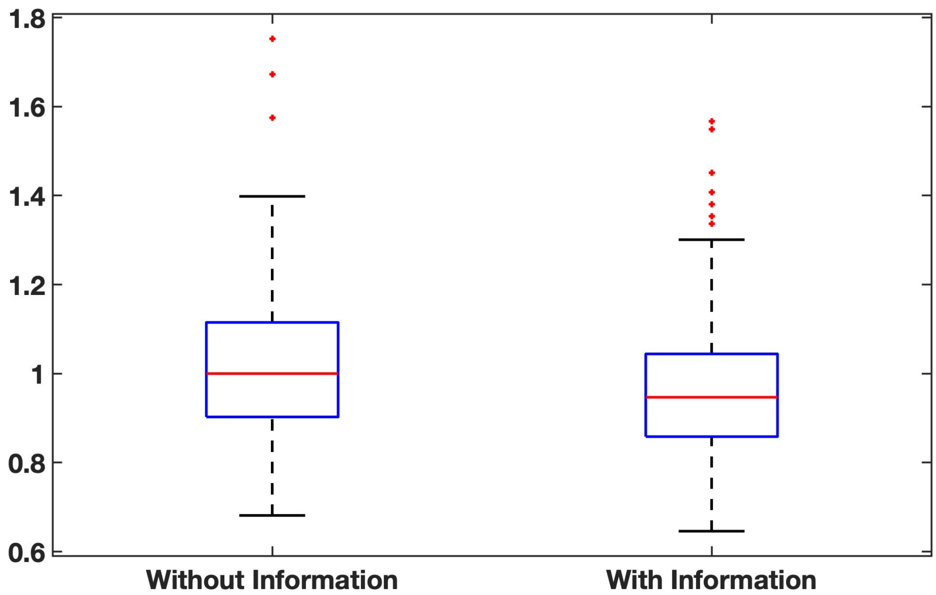

Figure 4.3: Boxplot over the first test with and without information excluding extreme outliers.

The data points in figure 4.3 were the ones that were used later in the z-test for the first test. The total time that the STS crane was disturbed by straddle carriers during the test was also measured with StarDriver and summarized in Matlab. A modification of the total disturbance time is displayed in table 4.1. The disturbance time during the first half hour without shared information has been set to 100 second. Then the time during the second half hour with shared information has been revised to that number so that the correlation between the numbers was kept.

Table 4.1: The total time that the crane was disturbed by straddle carriers during the first test. Note that the data have been modified.

Without information	**With information**
100 seconds	54,61 seconds

The average distance travelled for each straddle carrier during the test together with the standard deviation, is given in table 4.2. This data was provided by the case terminal and it has been modified. The average for the distance without information has been set to 100 and then the other values has been revised to this number so that they keep their correlation.

Table 4.2: The average distance travelled for each straddle carrier during the first test together with the standard deviation. Note that the distance has been modified.

	Without Information	**With Information**
Average distance	100 m	99,87 m
Standard deviation	27,25 m	27,44 m

Before doing the z-test on the data displayed in figure 4.3, the data 'with information' was subtracted with the data 'without information' in Matlab. The mean value ($\overline{x}_1$), standard deviation (σ_1) and number of measurements (n_1) for the subtracted data were calculated in Matlab and are given in table 4.3.

Table 4.3: Values for the difference in loading cycle time during the first test.

Mean value	$\overline{x}_1$	-0,042
Standard deviation	σ_1	0,200
Number of measurements	n_1	125

Since the data series contained more than 30 number of measurements a z-test could be carried out. To calculate the z-value for the first test, equation 2.2 was used together with the data from the data series in table 4.3. The z-value was calculated in Matlab, the procedure and result can be seen in equation 4.3

$$Z = \frac{\sqrt{n_1} * (\overline{x}_1)}{\sigma_1} = \frac{\sqrt{125} * (-0,042)}{0,200} \approx -2,356 \tag{4.3}$$

For a lower-tailed z-test, which was the case here, a 5% significance level gives a Z of -1.645. Since the z-value (-2.356) was less than -1.645 the null hypothesis was rejected, and the alternative hypothesis was accepted. Therefore, it was statistically concluded that there was a difference between sharing information and not sharing information at a 5% significance level. The p-value was also calculated in Matlab and it was equal to 0,9908 which gave that there was a 99,08% chance that the additional shared information gave an improvement at the case terminal.

4.4.2 Second test

The same procedure as for the first test was done for the second test as well. First a boxplot, which can be seen in figure 4.4, was made in Matlab with the collected data points from StarDriver for the second test. The data in this test has also been modified and divided with the median for the first half hour.

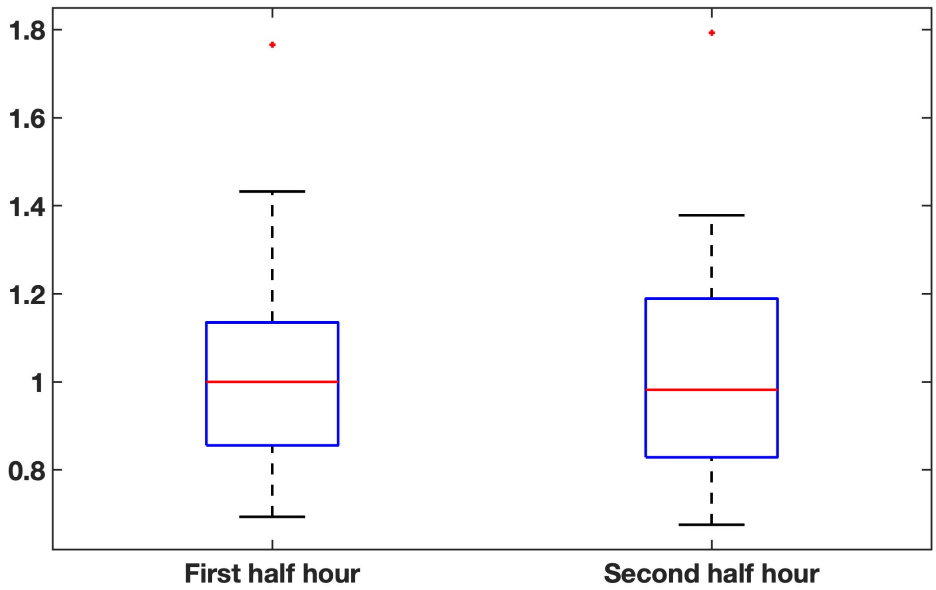

Figure 4.4: Boxplot over the second test between the first and second half hour.

For the data series during the first half hour, Matlab calculated the upper quartile (Q3) which was 1.1532 and the IQR which was 0.2215. With this data and equation 2.1 the upper limit for the extreme outliers was calculated:

$$\text{Extreme outliers} = Q3 + 3 * IQR = 1.1532 + 3 * 0.2793 \approx 1.99 \tag{4.4}$$

From Matlab, the maximum value in the data series for the first half hour was given and it was equal to 1.77, since this value was less than the value for extreme outliers (1.99) it was not excluded from the data.

For the second half hour the upper quartile (Q3), provided by Matlab, was 1.1937 and the IQR was 0.3604 which together with equation 2.1 gave the upper limit for the extreme outliers:

$$\text{Extreme outliers} = Q3 + 3 * IQR = 1.1937 + 3 * 0.3604 \approx 2.2748 \tag{4.5}$$

The maximum value in the data series for the second half hour was also calculated in Matlab and equal to 1.79. This value was also beneath the value for extreme outliers in this series (2.2748), hence it was not excluded from the data.

The total time that the STS crane was disturbed by straddle carriers during the second test was calculated in Matlab. StarDriver was also used to gather this data and a modification of the total disturbance time is displayed in table 4.4. The disturbance time has been revised to the number in table 4.1 without information. The correlation between the numbers is still valid but they do not reflect the reality.

Table 4.4: The total time that the crane was disturbed by straddle carriers during the second test. Note that the numbers have been modified.

First half hour	**Second half hour**
3,19 seconds	1,42 seconds

The average distance travelled for the straddle carriers during the second tests together with the standard deviation is given in table 4.5. This data was provided by the case terminal and it has been modified. The average distance during the first test has been set to 100 and the values in this second test has been revised to that number so that they keep their correlation with the numbers in the first test.

Table 4.5: The average distance traveled for each straddle carrier during the second test together with the standard deviation. Note that the distance has been modified.

	First half hour	**Second half hour**
Average distance	93,15 m	91,96 m
Standard deviation	26,20 m	19,84 m

To facilitate for the z-test the data during the second half hour was subtracted with the data during the first half hour in Matlab. The mean ($\overline{x}_2$), standard deviation (σ_2) and number of measurements (n_2) for the subtracted data were calculated in Matlab with the data from StarDriver. The values are given in table 4.6.

Table 4.6: Calculated values for the difference in loading cycle time in the second test.

Mean value	$\overline{x}_2$	-0,018
Standard deviation	σ_2	0,225
Number of measurements	n_2	78

Since the number of measurements were greater than 30, a z-test could be carried out. To calculate the z-value, equation 2.2 was used together with the values given in table 4.6. The z-value was calculated in Matlab, the procedure and result can be seen in equation 4.6

$$Z = \frac{\sqrt{n_2} * \overline{x}_2}{\sigma_2} = \frac{\sqrt{78} * (-0,018)}{0,225} \approx -0.703 \tag{4.6}$$

This z-test was also one tailed which gives a Z of -1.645 for a 5% significance level. The z-value above (-0.703) was greater than -1.645, hence the null hypothesis could not be rejected. Therefore, it was not statistically concluded at a 5% significance level that there was a difference between the first and second half hour when the STS cranes were loading containers. The p-value was also calculated with Matlab and it was equal to 0.7589 which means that there was a 75,89% chance that the loading cycle for the STS crane was faster during the second half compared to the first half hour. Since the p-value was lower than 95% it was not significant at a 5% significance level.

5

Discussion

In this chapter the reviewed literature and findings from the case terminal are discussed and analyzed in regard of the research questions.

5.1 Terminal operations

Within this section, the case terminal is analyzed and discussed in regard of findings and literature to elaborate on research question 1; *"How are STS cranes and straddle carriers operated in container terminals?"*.

5.1.1 Dispatching and balancing operations

Terminal operations differ between terminals, not only in equipment but in organization behind (Thoresen, 2014). Many of the different actor's impact are of importance to the operations performance and the customer experience. Within this business, time is an important factor (Zhen et al., 2016). Vessels traveling between terminals got their own time slots at the berth site along the quay. Being able to slow-steam between the ports predicting both arrivals and departures are key to keep the profitability as high as possible for both the shipping companies and terminals along the lanes (Ha & Seo, 2017; Liang, 2014). To serve vessels and have them depart on predicted time, finishing the vessel on time neither late nor hours before scheduled time window, are a balancing act that is performed everyday by the dispatchers (Bish et al., 2005). This is partially done when setting the yearly shipping lane time windows but manipulated daily to balance the different vessels to send them away on time. The case terminal is excellent on this task, to be able to serve the majority of all calls that arrive late and on time, to be sent away on time to other terminal operators. These skills imply that the dispatching function are a large portion of the ability to serve vessels and balance the operations. Being able to inform the shipping company hours before departure, allowing them to reschedule pilot, tugs and mooring. This allows the vessel to depart in close connection to the last container being lifted and the cranes being raised. This ability to support customers and satisfy their needs are key to increasing volumes and customer experience.

The dispatcher is responsible for balancing the work load to ensure delivery on targeted times to the customers (Bish et al., 2005). When balancing the teams, there are straddle carriers that belongs to certain yard pools that can be utilized where there is a need. In difference to the crane team and their straddle carriers, the yard machine gets pooled over where there is increased need of higher rates of operation. Being new and pooled in to a crane team, the new operator gets a message from the dispatcher, "next job on K1" where K is for crane. The operator then introduces himself on the cranes specific radio channel and that is it. As an advice for the dispatcher, an increased message to all straddle carriers that operates on that crane would be helpful. A clear message to increase the communication including the new machine and operator. Being pooled to a crane, depending on the situation, it can take time to figure out what other machines are operating on the same crane. Sending a message with "Next K1, on crane: SC15, SC14, SC09" or similar would be enough to inform all operators and further increase the productivity and interaction (Heilig & Voß, 2017).

5.1.2 Reduced dispatcher interaction

Being able to predict the operation levels and optimize them further, the dispatcher function would benefit by being relieved when handling standard procedures that machine operators could handle themselves. The different machines are already equipped with touch screens and the ability, if the system would be slightly adapted. Which would be in line with lean, increasing the involvement by operators in their daily work (Olesen et al., 2015). Today radio communications are a large portion of the daily task. Depending on issue and the number of machines that are contacting the dispatcher at the same time, further waiting will be added, delaying the operations even more. In worse case scenarios, making a whole crane team wait, due to a straddle carrier that is stuck in a row due to communication problems. Problems that could have been resolved with ease by the operator themselves, which also are considered as waste in line with the lean philosophy (Olesen et al., 2015). One of the dispatchers solved this by trying to talk as little as possible in the radio since it led to a lot of misunderstanding. Instead the dispatcher tried to clear as many problems as possible in the system itself.

Typical errors could be basic issue of not being able to go one step back in the system. This small glitch requires the operator to contact dispatcher, no matter what the issue was. Sometimes just a quick return would have answered that question and saved time when already being on the way to the next task. This problem was lifted by several users and daily appears with no regard to the wasted time it creates.

5.1.3 Continuous improvements and employee interaction

The case terminal has according to the interviews turned from being integrated and allowing the workers to handle a variety of features to a reduced interface, where every interaction outside the ordinary requires help from the dispatcher. Earlier being able to optimize procedures, working with lists, saving time when preparing future moves. In comparison to today when locked to a one step view making it impossible or tediously to do anything extraordinary. Interviewees implies that the workload has been moved from the operators to the system and dispatchers. This seems to be more of a management strategy to reduce the workers involvement to be able to control operations further. This strategy is contradictory if the terminal is working with lean, where the workers involvement is key to continuous improvements (Imai, 1986). By reducing the engagement of workers, making them almost detached, the level of possible impact on the continuous improvements will be affected or severely harmed.

By involving workers in the processes and explain the benefits, management and foremen will be able to see quick results. Having teams explain for others how they do and what they experienced being the difference. Having crane operators joining for a one or two cycles before taking over in the cabin, is considered a gain for the operators and crane team. By updating each other on where, both with information but also letting the operator, whom takes over the next shift, get an introduction with more senses. This approach will lead to increased information sharing between the crane operators, reducing the time to get a hang of what is going on. Introducing minor standard procedures and activity mapping during sensitive shift changes and information exchanges will improve operations and increase value-adding processes (Olesen et al., 2015).

5.1.4 Tally workers communication and education

Within the crane teams, the tally position is key to run the different sequences and communicate, mainly over the radio, what is going on and what is needed to be done to realize the planned operations. The reason why the tally worker is so important in the crane team is because he or she is sitting on all the data. Everything from where to operate on the vessel to ask for platform and cone bins to be moved and/or prepared. The tally worker is able to predict and make preparations that can reduce unnecessary moves of the platform and cone bins etc. Decisions might ease the straddle carrier's workload by communicating changes in time, to simplify the crane operation e.g. hatch lifts that requires the machines to block main roads and certain spaces close to the crane.

During the tests the authors noticed the difference of experienced and newer tally workers. In the sense that experience in communication, to communicate what can be done instead of the unnecessary information around it. If the team are loading layer by layer, and a container is picked up early by the crane operator. The tally worker can simply tell the crane operator; "this one in cell 12". Implying that this container is not in sequence and are going to be loaded in cell 12 and that information will follow automatically until the team is back in sequence continuing layer by layer. These are easy ways of communication that will reduce the unnecessary information that the receiver needs to interpret in that message. In this case ease the decision making for the crane operator to avoid a stop, instead of letting the operator process a complicated message and assess needed actions. In addition to the message being short and brief on target, there is a need to repeat the answer, making it obvious that the message is received as intended (Sonnenwald, 2006). This can reduce errors helping both actors to communicate and act on mistakes before they affect operations more than just a slip of the tongue or miss hearing. These are already part of SOPs in the terminal but as it seems few operators are following the intended communication regulations. To educate workers on the means why they are introduced and the effects an implementation could have within the terminal would be recommended.

5.1.5 Learning organization through lean

Lean thinking in evaluation of mistakes or unwanted situations, to be able to learn, the organization needs to be more interested of educating the workers and continually learn from mistakes. An old proverb says, a smart man learns from his mistakes, while a wise man learns from other's mistakes. By sharing experiences and mediate issues that appears to more than the ones noticing the issue, the whole organization will learn. This is done perfectly when larger accidents occur, but if all incidents are regarded as equals, larger issues are likely to be dealt with long before they appear. Being able to gather the shift regularly and share moments of revelations between the operators as part of education would be part of an organization health and safety procedures. In the same time reducing unwanted habits by lifting issues in an environment where it is done in a positive way, focusing on the long term wins instead of reprimands and the lost moment of education (Liker, 2004).

5.1.6 Call of Vessels and associated network

In long terms having abilities to accommodate larger vessels are key to lowering transport costs for customers and retaining the ability to be competitive in comparison to competitors (Ha & Seo, 2017). Larger vessels having the ability to plan and hire several shifts of workers that are engaged during the whole shifts and the large volumes that are moved without any additional wait increases the workforce utilization. In addition, it increases the impact from both yard planner and vessel planner to collaborate and provide the best possible starting point for crane teams to turn over the planned containers on the vessel. These planned volumes would be beneficial to have beforehand for the yard planner to individualize the possibilities to prepare the yard to suite the call. Together with the vessel planner and in regard of the planned order, shape the strategy to include possible destinations and sequences in the yard. To reduce the time it takes for the straddle carriers between two pickups or drop offs beneath the crane. This would imply taking part of shared information from the shipping companies and on earlier stages plan the individual calls. Also, in addition try to sort not only destinations and weight, but if possible, what containers that are booked together, to avoid impacts on the whole bookings being rearranged. This could avoid these bookings to be sequenced together in the storage area, three containers high. Only allowing them to be paired together, reducing the risk of unnecessary moves and housekeeping etc. (Carlo et al., 2014).

Smaller vessels are designed different than large vessels and affected more by how they are loaded. Loading one stack at a time can make small vessel capsize in comparison to a large vessel where a land-side hold can be filled without the vessel showing any impact at all. Due to massive ballast tanks where water is pumped in and out, the balance of the vessel is kept (Lumsden, 2007). This ability to load one side at a time could be used if the stowage on the vessel and the yard is prepared with it in mind. This is partially a task for the dispatcher to understand. Loading under deck in the far side of the vessel increases the movements for the crane and can possibly be operated with less straddle carriers if the stored containers are close by. In the same way loading below deck close to the crane, the movement of the crane is reduced, implying that more straddle carriers can be added to keep up with the cranes progress. These two ways of running could be combined if there are equal settings to be loaded in the different bays. Normally the land side and the far side is paired and loaded to reduce the vessels use of the ballast pumps. They are then loaded layer by layer starting in the far side and when the layer is filled in the land side, the crane operator starts over filling the next layer in the far side. Having two bays with this kind of setting, could reduce the imbalance between them. By letting one run in the far end, and the other close to the crane, letting the two crane teams run a more constant rate. Implying that the dispatcher can balance the straddle carriers more efficiently and, in the end, have the crane teams switch over to load the remaining hold (Bish et al., 2005). In an optimal setting this would be interesting, but if one crane get issues there can be problems with this way of working. But there are potential benefits, meaning that the alternately waiting period on both cranes in theory could be reduced if the cranes are able to load one hold, land side or far side, at a time.

During this type of loading, avoiding split holds being loaded at the same time within one bay, there is likely that the operation and the communication with the tally worker would be improved (Sonnenwald, 2006). Reducing the risk of miss-communication, which has been present during the tests performed, especially when loading in separated holds (Bicheno & Holweg, 2009; Sonnenwald, 2006).

5.2 Evaluation of shared information

Within this section, interviews and insights are presented and argued in regard of the possibility, to later use or dismiss ideas which were the foundation of the tests performed at the case terminal. In the section the authors analyze and answers research question 2; *"What information is required to be shared to improve the performance of straddle carriers in container terminals?"*.

5.2.1 Additional screen in the straddle carrier

There were thoughts about using an additional screen in the straddle carrier to present the extra information. The additional screen would likely have been able to display more information than the text message with 38 characters which was used during the tests. By using an additional screen, the information could also have been displayed in a more attractive way compared to green text on a black screen which was used in the test. However, after a discussion with the supervisor the current screen was used since the supervisor previously had poor experience with presenting information on additional screens. It would probably had taken the straddle carrier operators longer time to adapt to a new screen than just the extra information on the current screen. Two screens would probably also disturb the straddle carrier operators more in their daily work since they would have to focus on more things.

5.2.2 Sequence order

All the straddle carrier operators mentioned in the interviews that they lacked information about the sequence order, to place containers according to sequence underneath the STS crane. If the straddle carrier operators gambled and were wrong the tally worker often saw it and told them to either drive around, circling the crane and wait till their turn or proceed and place the container under the crane. When the tally worker told the straddle carrier to proceed, the same information had to be communicated to the crane operator. The crane operator could lift it and then skip a cell in the vessel when loading the container or wait for the correct container and then load in the correct sequence. Therefore, the sequence for the straddle carrier operator was not vital since the tally worker could just tell the crane operator to skip a cell if a straddle carrier overtook another in the sequence. But it happened that the tally worker missed the change in sequence order which led to confusion and sometimes misplacement on the vessel. Which eventually the next port would have to deal with, or in worst case it ends up in wrong terminal if the stacks got different destinations.

5.2.3 Improvement for the visibility issue

SC operator 3 mentioned in section 4.2.2 that it was hard to see in what motion in the load or discharge sequence the crane cabin and spreader are located beneath the beam. Particularly when the terminal was serving large vessels, that are positioned high in the water making it impossible to see the crane cabin in certain angles when the straddle carrier is passing beneath the crane. To help the straddle carrier operators with the visibility issue, there was a light which alternated between green and red at each crane. The red light meant that the straddle carriers were not allowed to proceed in under the crane. The cranes two zones called 'zone one', closest to the vessel and 'zone two', on the other side of the safety zone. Red is shown if the crane is passing over any zone with a container locked or just if it is beneath a certain height within the zones. Green light is showing when the spreader is out of the zones above the height limit when unloaded or in any position away from the zones when being loaded. It happened that the straddle carriers went in during green light affecting the crane since the red light only lit up when the crane came close to the quay. The straddle carrier operators had green light when they drove beneath the crane but since the red light lit up late, the straddle carrier still disturbed the crane. Sometimes this was solved by the crane operator through radio communication, telling the straddle carrier operator to either wait or enter depending on who's ahead of schedule. But sometimes the crane operator had to stop due to the straddle carrier already entered the work space.

One solution to the light problem could be to add a yellow light at the STS cranes. The yellow light would light up when the crane starts to go back to the quay. This would increase the information of where the crane cabin is located and therefore decrease the risk for confusion and the need for locating the crane cabin, which is in line with lean (Bicheno & Holweg, 2009). In order to be accurate when the crane slightly adjust forward and backwards when placing a container on the vessel. The light should also be required to sense that the crane has reached a certain speed going backward before the light turns yellow. This would warn the straddle carrier operators when the STS crane is heading back over the zones. If they proceed in beneath the crane when the yellow light is on, it would mean that there is a high risk that they will disturb the STS crane. The straddle carrier can then make the decision to continue beneath the crane or not. During discharging it would be better for the straddle carrier to wait since it will disturb the crane with only one exception, if there is one discharged container in zone two, where only one lane is used. Making it safe to enter when no loaded container will pass in to that zone and lane when a container or a straddle carrier is placed there. During loading, when there are no containers under the crane, the straddle carrier operator should proceed in beneath the crane and place the container so that the crane is continually fed. This implies that the straddle carrier operator should make sure to avoid entering zone one if (1) there are already one container in zone one, and the straddle carrier operator is unsure if there is enough time to place one extra (2) the crane is about to lift a container in zone two, on its way to pass zone one. (3) the straddle carrier operator is unable to interpret the crane sequence, or (4) the straddle carrier operator is told to not enter zone one. The terminal should consider during loading to avoid using both lanes in zone one, due to the risk of unnecessary stops and the simplification of the loading sequence for both the tally worker and the crane operator. N.B. that this amendment should not be confused with dual, when both zones, and all three lanes are used, making a one container restriction foolish.

5.2.4 Different departments

The focus has been on the vessel side department and the ability to share information and increase the performance within that specific department. There are ideas that can be used at other departments and unique gaps that needs to be addressed. Implementing anything or evaluating further changes could be beneficial to investigate similar but still unique data or information for other departments to use. By increasing the frequency of shared information in other departments it might improve their operations as well (Mohr & Nevin, 1990). As an example, knowing the machines that operate in a crane team can improve the communication in the crane team. To mention one other benefit like that would be, serving a truck with two container positions in the import/export grid. Knowing other straddle carriers that are assigned to the same truck would increase the ability to reduce time by communicating who should enter first. In rare cases both can operate during the same time if carrying two 40' containers. This example is just provided to expose mutual benefits between the departments and the beneficial ground to consider further alternatives when being slightly outside the scope.

5.3 Operational effects of sharing information at the case terminal

Within this section, the authors analyze and answers research question 3; *"What are the operational effects of information sharing in container terminals?"*. The developed test and measurements are described, and pros and cons are reviewed.

5.3.1 Test design

The measurement and shared information were designed to utilize the already existing features in the operating system and by few means the authors accomplished to manually execute the test. When loading FEUs under deck; without any cone handling, all buffer zones/lanes were utilized, and the crane operator could pick any available container which results in a lower influence on the crane. Providing stable measurements with low regard of interruptions in comparison of conducting measurements when discharging or dual-cycling. In addition, during loading the operation system, Navis, performed stable predictions of where the next container was positioned. When the authors performed minor tests during trials, they noticed during discharge the predicted storage positions changed rapidly and were unpredictable in the rate they were proposed. Part of the reason was the crane teams in some cases discharged without following the discharge sequence, which the system handled well. But this resulted in the impossible task to share any information manually that could improve the work flow. This was ruled as an uncertainty that could spoil the measurements ability to be correct and later evaluated.

5.3.2 Straddle carrier driving distances

One of the KPIs that was measured during the tests in the terminal was the distance travelled by the straddle carriers. The reason for measuring this was due to the fact that if there was a big difference in distance for the straddle carriers between the first and the second half hour it could have given a deceptive result. During the first test, the difference in distance was almost non-existent and therefore assumed to be negligible. In the second test though, the difference in distance for the straddle carriers, between the two samples, was greater. However, since the average distance was greater for the first half hour it did not impact the result in a beneficial way. It would have been worse if the average distance was greater for the second half hour, as it could have reduced the crane's productivity in the second half due to longer driving routes for the straddle carriers. Thereby, the result would have been negatively influenced by increased driving distance for the straddle carriers.

5.3.3 Driving distances and affected crane cycles

Comparing the two tests in regard of driving distance and the time the cranes where disturbed or affected by a straddle carrier within the buffer zone, are shown in tables 4.2, 4.5 and tables 4.1, 4.4. The distances are shorter in the second test compared to the first and so are the times where straddle carriers affect the STS crane. There is a considerable difference in time from the first test with 100 versus 54,61 seconds and the second test with 3,19 versus 1,42 seconds. Note that the numbers are modified, and they do not reflect the reality but their correlation between each other is still valid. Divided on the number of measurements there is a clear difference from first and second test. During the second test the disturbance caused by straddle carriers is very small compared to the first test, this could be an effect of the shorter distances during the second test. There is a maximum distance where the straddle carriers can be equally divided and able to deliver on time without interrupting the crane operators' pace. During the whole first test there is an impact on the crane, seen in table 4.1 with a distinct imbalance with lower impact when sharing information. It is almost halved during the second period when additional information is shared. This difference can be part of the impact of shared information of straddle carrier sequence and the early prediction of presenting information regarding the next row, where the next container in the sequence are stored. Measurements imply that the shared information in this regard makes a difference.

5.3.4 Deviation of the driving distances

The standard deviation of the distance driven by the straddle carriers during the first and second half hours are shown in table 4.2 and 4.5. The first test indicates that the deviation is negligible being comparable in their dispersal. But in the second test, there is an indication of a difference in the standard deviation. Data implies that the first half hour has a larger deviation, which means the distances are more spread out around the mean distance for the first half hour in the second test (Hargrave, 2019). If the distance of the straddle carrier directly affects the operation of the STS crane, it would have operated at lower rates. Increasing the difference between the two half hours when fed by the straddle carriers during the second half hour. In addition; the standard deviation is lower during the whole second test, first and second half hour, compared to the first tests half hour deviations. Making the measured data valid in both these regards.

5.3.5 Significant difference when sharing information

The difference between not sharing information and sharing information is statistically significant. However, after observations at the case terminal one risk which could have impacted the measurements was found. The measurements were made when the STS crane was loading. During the first half hour the terminal ran as normal and during the second half hour the straddle carriers received additional information. The noticed risk is, the more containers that are loaded in the hold, the shorter the distance gets for the STS crane when coming higher up in the bay, which is shorter during the second half hour compared to the first. This meant that the time that the STS crane had to carry a container might have been reduced during the second half hour which could impact the measurements in the first test. To see if there were any differences and how eminent they were, supplementary measurement (second test) were made between the first and second half hour and this time without any additional information sharing. The number of points measured in the second test are less compared to the first test, but the amount was still enough to get a realization of a difference between the first and second half hour.

5.3.6 Test interpretation regarding significance

It is important to understand that the meaning of the first test being statistically significant, only imply that the sample mean is lower than zero. Hence, it is not statistically significant that the difference is -0,042 just that the difference is below zero and therefore gives an improvement. The second test is not significant at a 5% significance level. Thus, the average value of that test could actually be higher than zero and thus mean that the STS crane is loading slower during the second half hour. However, the fact that the crane would load slower during the second half hour is unreasonable under normal conditions since nothing in the operation indicates that this is the case. It is more likely that the mean value is below zero due to, as mentioned earlier, that the STS crane generally loads higher up in the bay during the second half hour.

5.3.7 Improvement by information sharing

Since the first test is significant and the second test is not it means that the increased information sharing provides an improvement in the case terminal. The sample mean values are not statistically secured, but if it is assumed that these sample means symbolize the true mean values during the different tests, one can get a picture of how big the impact is of the extra shared information. The sample means for both tests are shown in table 5.1.

Table 5.1: Table of the sample means from the two tests.

	First test	**Second test**
Mean ($\overline{x}$)	-0,042	-0,018

The difference between the sample means are calculated in equation 5.1.

$$\overline{x}_1 - \overline{x}_2 = (-0,042) - (-0,018) = -0,024 \tag{5.1}$$

The difference between the two sample means are -0,024 (equation 5.1). If both sample means are assumed to symbolize their true mean values the difference between the true mean values would also be -0,024. This value has been divided with the median during the first half hour in the first test. The value can be converted back again by multiplying it with the time for a general lift cycle so that the improvement can be displayed in a more realistic way but still not reflect the productivity at the case terminal. According to literature the lift cycles with single spreader for an STS crane is between 90-120 seconds (Thoresen, 2014). This means that an STS crane is capable of handling 30 to 40 container lifts per hour. By implementing the increased shared information, the container handling time would decrease by -0,024 which for 90 seconds is calculated in equation 5.2.

$$90 * 0,976 = 87,84 \text{ seconds} \tag{5.2}$$

And for 120 seconds lift cycles in equation 5.3.

$$120 * 0,976 = 117,12 \text{ seconds} \tag{5.3}$$

The container lift per hour, with 87,84 seconds per container lift, is calculated in equation 5.4.

$$\frac{3600}{87,84} = 40,98 \text{ lifts per hour} \tag{5.4}$$

The container lift per hour, with 117,12 seconds per container lift, is calculated in equation 5.5.

$$\frac{3600}{117,12} = 30,74 \text{ lifts per hour} \tag{5.5}$$

By using increased information sharing at the case terminal, container lifts per hour would increase from 30-40 lifts per hour to approximately 31-41 lifts per hour. Or simply expressed; one extra container lift per hour. Depending on how many containers the case terminal's STS cranes moves their current capacity will change proportionally. This is only true if the true mean value for each test is the same as the sample means which is assumed in this section.

Effects of an improvement of one lift per hour for each crane on a large call, can be shown with a simple calculation. Let's say that several cranes are working 100 hours total during a call of a large vessel. The authors estimate an improvement on all lifts, when sharing information. If they are able to lift one extra container per hour, this would reduce 100 lifts. With a low average for the terminals production setting, let's say 30 containers per hour the saved time would have been three hours and 20 minutes. Let's say every crane was operated with three high straddle carriers with a fuel consumption of twelve liters per hour. The savings on just fuel would have been 120 liters during that time period. Having one of these calls every week during a year would save around 6240 liters of fuel and emissions through an implementation of information sharing. In addition, there will be a reduction of over 510 straddle carrier hours with an associated reduction of needed maintenance. As a reminder, the terminal serves additional vessels during the week and further savings on fuel and maintenance will be made.

6

Conclusion

This chapter states the conclusions drawn in this thesis. It shows the main results of the study, theoretical contribution, managerial contribution, and ends with limitations and further research suggestions.

The purpose of this work is to investigate how unnecessary stops of STS cranes can be reduced by improved management of straddle carriers through information sharing.

The thesis was carried out at a case terminal were the actor, resources and activities were defined with the ARA-model. Interviews were conducted and the interviewees emphasized the lack of information when driving straddle carriers in the case terminal. These interviews and several observations resulted in a test were additional information was sent out to the straddle carrier operators through a text message in the current operational system. The content of the message was carefully selected after asking interviewees and performing small trials before tests within the terminal. During the test the operational effect of the STS crane was measured together with the distance travelled by the straddle carrier and the time for which the STS crane was disturbed by the straddle carriers.

The text messages sent out to the straddle carriers provided an improvement in the case terminal, the text by itself seemed to be negligible during running operations, but significant enough to give a difference. Despite that the test was performed during least possible influence between crane and machines, a difference is present and showing in the data. The text message consisted of 38 characters and included sequence order and location of next container. Improving the way information is displayed and by sharing even more information than what was shared during the test, it is likely that the terminal can increase the productivity even further. By also sharing specific information depending on department and ongoing activity, straddle carriers and other machines could increase their production rate both at the STS cranes and at other grids. Increasing the standardization at the terminal, the crane teams perform their jobs according to the documented, standard operations and procedures (SOPs). Having all crane team members make break shifts at the same preset point of time and in the natural flow. The crane productivity can be increased even further since the straddle carriers will not have to adapt to more than one way of handling containers for the different sequences (loading, discharge and dual) at the STS cranes. If the terminal in later stages are to introduce pooling where the

STS cranes are involved, standardization will be utterly important to ensure the performance in the terminal and the health and safety regulations. This implies that they are followed in reality, not only stated on paper.

The ARA-model and lean thinking was used in this thesis to analyze the terminal operations. With the support of the ARA-model and lean philosophy the main results were accumulated. To reduce waste in various situations and address them accordingly, the authors analyzed issues within the operating system and the different workflows. Many of them in relation to communication, handing over or delegating work, either from sending information to being short and brief when transmitting a message. Educating both white and blue collars would contribute to an improved environment with standard phrases and messages. Further information sharing was the frame for the authors indication and later the design of the test that was performed. Being able to contribute with significant data that indicates possible improvements within the operating system and the terminals approach in this matter.

The case terminal can benefit from this thesis in several ways. First, by increased implementation of standardization and lean, the terminal would be able to improve their operation and increase the health and safety within the terminal. Much due to strict regulations and education within SOPs, where optimal procedures for every activity. Creating unity among the operators and structures within communication, with sharper phrases be able to reach the targeted result. Second, by increasing the information sharing in the terminal, will obtain the possibility to improve the operation at ship-side. But also investigate what levels other departments can benefit by implementing similar but individual information in their own interest. At ship-side an implementation would lead to a reduced turnaround time for vessels, or increased ability to predict departure times or by planning a departure and operate using less resources. The thesis could imply a lower environmental impact through increased utilization. Providing the shipping company with an increased ability to slow-steaming and through decreased emissions from the terminal machines. Increasing their utilization with additional information sharing to perform the same work with a reduction of waiting or standing idle.

The work was meant to decrease stops for STS cranes who are lifting containers at a container terminal. There can be many reasons for why an STS crane stops but this work was limited to stops caused by straddle carriers. Future research could investigate the impact of other disturbances such as technical faults, electrical faults or loading/discharging processes behind stack where the crane operator's visibility was limited.

At the case terminal, the STS cranes were not supported by all active straddle carriers. For example, some straddle carriers were loading or discharging trucks or trains, and some were rearranging containers to better locations. This work only distinguishes the potential enhancements for the straddle carriers assisting the STS cranes. The performance of other straddle carriers could possibly be improved by sharing data with them as well, this could be investigated in further research.

This work investigated the operational effects of the STS cranes when enhancing the shared information to the straddle carrier. The operational effect of the STS crane was only measured when the STS crane was working below deck during loading operations, handling 40' containers. Further research could investigate the impact of increased information sharing to the straddle carrier for operation above deck and during discharge and dual-cycle operations.

References

Ali, Z., & Bhaskar, S. B. (2016, 9). Basic statistical tools in research and data analysis. doi: 10.4103/0019-5049.190623

Babicz, J. (2015). Wärtsilä encyclopedia of ship technology (2nd edition).

Bartošek, A., & Marek, O. (2013, 01). Quay cranes in container terminals. *Transactions on Transport Sciences*, *6*. doi: 10.2478/v10158-012-0027-y

Bell, J. (2011). *Introduktion till forskningsmetodik*. Studentlitteratur AB, Lund.

Berlec, T., & Starbek, M. (2019, 04). Eliminating waste in companies.

Bicheno, J., & Holweg, M. (2009). *The lean toolbox : the essential guide to lean transformation* (4th ed.). Retrieved 2019-04-27, from http://lib.ugent.be/catalog/rug01:001328336

Bish, E. K., Chen, F. Y., Leong, Y. T., Nelson, B. L., Ng, J. W. C., & Simchi-Levi, D. (2005). Dispatching vehicles in a mega container terminal. *OR Spectrum*, *27*(4), 491–506. Retrieved 2019-02-27, from https://doi.org/10.1007/s00291-004-0194-2 doi: 10.1007/s00291-004-0194-2

Bryman, A. (2012). *Social research metods* (Fourth ed.). Oxford University Press Inc., New York.

Burgess, E., Peffers, M., & Silverman, I. (2009). The health, environmental and economic impacts of engine idling in new york city. Retrieved 2019-03-30, from https://www.edf.org/sites/default/files/9236_Idling_Nowhere_2009.pdf

Carlo, H. J., Vis, I. F., & Roodbergen, K. J. (2014). Storage yard operations in container terminals: Literature overview, trends, and research directions. *European Journal of Operational Research*, *235*(2), 412 - 430. Retrieved 2019-02-13, from http://www.sciencedirect.com/science/article/pii/S0377221713008771 (Maritime Logistics) doi: https://doi.org/10.1016/j.ejor.2013.10.054

Casaca, A., & Bernard Marlow, P. (2003, 05). Fourth generation ports - a question of agility? *International Journal of Physical Distribution & Logistics Management*, *33*, 355-376. doi: 10.1108/09600030310478810

Chen, J. (2019, 3). Z-test. Retrieved 2019-04-08, from https://www.investopedia.com/terms/z/z-test.asp

Chen, L., Xu, X., Zhang, P., & Zhang, X. (2018). Analysis on port and maritime transport system researches. *Journal of Advanced Transportation*. doi: 10.1155/2018/6471625

Christopher, M. (2000). The agile supply chain: Competing in volatile markets. *Industrial Marketing Management*, *29*(1), 37 - 44. Retrieved 2019-04-09, from http://www.sciencedirect.com/science/article/pii/S0019850199001108 doi: https://doi.org/10.1016/S0019-8501(99)00110-8

Dubois, A., & Gadde, L.-E. (2002, 07). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*, 553-560. doi: 10.1016/S0148-2963(00)00195-8

Dubois, S. (2017). The importance of hypothesis testing. Retrieved 2019-04-15, from https://sciencing.com/the-importance-of-hypothesis-testing-12750921.html

Ducruet, C., Rozenblat, C., & Zaidi, F. (2010). Ports in multi-level maritime networks: evidence from the atlantic (1996–2006). *Journal of Transport Geography*, *18*(4), 508-518. Retrieved 2019-03-08, from http://www.sciencedirect.com/science/article/pii/S0966692310000372 doi: https://doi.org/10.1016/j.jtrangeo.2010.03.005.

Duistermaat, M., Vink, N., J. Smeenk, B., L. Cleophas, P., R. Barbier, R., & G. Gouweleeuw, R. (2007, 09). Analysing operational effects (het analyseren van operationele effecten). , 59.

du Prel, J.-B., Hommel, G., Röhrig, B., & Blettner, M. (2009). Confidence interval or p-value?: part 4 of a series on evaluation of scientific publications. *Deutsches Arzteblatt international,*, *106*(19), 335-339. doi: 10.3238/arztebl.2009.0335

Dwarakisha, G., & Salima, A. M. (2015). Review on the role of ports in the development of a nation. , 295-301. doi: 10.1016/j.aqpro.2015.02.040

Folan, P., Browne, J., & Jagdev, H. (2007). Performance: Its meaning and content for today's business research. *Computers in Industry*, *58*(7), 605 - 620. Retrieved from http://www.sciencedirect.com/science/article/pii/S0166361507000668 (Performance Measurement Special Issue) doi: https://doi.org/10.1016/j.compind.2007.05.002

Ford, D., Gadde, L.-E., Håkansson, H., Snehota, I., & Waluszewski, A. (2010, 01). Analysing business interaction. *IMP Journal*, *4*, 82-103.

Galarnyk, M. (2018, 09). Understanding boxplots.

Grbic, T. (2016). The importance of shipping in the transportation industry. Retrieved 2016-02-13, from https://greencarrier.com/importance-shipping-transportation-industry/

Ha, Y. S., & Seo, J. S. (2017). An analysis of the competitiveness of major liner shipping companies. *The Asian Journal of Shipping and Logistics*, *33*(2), 53 - 60. Retrieved 2019-02-20, from http://www.sciencedirect.com/science/article/pii/S2092521217300202 doi: https://doi.org/10.1016/j.ajsl.2017.06.002

Hargrave, M. (2019, 4). Standard deviation definition. Retrieved 2019-04-24, from https://www.investopedia.com/terms/s/standarddeviation.asp

Heilig, L., & Voß, S. (2017, 9). Information systems in seaports: a categorization and overview. *Information Technology and Management*, *18*(3), 179–201. Retrieved from https://doi.org/10.1007/s10799-016-0269-1 doi: 10.1007/s10799-016-0269-1

Håkansson, H., & Snehota, I. (1995). *Developing relationships in business networks.*

Routledge, London.
Imai, M. (1986). The key to japan's competitive success.
Jadayil, W. A., Khraisat, W., & Shakoor, M. (2017). Different strategies to improve the production to reach the optimum capacity in plastic company. *Cogent Engineering*, *4*(1). doi: 10.1080/23311916.2017.1389831
Jones, D. (2006, 08). Heijunka: Leveling production. *Manufacturing Engineering*, *132*(2), 29–36.
Kalmar. (2007). Kalmar container handling systems: complete range of products and knowhow. Retrieved 2019-03-14, from https://docplayer.net/storage/60/44603127/1552560317/JtbOpBklbDwJFl3ynfJxZQ/44603127.pdf
KalmarOttawa. (2018). Kalmarottawa 60 years and going strong. Retrieved 2019-03-08, from https://kalmarottawa.com
Kaluza, P., Kölzsch, A., Gastner, M. T., & Blasius, B. (2010). The complex network of global cargo ship movements. *Journal of The Royal Society Interface*, *7*(48), 1093-1103. Retrieved 2019-04-12, from https://royalsocietypublishing.org/doi/abs/10.1098/rsif.2009.0495 doi: 10.1098/rsif.2009.0495
KoneCranes. (2017a). *Konecranes noell spreaders for konecranes noell sprinter and straddle carriers - perfectly integrated.* Retrieved 2019-03-05, from https://www.konecranes.com/sites/default/files/2018-08/kc-sc-spreader-en-01.pdf
KoneCranes. (2017b). *Straddle carriers.* Retrieved 2019-03-05, from https://www.konecranes.com/equipment/container-handling-equipment/straddle-carriers
Krzywinski, M., & Altman, N. (2014, 01). Visualizing samples with box plots. *Nature Methods*, *11*, 119-120. doi: 10.1038/nmeth.2813
Liang, L. H. (2014, 10). The economics of slow steaming. Retrieved 2019-02-20, from http://www.seatrade-maritime.com/news/americas/the-economics-of-slow-steaming.html
Liker, J. K. (2004). *The toyota way: 14 management principles from the world's greatest manufacturer.* McGraw-Hill.
Losee, R. M. (1998). *A discipline independent definition of information* (Vol. 48) (No. 3).
Lumsden, K. (2007). *Fundamentals of logistics.* Gothenburg: Chalmers University of Technology.
Mærsk. (2017). Ships for the long (and short) haul. Retrieved 2018-02-19, from https://www.maersk.com/news/2018/06/29/ships-for-the-long-and-short-haul
Mærsk. (2018). Manchester maersk makes maiden call in the uk honouring maersk line's commitment to britain. Retrieved 2018-02-14, from https://www.maersk.com/en/news/2018/02/26/manchester-maersk-makes-maiden-call
Maxwell, J. A. (2012, 01). Qualitative research design : An interactive approach.
Mili, K., & Gassara, M. (2015). Multiple straddle carrier routing problem. *Journal of Maritime Research*, *12*(2).
Mohr, J., & Nevin, J. (1990, 10). Communication strategies in marketing channels:

A theoretical perspective. *Journal of Marketing*. doi: 10.2307/1251758

MSC. (2015). Msc oscar world's largest container ship makes maiden call at eurogate container terminal wilhelmshaven. Retrieved 2018-02-15, from https://www.msc.com/swe/press/press-releases/2015-march/msc-oscar-world-s-largest-container-ship1-makes-ma

Navis. (2018). Terminal solutions and optimization. Retrieved 2019-02-22, from https://www.navis.com/en/products/terminal-solutions/

NCSS. (2019). *Pass statistical software training documentation*. Retrieved 2019-04-10, from https://ncss-wpengine.netdna-ssl.com/wp-content/themes/ncss/pdf/Procedures/PASS/Paired_Z-Tests.pdf

Nidec. (2009). An Introductory Guide to Port Cranes and the Application of Variable Speed Drives. Retrieved 2019-04-17, from https://www.nidec-netherlands.nl/media/2928-an-introductory-guide-to-port-cranes-and-the-application-of-variable-speed-drives-iss1x-0704-0005-01x.pdf

N Spasovic, L., Professor, A., Sideris, A., Das, S., & Chao, X. (1999, 11). Increasing productivity and service quality of the straddle carrier operations at a container port terminal.

Olesen, P., Powell, D., Hvolby, H.-H., & Fraser, K. (2015, 04). Using lean principles to drive operational improvements in intermodal container facilities a conceptual framework. *Journal of Facilities Management*, *13*, 266-281. doi: 10.1108/JFM-09-2014-0030

OOIL Group. (2017). Ooil group - significant events november 2017. Retrieved 2018-02-18, from https://www.ooilgroup.com/corporate/significantevents/2017/Pages/default.aspx

Patel, R., & Davidson, B. (2011). *Forskningsmetodikens grunder*. Studentlitteratur AB, Lund.

Pjevcevica, D., Nikolica, M., Vidicb, N., & Vukadinovica, K. (2017). Data envelopment analysis of agv fleet sizing at a port container terminal. , *55*(14), 4021-4034. doi: 10.1080/00207543.2016.1241445

Portela, E., Ribeiro, R., & Gama, J. (2019, 02). The search of conditional outliers. *Intelligent Data Analysis*, *23*, 23-39. doi: 10.3233/IDA-173619

Prockl, G., & Sternberg, H. (2015, 04). Counting the minutes—measuring truck driver time efficiency. *Transportation Journal*, *54*(2), 275-287. doi: 10.5325/transportationj.54.2.0275

Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, A., & Gorecky, D. (2016, 10). Towards an operator 4.0 typology: A human-centric perspective on the fourth industrial revolution technologies.

Roso, V. (2013). Sustainable intermodal transport via dry ports – importance of directional development. *World Review of Intermodal Transportation Research*, *4*(2-3), 140-156. Retrieved 2019-04-24, from https://www.inderscienceonline.com/doi/abs/10.1504/WRITR.2013.058976 (PMID: 58976) doi: 10.1504/WRITR.2013.058976

Rouse, M. (2007, 6). Excel. Retrieved from https://searchenterprisedesktop.techtarget.com/definition/Excel

Rouse, M. (2015, 4). Matlab. Retrieved from https://whatis.techtarget.com/

definition/MATLAB

Rubin, A., & Babbie, R. (2009). *Essential research methods for social work.* Cengage Learning. Retrieved 2019-02-20, from https://books.google.se/books?id=c08lh0omJtMC

Rushton, A., Croucher, P., & Baker, P. (2010). 25 rail and intermodal transport. Retrieved 2019-04-09, from https://app.knovel.com/hotlink/khtml/id:kt00A0YSP8/handbook-logistics-distribution/rail-inter-introduction

Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research methods for business students.* Pearson.

SeaRates LTD. (2019). Parameters of sea containers. Retrieved 2019-03-21, from https://www.searates.com/reference/equipment/

Shingo, S. (1989). A study of the toyota production system: From an industrial engineering viewpoint.

SixSigma. (2017). Understanding lean manufacturing principles. Retrieved 2019-03-15, from https://www.6sigma.us/six-sigma-articles/understanding-lean-manufacturing-principles/

Sonnenwald, D. H. (2006, 7). Challenges in sharing information effectively: examples from command and control. , *11*(4).

Spens, K. M., & Kovács, G. (2006). A content analysis of research approaches in logistics research. *International Journal of Physical Distribution & Logistics Management*, *36*(5), 374-390. doi: 10.1108/09600030610676259

Sullivan, L. (2017, 11). Hypothesis testing for means & proportions.

Tec Container Asia Pacific. (2015). Overheight frames. Retrieved 2019-03-21, from https://www.teccontainer.com.au/products/overheight-frames/

Thoresen, C. A. (2014). *13.1 site location.* ICE Publishing. Retrieved 2019-03-16, from https://app.knovel.com/hotlink/khtml/id:kt00U72CG8/port-designers-handbook/site-location

Unifeeder. (2019). Best-connected feeder network in Europe. Retrieved 2018-02-26, from https://www.unifeeder.com/feeder/coverage

Veazie, P. J. (2015). Understanding statistical testing. *SAGE Open*, *5*(1). doi: 10.1177/2158244014567685

Wilson, I. D., & Roach, P. A. (2000). Container stowage planning: A methodology for generating computerised solutions. *The Journal of the Operational Research Society*, *51*(11), 1248–1255. Retrieved from http://www.jstor.org/stable/254210

Zhen, L., Xu, Z., Wang, K., & Ding, Y. (2016). Multi-period yard template planning in container terminals. *Transportation Research Part B: Methodological*, *93*, 700 - 719. Retrieved 2019-03-03, from http://www.sciencedirect.com/science/article/pii/S0191261515002672 (Maritime Logistics) doi: https://doi.org/10.1016/j.trb.2015.12.006

A

Interview guide

For crane drivers

- How long have you been operating STS cranes?
- How much influence does the straddle carrier drives have on your work?
  - How often do you have to stop because straddle carriers fail to deliver containers in time?
  - How often do you have to stop for straddle carries that are in your way?
  - Is there any step (dispatch / load / over or under deck / type of boat) when the boundary trucks have a greater impact on your work?
- Do you see any information that could be automated from the STS crane to the straddle carrier driver or vice versa?

For straddle carrier drivers

- How long have you been driving straddle carriers at this terminal?
- Do you have enough information to perform your duties?
  - Give suggestions for missing information.
  - In what way would you be able to perform your work better if you had access to that information?
- Have you worked with a different system than what is used today?
  - What sets the different systems apart?
  - Is there any information you miss in today's system that existed in previous systems?
  - Are there any benefits to today's systems compared to previous systems?
  - Which system do you prefer?

- We have some suggestions for shared information (suggestions explained), do you think they could be useful at this terminal?

B

Example of data from StarDriver

N.B. The duration for each motion in this example is randomized between 40 to 60 seconds

Name	Username	Start	Finish	Duration
In Motion Loading	Test	'2019-05-16 07:05:00'	'2019-05-16 07:05:49'	'0:00:49'
In Motion Unloading	Test	'2019-05-16 07:05:49'	'2019-05-16 07:06:31'	'0:00:42'
In Motion Loading	Test	'2019-05-16 07:06:31'	'2019-05-16 07:07:17'	'0:00:46'
In Motion Unloading	Test	'2019-05-16 07:07:17'	'2019-05-16 07:08:03'	'0:00:46'
In Motion Loading	Test	'2019-05-16 07:08:03'	'2019-05-16 07:08:51'	'0:00:48'
In Motion Unloading	Test	'2019-05-16 07:08:51'	'2019-05-16 07:09:41'	'0:00:50'
In Motion Loading	Test	'2019-05-16 07:09:41'	'2019-05-16 07:10:23'	'0:00:42'
In Motion Unloading	Test	'2019-05-16 07:10:23'	'2019-05-16 07:11:08'	'0:00:45'
In Motion Loading	Test	'2019-05-16 07:11:08'	'2019-05-16 07:12:04'	'0:00:56'
In Motion Unloading	Test	'2019-05-16 07:12:04'	'2019-05-16 07:12:45'	'0:00:41'
In Motion Loading	Test	'2019-05-16 07:12:45'	'2019-05-16 07:13:44'	'0:00:59'
In Motion Unloading	Test	'2019-05-16 07:13:44'	'2019-05-16 07:14:39'	'0:00:55'
In Motion Loading	Test	'2019-05-16 07:14:39'	'2019-05-16 07:15:29'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 07:15:29'	'2019-05-16 07:16:21'	'0:00:52'
In Motion Loading	Test	'2019-05-16 07:16:21'	'2019-05-16 07:17:06'	'0:00:45'
In Motion Unloading	Test	'2019-05-16 07:17:06'	'2019-05-16 07:17:55'	'0:00:49'
In Motion Loading	Test	'2019-05-16 07:17:55'	'2019-05-16 07:18:54'	'0:00:59'
In Motion Unloading	Test	'2019-05-16 07:18:54'	'2019-05-16 07:19:45'	'0:00:51'
In Motion Loading	Test	'2019-05-16 07:19:45'	'2019-05-16 07:20:35'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 07:20:35'	'2019-05-16 07:21:20'	'0:00:45'
In Motion Loading	Test	'2019-05-16 07:21:20'	'2019-05-16 07:22:10'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 07:22:10'	'2019-05-16 07:23:02'	'0:00:52'
In Motion Loading	Test	'2019-05-16 07:23:02'	'2019-05-16 07:23:56'	'0:00:54'
In Motion Unloading	Test	'2019-05-16 07:23:56'	'2019-05-16 07:24:44'	'0:00:48'
In Motion Loading	Test	'2019-05-16 07:24:44'	'2019-05-16 07:25:31'	'0:00:47'
In Motion Unloading	Test	'2019-05-16 07:25:31'	'2019-05-16 07:26:31'	'0:00:60'
In Motion Loading	Test	'2019-05-16 07:26:31'	'2019-05-16 07:27:12'	'0:00:41'
In Motion Unloading	Test	'2019-05-16 07:27:12'	'2019-05-16 07:28:10'	'0:00:58'
In Motion Loading	Test	'2019-05-16 07:28:10'	'2019-05-16 07:29:08'	'0:00:58'
In Motion Unloading	Test	'2019-05-16 07:29:08'	'2019-05-16 07:30:04'	'0:00:56'

In Motion Loading	Test	'2019-05-16 08:05:00'	'2019-05-16 08:05:56'	'0:00:56'
In Motion Unloading	Test	'2019-05-16 08:05:56'	'2019-05-16 08:06:50'	'0:00:54'
In Motion Loading	Test	'2019-05-16 08:06:50'	'2019-05-16 08:07:43'	'0:00:53'
In Motion Unloading	Test	'2019-05-16 08:07:43'	'2019-05-16 08:08:34'	'0:00:51'
In Motion Loading	Test	'2019-05-16 08:08:34'	'2019-05-16 08:09:28'	'0:00:54'
In Motion Unloading	Test	'2019-05-16 08:09:28'	'2019-05-16 08:10:21'	'0:00:53'
In Motion Loading	Test	'2019-05-16 08:10:21'	'2019-05-16 08:11:05'	'0:00:44'
In Motion Unloading	Test	'2019-05-16 08:11:05'	'2019-05-16 08:11:48'	'0:00:43'
In Motion Loading	Test	'2019-05-16 08:11:48'	'2019-05-16 08:12:48'	'0:00:60'
In Motion Unloading	Test	'2019-05-16 08:12:48'	'2019-05-16 08:13:31'	'0:00:43'
In Motion Loading	Test	'2019-05-16 08:13:31'	'2019-05-16 08:14:12'	'0:00:41'
In Motion Unloading	Test	'2019-05-16 08:14:12'	'2019-05-16 08:15:03'	'0:00:51'
In Motion Loading	Test	'2019-05-16 08:15:03'	'2019-05-16 08:16:01'	'0:00:58'
In Motion Unloading	Test	'2019-05-16 08:16:01'	'2019-05-16 08:16:54'	'0:00:53'
In Motion Loading	Test	'2019-05-16 08:16:54'	'2019-05-16 08:17:38'	'0:00:44'
In Motion Unloading	Test	'2019-05-16 08:17:38'	'2019-05-16 08:18:25'	'0:00:47'
In Motion Loading	Test	'2019-05-16 08:18:25'	'2019-05-16 08:19:14'	'0:00:49'
In Motion Unloading	Test	'2019-05-16 08:19:14'	'2019-05-16 08:20:14'	'0:00:60'
In Motion Loading	Test	'2019-05-16 08:20:14'	'2019-05-16 08:20:57'	'0:00:43'
In Motion Unloading	Test	'2019-05-16 08:20:57'	'2019-05-16 08:21:54'	'0:00:57'
In Motion Loading	Test	'2019-05-16 08:21:54'	'2019-05-16 08:22:47'	'0:00:53'
In Motion Unloading	Test	'2019-05-16 08:22:47'	'2019-05-16 08:23:35'	'0:00:48'
In Motion Loading	Test	'2019-05-16 08:23:35'	'2019-05-16 08:24:19'	'0:00:44'
In Motion Unloading	Test	'2019-05-16 08:24:19'	'2019-05-16 08:25:08'	'0:00:49'
In Motion Loading	Test	'2019-05-16 08:25:08'	'2019-05-16 08:25:58'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 08:25:58'	'2019-05-16 08:26:40'	'0:00:42'
In Motion Loading	Test	'2019-05-16 08:26:40'	'2019-05-16 08:27:32'	'0:00:52'
In Motion Unloading	Test	'2019-05-16 08:27:32'	'2019-05-16 08:28:17'	'0:00:45'
In Motion Loading	Test	'2019-05-16 08:28:17'	'2019-05-16 08:29:05'	'0:00:48'
In Motion Unloading	Test	'2019-05-16 08:29:05'	'2019-05-16 08:29:57'	'0:00:52'
No more data after this point				

Name	Username	Start	Finish	Duration
In Motion Loading	Test	'2019-05-16 07:30:04'	'2019-05-16 07:30:57'	'0:00:53'
In Motion Unloading	Test	'2019-05-16 07:30:57'	'2019-05-16 07:31:38'	'0:00:41'
In Motion Loading	Test	'2019-05-16 07:31:38'	'2019-05-16 07:32:28'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 07:32:28'	'2019-05-16 07:33:11'	'0:00:43'
In Motion Loading	Test	'2019-05-16 07:33:11'	'2019-05-16 07:34:11'	'0:00:60'
In Motion Unloading	Test	'2019-05-16 07:34:11'	'2019-05-16 07:35:05'	'0:00:54'
In Motion Loading	Test	'2019-05-16 07:35:05'	'2019-05-16 07:35:55'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 07:35:55'	'2019-05-16 07:36:44'	'0:00:49'
In Motion Loading	Test	'2019-05-16 07:36:44'	'2019-05-16 07:37:25'	'0:00:41'
In Motion Unloading	Test	'2019-05-16 07:37:25'	'2019-05-16 07:38:19'	'0:00:54'
In Motion Loading	Test	'2019-05-16 07:38:19'	'2019-05-16 07:39:00'	'0:00:41'
In Motion Unloading	Test	'2019-05-16 07:39:00'	'2019-05-16 07:39:41'	'0:00:41'
In Motion Loading	Test	'2019-05-16 07:39:41'	'2019-05-16 07:40:31'	'0:00:50'
In Motion Unloading	Test	'2019-05-16 07:40:31'	'2019-05-16 07:41:13'	'0:00:42'
In Motion Loading	Test	'2019-05-16 07:41:13'	'2019-05-16 07:42:09'	'0:00:56'
In Motion Unloading	Test	'2019-05-16 07:42:09'	'2019-05-16 07:43:05'	'0:00:56'
In Motion Loading	Test	'2019-05-16 07:43:05'	'2019-05-16 07:43:59'	'0:00:54'
In Motion Unloading	Test	'2019-05-16 07:43:59'	'2019-05-16 07:44:42'	'0:00:43'
In Motion Loading	Test	'2019-05-16 07:44:42'	'2019-05-16 07:45:35'	'0:00:53'
In Motion Unloading	Test	'2019-05-16 07:45:35'	'2019-05-16 07:46:25'	'0:00:50'
In Motion Loading	Test	'2019-05-16 07:46:25'	'2019-05-16 07:47:24'	'0:00:59'
In Motion Unloading	Test	'2019-05-16 07:47:24'	'2019-05-16 07:48:17'	'0:00:53'
In Motion Loading	Test	'2019-05-16 07:48:17'	'2019-05-16 07:49:13'	'0:00:56'
In Motion Unloading	Test	'2019-05-16 07:49:13'	'2019-05-16 07:50:02'	'0:00:49'
In Motion Loading	Test	'2019-05-16 07:50:02'	'2019-05-16 07:50:51'	'0:00:49'
In Motion Unloading	Test	'2019-05-16 07:50:51'	'2019-05-16 07:51:48'	'0:00:57'
In Motion Loading	Test	'2019-05-16 07:51:48'	'2019-05-16 07:52:30'	'0:00:42'
In Motion Unloading	Test	'2019-05-16 07:52:30'	'2019-05-16 07:53:13'	'0:00:43'
In Motion Loading	Test	'2019-05-16 07:53:13'	'2019-05-16 07:53:56'	'0:00:43'
In Motion Unloading	Test	'2019-05-16 07:53:56'	'2019-05-16 07:54:44'	'0:00:48'
In Motion Loading	Test	'2019-05-16 08:29:57'	'2019-05-16 08:30:38'	'0:00:41'
In Motion Unloading	Test	'2019-05-16 08:30:38'	'2019-05-16 08:31:23'	'0:00:45'
In Motion Loading	Test	'2019-05-16 08:31:23'	'2019-05-16 08:32:09'	'0:00:46'
In Motion Unloading	Test	'2019-05-16 08:32:09'	'2019-05-16 08:33:01'	'0:00:52'
In Motion Loading	Test	'2019-05-16 08:33:01'	'2019-05-16 08:33:46'	'0:00:45'
In Motion Unloading	Test	'2019-05-16 08:33:46'	'2019-05-16 08:34:42'	'0:00:56'
In Motion Loading	Test	'2019-05-16 08:34:42'	'2019-05-16 08:35:42'	'0:00:60'
In Motion Unloading	Test	'2019-05-16 08:35:42'	'2019-05-16 08:36:37'	'0:00:55'
In Motion Loading	Test	'2019-05-16 08:36:37'	'2019-05-16 08:37:24'	'0:00:47'
In Motion Unloading	Test	'2019-05-16 08:37:24'	'2019-05-16 08:38:16'	'0:00:52'
In Motion Loading	Test	'2019-05-16 08:38:16'	'2019-05-16 08:38:58'	'0:00:42'
In Motion Unloading	Test	'2019-05-16 08:38:58'	'2019-05-16 08:39:56'	'0:00:58'
In Motion Loading	Test	'2019-05-16 08:39:56'	'2019-05-16 08:40:54'	'0:00:58'
In Motion Unloading	Test	'2019-05-16 08:40:54'	'2019-05-16 08:41:50'	'0:00:56'
In Motion Loading	Test	'2019-05-16 08:41:50'	'2019-05-16 08:42:35'	'0:00:45'
In Motion Unloading	Test	'2019-05-16 08:42:35'	'2019-05-16 08:43:27'	'0:00:52'
In Motion Loading	Test	'2019-05-16 08:43:27'	'2019-05-16 08:44:07'	'0:00:40'

In Motion Unloading	Test	'2019-05-16 08:44:07'	'2019-05-16 08:44:56'	'0:00:49'
In Motion Loading	Test	'2019-05-16 08:44:56'	'2019-05-16 08:45:42'	'0:00:46'
In Motion Unloading	Test	'2019-05-16 08:45:42'	'2019-05-16 08:46:25'	'0:00:43'
In Motion Loading	Test	'2019-05-16 08:46:25'	'2019-05-16 08:47:09'	'0:00:44'
In Motion Unloading	Test	'2019-05-16 08:47:09'	'2019-05-16 08:47:57'	'0:00:48'
In Motion Loading	Test	'2019-05-16 08:47:57'	'2019-05-16 08:48:39'	'0:00:42'
In Motion Unloading	Test	'2019-05-16 08:48:39'	'2019-05-16 08:49:31'	'0:00:52'
In Motion Loading	Test	'2019-05-16 08:49:31'	'2019-05-16 08:50:20'	'0:00:49'
In Motion Unloading	Test	'2019-05-16 08:50:20'	'2019-05-16 08:51:14'	'0:00:54'
In Motion Loading	Test	'2019-05-16 08:51:14'	'2019-05-16 08:52:08'	'0:00:54'
In Motion Unloading	Test	'2019-05-16 08:52:08'	'2019-05-16 08:53:01'	'0:00:53'
In Motion Loading	Test	'2019-05-16 08:53:01'	'2019-05-16 08:53:42'	'0:00:41'
In Motion Unloading	Test	'2019-05-16 08:53:42'	'2019-05-16 08:54:23'	'0:00:41'
No more data after this point				

C

Code used for boxplot and z-value calculations

```
%-------- Created by Arvid Edforss and Jesper Hansson -----%
%----------------------------------------------------------%
%-------- Master thesis in Supply Chain management ---------%
%-------- Spring 2019 -------------------------------------%
%----------------------------------------------------------%
%
% File for ploting a boxplot and calculating the
% statistical values from data collected with StarDriver
%

close all % Close all figures
clear all % Clear all variables
clc % Clear command window

xlsx = 'StarDriver.xlsx'; % Name of the excel file

timeperlift{1,1} = 'First half hour'; % Define headline
timeperlift{1,2} = 'Second half hour'; % Define headline

for t = 1:2 % looping over the two sheets
    [~,~,sheet] = xlsread(xlsx,t); % Reading the sheet
    n = size(sheet); % Calculate the size of the sheet
    k = 2; % Iterator
    q = 2; % Iterator
    w = 1; % Iterator
for i = 2:n(1) % looping over the amount of rows in sheet
    if sheet{i,1}(1:11) == 'In Motion U' % Time for cycle
        if sheet{i+1,1}(1:10) == 'Crane stop'
        elseif q<i
            time = 0;
        for ii = q:i
            seconds = str2double(sheet{ii,5}(7:8));
            minutes = str2double(sheet{ii,5}(4:5));
```

```
            time = minutes*60+seconds+time; % total time
        end
        timeperlift{k,t} = time;
        x(k-1,t) = time;
        q = i+1;
        k = k+1;
        end
    elseif sheet{i,1}(1:12) == 'Crane stop o' % Crane stop
            seconds = str2num(sheet{i,5}(7:8));
            minutes = str2num(sheet{i,5}(4:5));
            Stop(w,t) = minutes*60+seconds;
            w=w+1;
    end
end
if exist('Stop')>0 % Checks if there has been any stops
Cranestop(1,t) = sum(Stop(:,t)); % Summarzing crane stops
end
mx(t) = median(x(:,t));
end

for i = 1:length(x) % Divide the data with the median
   x(i,1) = x(i,1)/mx(1);
   x(i,2) = x(i,2)/mx(1);
end

figure(1) % Plot the boxplot
boxplot([x(:,1),x(:,2)],'labels',{timeperlift{1,1}, ...
    timeperlift{1,2}})
set(gca, 'ActivePositionProperty','position',...
    'FontWeight','bold','FontSize',30,'LineWidth',2)
set(findobj(gca,'type','line'),'linew',3)

for i = 1:2  % Calculate the extreme values
    y = x(:,i);
    Q3(i) = median(y(find(y>median(y))));
    IQR(i) = iqr(y);
    Extreme(i) = Q3(i)+3*IQR(i);
end

maxvalues = max(x); % Calculating max-values

x = x(:,2)-x(:,1); % Subtract the data with each other

meanx = mean(x); % Calculate the mean
stdx = std(x); % Calculate the standard deviation
n = length(x); % Number of measurments
```

```
z = meanx*sqrt(n)/stdx; % Calculate the z-value

p = normcdf((z*(-1)),0,1); % Calculate the p-value
```