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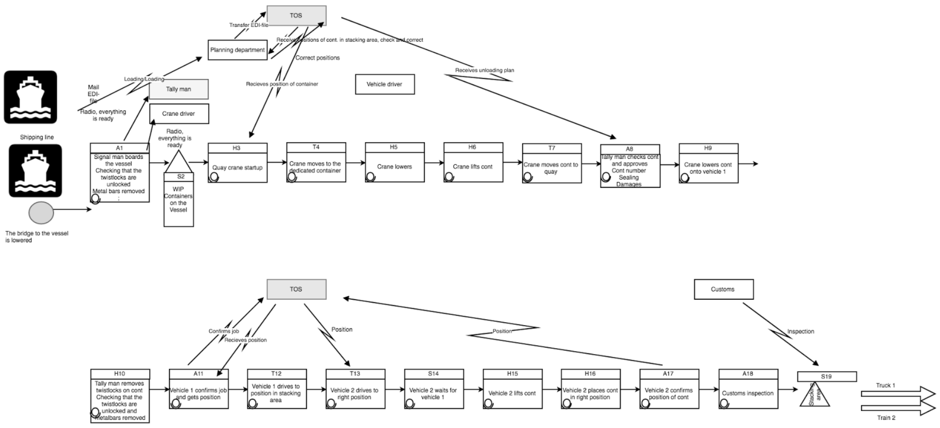

Value Stream Mapping of Container Flows at Seaports

- A case study of four seaport container terminals

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

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Cover:
[Current state map of the unloading process of a vessel in a container terminal, figure 22, pp 43]

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Abstract

Ports are important actors in many supply chains. Up to 90 % of all cargo are transported through sea transport today, and containers are used for transporting the cargo on the vessels (Lighthouse, 2017). Containers play a crucial role with its loading capacity and unification, facilitating the loading and unloading processes. The operations that concerns the containers in container terminals are quite similar for many ports, however other factors such as IT systems and choice of equipment differ and thereby affect the performance of the port.

This project was done in collaboration with SSPA Sweden AB and was conducted during the spring of 2017. The purpose of this study was to develop value stream mapping for seaport container terminals and identify eventual inefficiencies through the mapping. Four container terminals were studied and this combination of ports created faceted and deepened understanding of the operations taking place in the terminals. Several similarities and differences could be identified and are discussed.

Finally, some suggestions about improvement within the operations in the container terminals were brought up. In the short term, the terminals are generally recommended to assess their need of equipment with better capacity. As a long-term solution, implementing automated container handling and transportation technology is recommended to obtain more standardised work and to eliminate human errors. In addition, better collaboration between involved actors are crucial to obtain better levelled and coordinated flows.

Keywords: seaports, lean in ports, value stream mapping in container terminals, seaport activities, efficiency.

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Sofie Franzén & Linnéa Streling

Dictionary/Abbreviations

Berth = Quay at the seaside/vessel
Cont = Container
ICT = Information, Communication and Technology
KPI = Key Performance Indicator
RMGC = Rail Mounted Gantry Crane
RTGC = Rubber Tyred Gantry Crane
SC = Straddle Carrier
Shift containers = Moving containers in a stack in order to reach a lower container in the
Stevedore = Terminal worker
STS = Ship to Shore crane. The same as quay crane
QC = Quay Crane. The same as STS Crane
TOS = Terminal operating system
Tally man = Person that checks the containers when loading/unloading container to/from the vessel and manages the twistlocks on the containers
Twistlocks = Locking device for containers
Vessel = Ship
VSM = Value Stream Mapping

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1 Introduction

In the introduction, the background, the purpose, the research questions and the scope of the master thesis are presented.

1.1 Background

Due to the globalization of the shipping industry and trade, port operators experience an increased pressure to reduce container terminal costs and improve operational efficiency to cope with the development (Mangan et al., 2008). In addition, shippers generally seek single supplier contracts for carriers that could provide both efficient and cost effective services. As a result, carriers search for ways to reduce costs and increase efficiency gains at the ports they utilise. Multi-functioning ports, in terms of port terminal operations, are becoming more common and thus it is important for ports to become more efficient in their operations (ibid).

Cullinane and Song (2002) suggested that the country's ports performance determine to a large extent, a country's competitiveness In addition, they are of a critical link of a supply chain influence the performance of the supply chain. Charlier and Ridolfi (1994) explained that ports are where ships, short-sea/river ships, road and rail modes converge and where there must exist complementary waterborne and land modes in order to function, illustrating the need of coordinating the complex network in the port.

Furthermore, the port acts as a hub and handles a lot of cargo and transports to and from the port, which do not always arrive on schedule because of ripple effects throughout the supply chain (Mangan et al. 2008). Panayides (2006) mentioned the integration as the central tenet in maritime logistics, and how the modes and organisations along the global supply chain have to be interlinked in order to perform well. To achieve well-functioning maritime transports and logistics goals in terms of time and place utility at the least cost, the implications of the integration strategies have to be considered.

If examining ports from a logistics perspective, Ainsworth (1992) suggested that ports need to respond to pull logistics since the actions of the port both affects and are affected by the customers' inventory, service levels and the lead-time. Hence, the main focus on ports should be on creating value rather than costs.

In addition, it is difficult to identify more specifically where the inefficiencies might appear in the supply chains due to complex network consisting of many actors involved in operation of transporting the containers in the supply chain.

Furthermore, Woodburn (2007) stated how supply chains are becoming increasingly global and companies are seeking greater efficiencies, leading to an increased importance of well-functioning and reliable land-based transport linkages to and from ports. In order to improve the efficiency in ports, the concept of lean could be implemented. A tool that can be used when implementing lean and facilitate continuous improvement is value stream mapping. Value stream mapping is a lean management tool used for analysing and evaluating the processes from the beginning of the manufacturing of the products or services until it reach the end- customer or has been carried out (Serrano Lasa et al., 2009). This is done by conducting, analysing and evaluating the current state of the company in order to design an improved future state.

1.2 Purpose and Research questions

In order to increase efficiency in ports, value stream mapping is one way to obtain this. It is a tool used within lean with the purpose to improve the current operations in an existing industry. Therefore, the purpose of this master thesis is to develop value stream mapping for seaport container terminals and identify eventual inefficiencies through the mapping. The master thesis was carried out in collaboration with SSPA Sweden AB. Four different container terminals seaports was studied, APM terminals at the port of Gothenburg, Noatum terminal at the port of Valencia, Port of Helsingborg and Port of Norrköping.

Applying value stream mapping to the port environment may implicate some challenges to adjust it from the manufacturing industry to the seaport industry. To fulfil the purpose of this thesis, the first research questions for this project is:

- How can value stream mapping be used as a tool to study the involved operations in the flows of containers in seaports, in order to improve efficiency in container terminals?

  When conducting the value stream mapping the operations in the company need evaluated and maybe some inefficiencies are identified. Therefore this question was formulated to highlight any general issues of the studied seaport container terminals:
- Are there any general inefficiencies identified in the container terminals?

  Since the aim of the value stream mapping is to improve the current operations, it is important to strive to eliminate the identified inefficiencies, hence this question was formulated:
- What improvements can be suggested in order to eliminate those inefficiencies?

1.3 Scope

This thesis investigated how to use VSM to study the flows in container terminals in seaports. This thesis investigated full and regular containers. Hence, containers with dangerous cargo and refrigerated cargo were excluded since they correspond to a minor share of the total number of container handled in the studied ports. The reason of excluding the empty containers was that they were handled differently. In addition, only the processes that the terminals had control of were studied. Data from four different container terminals were collected, however, the amount of data collected from each terminal differed. In addition, only qualitative data was collected.

2 Methodology

This chapter describes the methodology used during this project in order to reach the purpose of the thesis. The chapter starts off by describing the research design of the master thesis. Afterwards the research process and how the analysis was conducted are presented.

2.1 Design of the Process

The master thesis can be divided into two different stages, namely a pre-study and a main study (see figure 1 and 2). The purpose of the pre-study was to gain some general knowledge about the shipping industry and to find out the most appropriate way of conducting the main study.

The pre-study started off with a planning phase, then interviews were conducted based on the planning. Based on the interviews, a preliminary structure of the project was made and then literature was studied. This was then repeated accordingly to the figure 1.

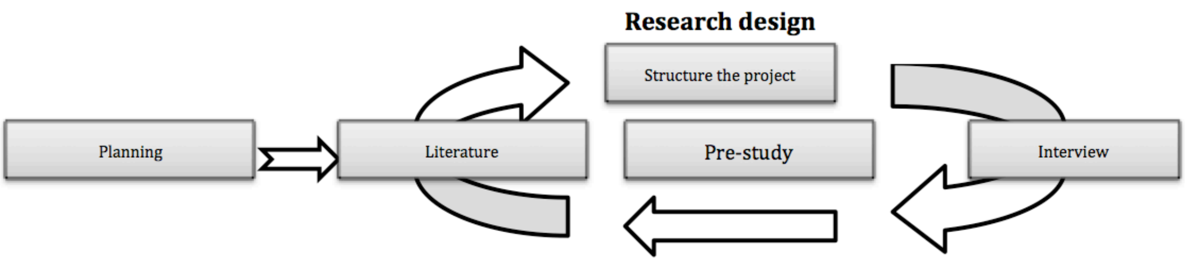


Figure 1. How the pre- study were conducted.

Figure 2 presents how the main study was conducted. The main study was designed based on the insight of the pre-study. The main study started off by an extensive literature study. After that, the findings of the literature study were summarized in a draft of the report and then the data collection was carried out. The findings from the literature study and the pre-study were used to design an interview guide, used for the data collection. After the data collection, a synthesis was made by the result of the data collection and the theory found in the literature report. This foundation was then used in the analysis and discussions. The research questions were then reviewed and then the whole process started over.

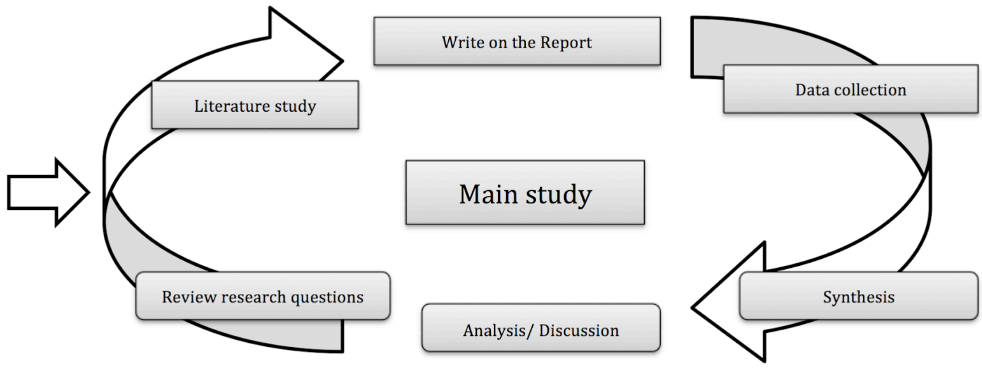


Figure 2.How the main study was conducted.

2.2 The Research Process

Figure 3 describes the research process used in this project, namely a modified versions of the onion model from Saunders et al. (2007). The main reason for choosing the onion process was that it was considered to be a structural model of different method choices made in this master thesis. The onion model consists of several different layers; the research philosophy, the research approach, the research strategy, the time horizon and data collection methods. The chosen approach in each of the layers is marked in bold. The choices will together provide the chosen framework for this project with the aim of answering the stated research questions.

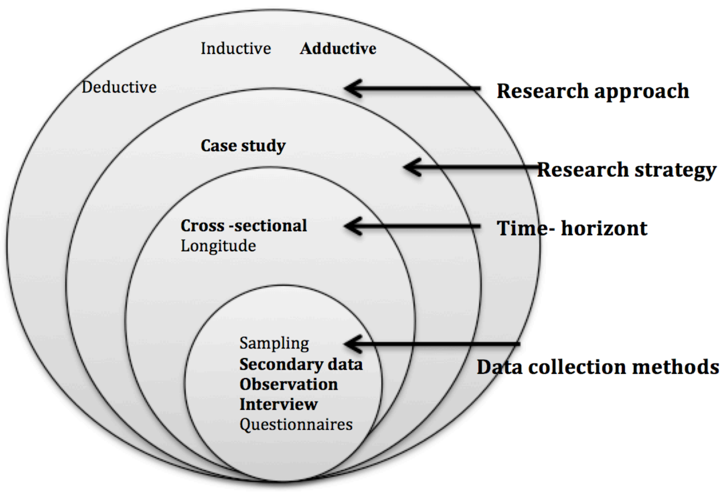


Figure 3. The onion model, modified from Saunders et al. (2007).

The onion model consists of five different layers and the decisions in the outer layers affect the decisions in the inner layers (Saunders et al., 2007. According to the modified model, first a decision of the research approach should be made, followed by a decision concerning the time horizon, continuing with a decision of what time horizon should be used and then finally a decision about the data collection methods.

The chosen research approach for this master thesis was abductive. In Saunders et al. (2007), abductive is not mentioned as a concept. However, reading the definition of abductive of Dubois & Gadde (2002), it seems to be an appropriate research approach for this master thesis. The approach should not be seen as simply a mixture of inductive and deductive approaches (assuming theory or a case study), since an abductive approach implies that the researchers discover new things such as other variables and other relationships.

The research strategy used in this master thesis consisted of case studies in four different container terminals since it was considered to be a sensible approach of understanding how different contextual factors affects the organisation of the operations. The terminals studied were APMT in the Port of Gothenburg, the Port of Helsingborg, Noatum container terminal in the Port of Valencia in Spain and the Port of Norrköping. The container terminals were chosen based on its geographical location, size and mediated contacts to the port. Good contacts with the ports made it easier to get invited and access the terminals. The spread of the characteristics of the terminals help to increase the validity of the results to find out if value stream mapping was applicable for more than one type of container terminal.

The time horizon for this master thesis was cross-sectional. This since the research questions was stated for today's situation in the terminals. Saunders et al. (2007) explained that the cross-sectional time horizon implies that the research is a "snapshot" at a particular time. The chosen research question explains the situation of today through mapping the operations taking place in the terminals.

The data collection methods used in this thesis consisted of a mix of primary and secondary sources. Primary sources consisted of observations, interviews and how different container terminals in ports did operate and how value stream mapping could be applied in different contexts.

2.3 Primary Data

The primary data consisted of data from interviews and observations. The main reason of why interviews and observations were chosen was to get an insight of how the terminals worked and to gain knowledge, both about the perceived and actual problems as well as motivations about why the terminals were operating in a certain way.

2.3.1 Interviews

The interviews consisted of face to face and telephone interviews depending on the respondent's availability and preference. The table 1 describes the people interviewed, their representing company, how they were interviewed and if they were part of the pre- or main study. In appendix 3 the interview guide is presented.

The respondents were chosen due to their working experience and were both identified by the authors themselves and found by recommendations from previous respondents. All of the interviews were carried out as semi-structured interviews and the main part of the interviews was carried out with only one respondent at a time. However, some interviews were carried out in pairs. Semi-structured interviews were chosen because they had the balance between the standardized questions, allowing the authors to compare the answers and also allowed the flexibility to change the order of the questions to gain a better flow (Bryman & Bell, 2015). Since the respondents had various positions and background, the semi-structured interviews facilitated a deeper understanding in their expertise area and their perspective on the processes in the terminals.

All of the interviews were recorded and notes were taken during the interviews to verify details. In addition, the interviews in the main study were also transcribed in order to analyse the data more careful. Most of the interviews lasted between 1- 1 ½ hour and was followed up by mail for confirmation and clarification.

To ensure that no respondents would take any harm from the interviews, names were excluded and the respondents were informed that the interviews were recorded. The respondents were also presented the opportunity to read the report to enable to see how the material was used. The results from the interviews were integrated in the findings and analysis, to support an argument or to demonstrate a certain approach. It could also be used to explain some operations or approaches where the interviewee had a good explanation of a certain concept.

Table 1. List of interviewed people and the topics discussed.

Professional title	Company	Interview type	Interview topics	Pre- or main study
Berth Planner	APMT in the Port of Gothenburg	Face to face	Berth activities	Main study
Operations Execution Manager	APMT in the Port of Gothenburg	Face to face, email	Rail activities	Main study
Business Development Manager and Commercial Manager Rail	APMT in the Port of Gothenburg	Face to face	The port in general	Main study
Customs Coordinator	APMT in the Port of Gothenburg	Phone	Customs for containers	Main study
Business Developer	APMT in the Port of Gothenburg	Face to face	The port in general	Pre-study
Senior Manager Market Intelligence	APMT in the Port of Gothenburg	Face to face	The container port	Pre-study
Researcher	RISE Viktoria	Face to face	ICT systems	Pre-study
Coordinator Innovation & Development	Sjöfartsverket	Face to face	Seaside operations	Pre-study
Director	Lighthouse	Face to face	The port in general	Pre-study
Group Manager	Tullverket	Phone, email	Customs for containers	Main study
Project Manager	Noatum Container Terminal in the Port of Valencia	Face to face	The terminal operations	Main study
Energy in Ports and Safety Director	Port Authority of Valencia	Face to face	The port in general	Main study
Production Manager	Port of Helsingborg	Face to face,	Operations in the	Main study

		email	terminal	
COO	Port of Helsingborg	Face to face, email	The terminal in general	Main study
Production Leader	Port of Helsingborg	Face to face, email	The daily work in the terminal	Main study
Production Manager	Port of Norrköping	Face to face, email	The terminal in general	Main study
Terminal Manager	Port of Norrköping	Face to face	Operations in the terminal	Main study
Operative Manager	Port of Norrköping	Face to face	The daily work in the terminal	Main study
Sales Manager	Port of Norrköping	Face to face	Commercial decisions	Main study

2.3.2 Observations

Several observations were conducted to collect data of the processes in the terminals in order to try to conduct a value stream mapping. The observations were conducted differently depending on the purpose and the resources that were available such as time available for the employees in the terminal. This resulted in different amount and different kinds of data were collected from each observation. Table 2 presents the observations that were conducted during the master thesis. The main benefit of conducting observations was to observe the flow in real life.

The weakness of the observations was that they were conducted in different ways and hence some observations were difficult to compare with each other since the same question could give subjective and incomparable answers from the different terminals. During the observations notes were taken on the observation and discussions made during the car tours. Attempts to carry out clock studies were executed to get an idea of durations of certain operations, however the results were difficult to analyse since the duration of several operation could not be measured. The results from the observations were used in the findings and analysis to describe how the seaport terminals operated and differed from each other concerning approaches and coordination.

Table 2. The different observations made during the master thesis.

Organisation	**Purpose**	**How the observation was conducted**
APM in the Port of Gothenburg	General tour around the terminal.	Car tour with an employee from APMT.
APM in the Port of Gothenburg	To observe the truck operations.	Car tour with an employee from APMT.
APM in the Port of Gothenburg	To study the processes when a container is unloaded/ loaded onto the train.	Crane visit with an employee from APMT.
Sjöfartsverket	To investigate how the processes was carried out when a vessel leaves the quay.	On-board a container vessel when leaving the quay.
Sjöfartsverket	To investigate how the processes was carried out when a vessel arrives to the quay.	On-board a container vessel when arriving the quay.
Noatum Container Terminal at the Port of Valencia	To observe the terminal.	Car tour with an employee from Noatum.
Port of Helsingborg	General tour around the terminal.	Car tour with an employee from Helsingborg.
Port of Helsingborg	To observe the terminal.	Car tour with an employee from Helsingborg. Observed the flows from one of the STS cranes.
Port of Norrköping	To observe the terminal.	Watching the unloading/loading process from the quay and from the reach stacker. Talked to different stevedores. Was also up in the STS crane when it was operating.

2.4 Secondary Data

The secondary data used in this thesis was

- Literature review
- Websites of the different operators of the container terminals
- YouTube videos of container terminals in seaports
-

2.4.1 Literature Review

The literature study was conducted in Chalmers library database, by mainly searching for keywords within the dedicated area, such as ports, lean in ports, value stream mapping in container terminal, port activities and efficiency. The literature review has also been conducted through recommendations of specific articles or subjects provided by the supervisors. The purpose with the literature study was to provide a broad and comprehensive literature review to facilitate understanding and further reading.

2.4.2 Webpages and YouTube Videos

All of the studied container terminals have webpages, which were studied prior to the visits to gain a better understanding of the terminal's services and to identify contextual factors. Other container terminals' webpages were also briefly studied to get a general idea of how terminals operate.

To quickly gain an overview of the operations of the container terminals, various YouTube videos of container terminals and its operations were watched in the pre-study. The YouTube videos were also used to develop the interview guide.

2.5 Data Collection and Analysis

The data collection and analysis consist of five different parts, namely description of the studied container terminals, mapping, evaluation of the current state and transition to the future state map, the future state map and finally challenges with executing a value stream mapping on a seaport industry. The three steps of the value stream mapping are illustrated in figure 4.

The container terminals are firstly described out of general characteristics such as geographical location and size. Then the current state maps are presented. The current state maps was mainly based on observations and interviews from the terminals but were also based on literature over the operations. In addition, explanation and comments of the current state map are also presented in this part.

The third part consists of assessment and transition of the current state to the future state map. The assessment of the current state was mainly based on literature, interviews and observation combined. The transition of the current state to the future state map was based on seven questions evaluated by Medbo (2016), focusing on evaluating the current state in order to create new improved maps, the future state maps. The fourth part consists of a future state map and was based on the improvement areas identified through the analysis of the current state map. The final part describes challenges discovered when executing the value stream mapping in the terminals.

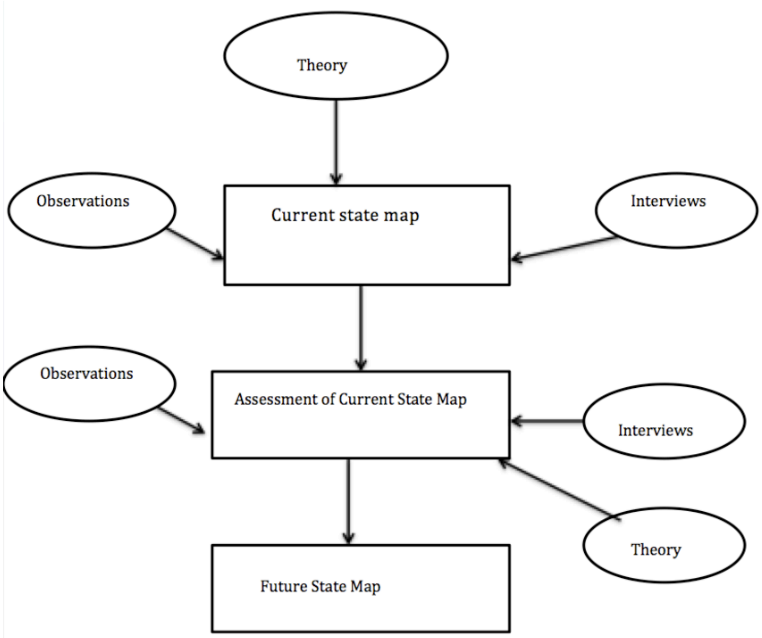


Figure 4. The three steps of value stream mapping and how they are supported in this thesis.

2. 6 Reliability and validity

In order to assess the quality of research the concepts reliability and validity are commonly used. The concept of trustworthiness is also evaluated for assessing the quality of qualitative research (Bryman and Bell, 2011). This has been demonstrated through the data collection generated from different terminals and persons. Bryman and Bell (2011) suggested a combination of methods in research, namely triangulation, in order to get a reliable and valid understanding of the research, especially in complex settings. Therefore secondary data from articles, books and case studies have been used in order to validate and triangulate the primary data collected from the interviews.

Many aspects mentioned in the interviews were confirmed by secondary data from other references. The combination of interview data and documentation from the observations gave a balanced and comprehensive view and the combination of mappings and other documentation complemented and validated the interviews. The evaluation of reliability and validity will be brought up in the discussion.

3 Frame of Reference

The frame of reference consists of three parts, namely Seaports (3.1), Lean (3.2) and Value Stream Mapping (3.3). In the first chapter, Seaports (3.1), the contextual factors of the industry are presented to facilitate an understanding of the challenges and opportunities a port faces to be able to understand how lean and value stream mapping may be used in a port environment. In the next chapter, Lean (3.2), the concept of lean is introduced to provide a base for understanding the tool Value stream mapping. The frame of reference ends with the chapter Value Stream Mapping (3.3), describing the tool value stream mapping in detail. The findings were then used as a foundation for the thesis.

3.1 Seaports

Seaports are important actors in many supply chains. Ninety percent of all cargo is today transported through sea transport (Lighthouse, 2017). McLinden (2011) enhanced the importance of the role of ports in the competitive strategy of efficient logistics. The transport sector's overall challenge is to meet the significant increase in demand for transport while developing a sustainable transport system. This is a prerequisite to continue creating social benefits in the long term (Lighthouse, 2017). Woodburn (2007) suggested that the increased internationalization of the supply chains increases the need for global interlinked transports. Therefore, Woodburn (2007) stated how supply chains are becoming increasingly global and companies are seeking greater efficiencies, leading to an increased importance of well-functioning and reliable land-based transport linkages to and from ports.

3.1.1 Containers

The main unit in a container port is a container, a load unit that is often referred to as a TEU, Twenty-foot Equivalent Unit (Meisel, 2009). It is of a certain size according to an international standardization of container measures achieved in 1964, with the purpose to standardise the container size to facilitate handling (ibid.). However, the prevailing containers in maritime transport have a length of 40 feet, twice the size as one TEU, defined as two TEUs or referred to as a FEU (Forty- foot equivalent unit) (ibid.). There are many benefits of handling containers instead of conventional bulk including less product packaging, less damaging and higher productivity (Agerschou et al., 1983).

3.1.2 Container Terminal

Container terminal is a type of transhipment terminal where containers are loaded and unloaded onto container vessels, using specialised port equipment that can manage the heavy weights (Bichou, 2009). The terminal also serves as a node link between sea and land, which clearly demonstrates intermodality (Tarantola, 2005). Steenken et al. (2004) stated that terminals consist of two components; namely stocks and transport vehicles, which defines the basic logistic characteristics. The terminal is a system consisting of berths, quays, loading and unloading areas for cargo, allowing the transfer of cargo from one means of transport to another (Roa et al., 2013).

3.1.3 Processes in a Container Terminals

There exist a lot of views of how the different flows, operations and processes should be named and divided. The subprocesses are usually divided depending on the location where the processes take place. There exist some different definitions of the different areas of a container terminal. Some of the different definitions used are summarised and can be found in table 3.

Table 3. A summary of different definitions of the different areas of a container terminal.

Articles	Number of internal Interfaces.	Definitions and examples of operations in the different areas of terminals.		
Henesey (2006)	2	**Berthside** Unloading/loading of vessels	**Storage** Placing/picking of stacking area	**Landside** Unloading/loading of trucks/trains.
Vis & De Koster (2003)	Not specified	Not specified	Not specified	Not specified
Olesen et al. (2015)	2	**Dockside** Unloading/loading of vessels	**Terminal** Placing/picking of stacking area	**Gateside** Unloading/loading of trucks/trains.
Steenken et al. (2004)	2	**Quayside terminal area** Unloading/loading of vessels	**Container terminal area** Placing/picking of stacking area	**Landside terminal area** Unloading/loading of trucks/trains.

Henesey (2006) suggested that the process in a container terminal consists of four subsystems, as illustrated by figure 5. These are ship to shore, transfer, and storage and finally deliver and receipt.

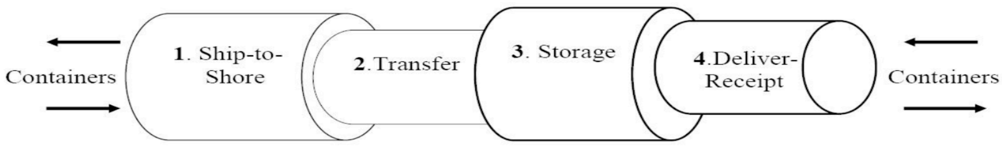


Figure 5. System of a container terminal and the four subsystems (Henesey, 2006).

1. Ship to shore

The first subflow is the Ship to Shore process, when the ship enters the port until it is moored.

2. Transfer

The second subsystem is the transfer flow, which includes the unloading/loading of the container from the vessel to the berth, unloading/loading to a transport vehicle and the transport from the berth to the storage area.

3. Storage

The third subsystem is the flow is the storage flow, including the unloading/loading of a transport vehicle to the storage area, unloading/loading to straddle carrier, the transport to the assigned storage place and dropping/picking of the container.

4. Deliver/ Receipt

The fourth subsystem is the flow is the delivery/receipt, including picking up/dropping of a container, transport of the container to and from the landside. The container is then loaded/unloaded onto a truck or a train for further transportation.

Vis & De Koster (2003) suggested on the other hand that two main processes can be identified in a container terminal, namely the loading and unloading of containers. The two main processes can further be divided into subprocesses as figure 6 illustrates. However, Vis & De Koster (2003) do not precise any further which subprocesses exist and do not divide the terminal into specific areas such as the other authors, see table 3.

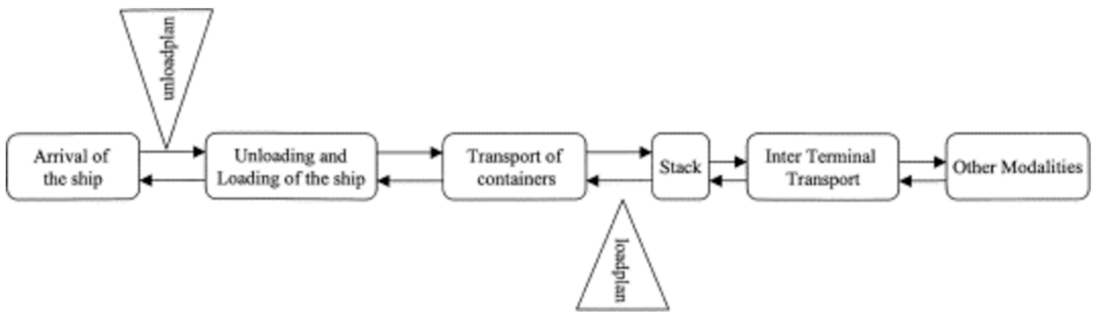


Figure 6. The view of the processes in a container terminal by Vis & De Koster (2003).

Olesen et al. (2015) presented a similar model compared to Henesey (2006), see figure 7. In this model the operations are divided into three different subflows depending on where in the container terminal they take place. The three flows are located at: dockside, terminal and gateside. The dockside is at the quay, and is separated from the terminal due to that the activities are related to the vessel. The terminal is, according to Olesen et al. (2015), the central part of the container terminal where the containers are moved within the yard area. Finally, at the gate side, the trucks interfere with the terminals.

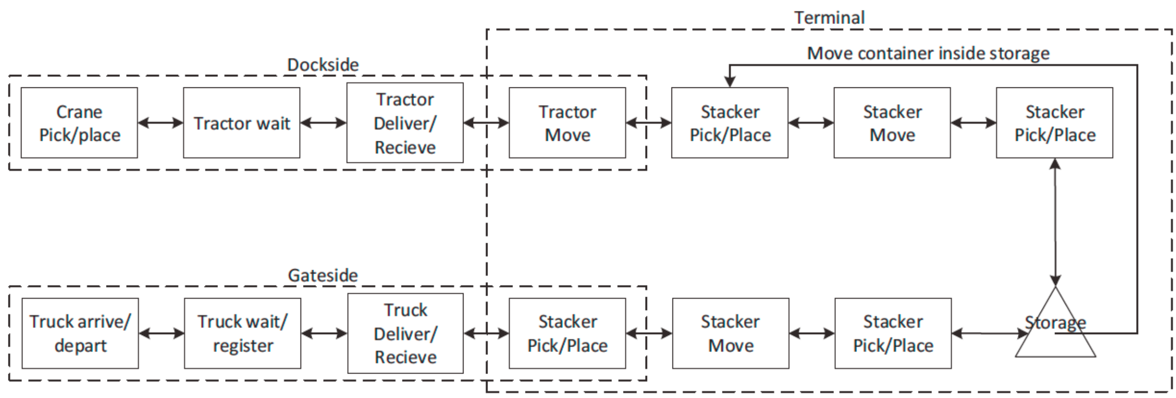


Figure 7. Overview of the different operations at a container terminal by Olesen et al. (2015).

Steenken et al. (2004) on the other hand view the operations of a container terminal as a system, see figure 8, consisting of three different areas, namely the quayside, the yardside and the landside.

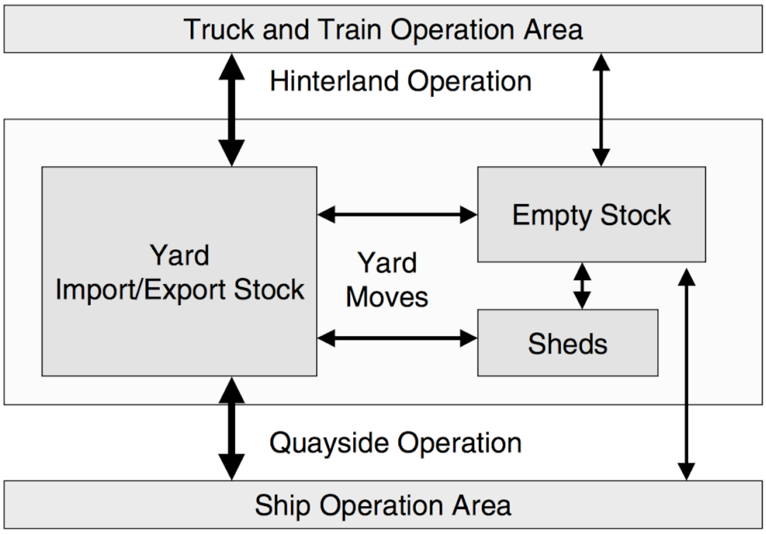


Figure 8. Overview of the different operations at a container terminal, Steenken et al. (2004).

Based on the theory mentioned above, in this thesis, the process of unloading a vessel is referred to the main process, consisting of three subprocesses (landside process, yardside process and quay process) that in turn consists of several operations, see figure 9. Examples of operations taking place in the different subprocesses are provided. The main reason of choosing this division is that since the subprocesses are taking part in two directions at the same time, the division will enhance the understanding of the different operations. Flows are referred to the information flow or material flow. The flow of information illustrates the information exchanges between actors, both internal and external. The material flow is referred to as the movement of the container.

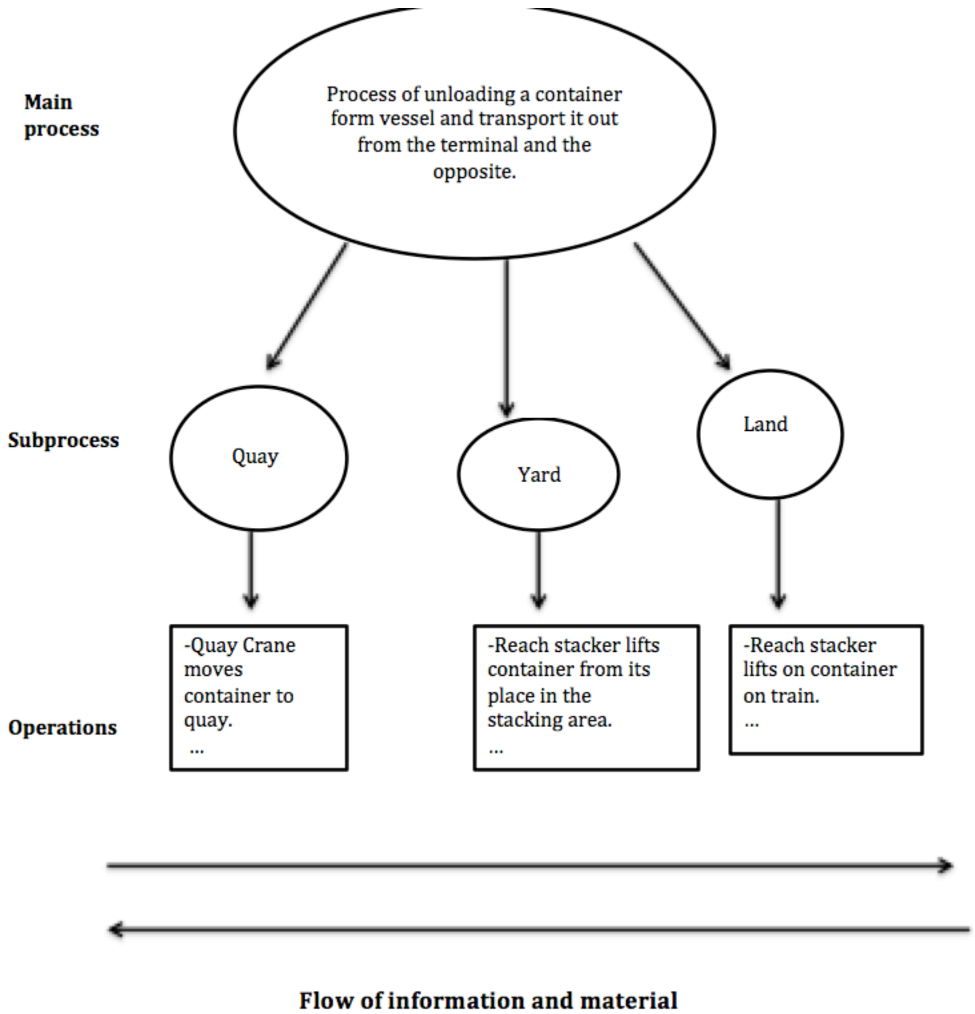


Figure 9. The authors' view of the relationships of main process, subprocesses, operations and flows in this thesis.

3.1.4 Description of Operations and Equipment Used in a Container Terminal

There exist different equipment that, can be used in a container terminal depending on a different factors including annual volume, size of vessels at quay, how large the terminal is and how much the terminals can invest. Due to the size and weight of containers, highly specialised equipment are required to cope with the cargo services to shipping lines (Bichou et al., 2007). The most commonly used are illustrated in the figure 10 and a more detailed explanation will follow, starting with the equipment used at the quay. Figures of equipment are presented in appendix 4.

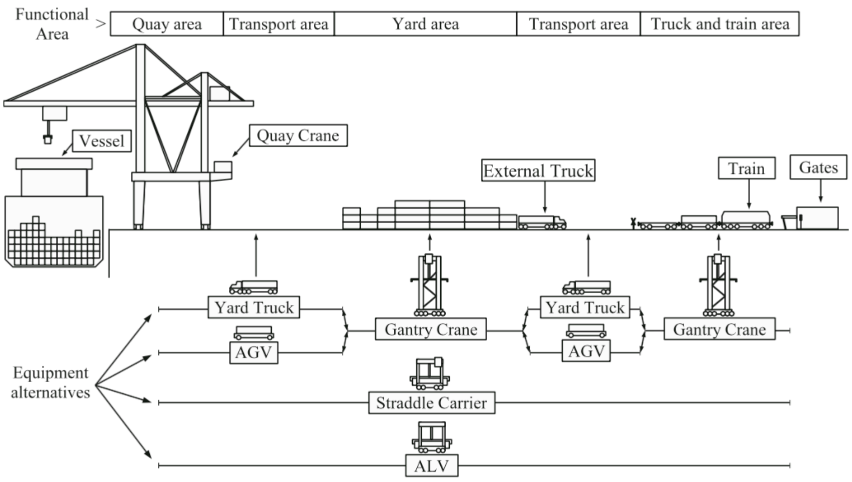


Figure 10. Schematic cross-sectional view of a container terminal (Meisel, 2009).

Starting off when the vessel has berthed at the quay, quay cranes are used to facilitate loading and unloading the containers. Quay cranes (QCs) are large cranes used for loading and unloading operations of containers (Meisel, 2009). The vessel may be served by several QCs simultaneously depending on the size of the vessel. To unload a container, the QC's spreader is placed on it and fixed by twistlocks in the corners of the container. The container is then lifted by a hoist.

The crane's trolley is then moved to the quay where the spreader is lowered and the container is put, either directly on the ground or onto a transport vehicle (ibid.). The container is released by unlocking the twistlocks, and the spreader is hoisted again. To load the vessel with a container, the same crane operations are performed but in the opposite direction (ibid.).

In the transport area, the container is then moved from the berth to the yard area. Usually yard trucks or straddle carriers are used, with different characteristics (Meisel, 2009). Yard trucks are manned chassis vehicles, unable to lift containers and thereby depending on careful synchronization with cranes for loading/unloading operations (ibid.). A more integrated alternative is straddle carriers, with the capacity to both move and lift containers. This facilitates the QC operations; where the QC doesn't have to wait for a vehicle to put the container on but can simply drop the unloaded container straight on the ground in case of a free ground position (ibid.). The straddle carrier provides more flexibility, however there is a higher purchase, maintenance, and operational costs than yard trucks (ibid.).

There exist automated vehicles that can replace yard trucks and straddle carriers. AGVs (Automated Guided Vehicles) and ALVs (Automated Lifting Vehicles) are pre-programmed and guided by induction coils installed in the pavement. The flexibility of these vehicles is relatively low due to their pre-destined routes and there is a risk of a total system breakdown if one of those vehicles breaks (ibid.). Grunow et al. (2004) enhanced the development of those automated vehicles, due to that their potential offering increased availability and lower operating costs, thereby lowering elimination of human failure. In many larger ports, automated vehicles are used in the daily work, however Ioannou et al. (2000) suggested that more terminals should use automated vehicles in order to improve the efficiency of the terminal. It is especially attractive for terminals with a high labour cost level since the investment in automation needs to pay off (Nam & Ha, 2001). Günther & Kim (2006) confirmed that ports may become more efficient by implementing automated container handling and transportation technology.

Hence, the operations in a container terminal can either be performed manually or automated. There are several terminals around the world that have implemented automatic equipment or vehicles to perform different operations in the container handling process. Gunther and Kap Hwan (2005) described how the ECT terminal of Rotterdam use AGVs as their prime movers to transport the containers. The vehicles used in the yard are automated stacking cranes that only need programming and supervising.

Continuing with the yard area, the containers are then passed through, either for immediate further transportation or storage (Meisel, 2009). Storage for empty containers might also exist in this area. The yard area can be divided into certain sections depending on the containers and its purpose/destination or if it is import/export.

Gantry cranes are examples of vehicles that could be used for movement, stacking and retrieval of containers to the right position (ibid.). The gantry cranes can be furthered divided into two subgroups, namely RMGCs (Rail Mounted Gantry Cranes) and RTGCs (Rubber Tired Gantry Cranes). The RMGCs are driven on rails and have often a higher capacity than RTGCs, which have rubber wheels. In addition, RMGCs provides a higher flexibility since it is easier to operate them in sideways compared to RTGCs (ibid.). One benefit of using gantry cranes compared to straddle carriers are that they require smaller space to operate compared to straddle carriers since they can often pass over a high stack of containers.

Furthermore, container terminals at seaports serve as transhipment facilities with interfaces to trains and trucks. To be able to keep track of which trucks enters and leaves the terminal, the terminals usually have gatehouses where the trucks need to pass. At the gatehouses the terminal check the transport documents and identification of the drivers (Meisel, 2009).

Depending on which equipment used to load and unload a container from a truck, the placement of the assigned area of loading/unloading of a truck differs. Concerning trains, the railways are often leading straight into the terminal to shorten the distance to loading/unloading (ibid.). Yet again, different equipment may be used to load / unload the container of the train. For instance, both reach stacker, straddle carrier and gantry crane may be used.

The different equipment can be combined quite independently, Meisel (2009) stated that no overall best equipment selection exist due to different characteristics and contextual factors of the container terminal. As mentioned, there are exist many criteria to consider when selecting what equipment should be used. Different factors affecting the equipment used include transhipment capability, investments, operational costs, internal- and local condition. Examples of internal and local conditions may be available space in the terminal or labour (Meisel, 2009). Other factors, that needs to be considered, according to Kozan (2000), includes container throughput, physical operating space, operating space among others and how different types of equipment be used together.

3.1.5 Organisation

The shipping industry consists of a large and relatively complex network of involved partners with specific roles and responsibilities. To facilitate the understanding of the shipping container industry, Martin & Thomas (2001) have presented a framework of the key players in the container transport chain and their inter-organisational relationship. The key players are the shipping lines, inland transport operators, the terminal operators and the freight forwarders. Figure 11 illustrates the relationship between the key players.

The relationship between the shipping line and the inland transport operators has grown stronger in recent years and with the development in intermodal transport, the shipping lines have extended their area of control to control cargo and rail operators in order to better coordinate them with the arrival of the vessels.

In addition, the evolving development in network-based management (managing the connection between several involved actors), has contributed to closer relationships between terminal operators and shipping lines. Lun et al. (2010) described how shipping lines have high bargaining power since terminal services can be purchased from many terminals, generating a bias market with a high level of dependence on the shipping lines. This situation is similar in all types of terminals.

Furthermore, from the shipping line's perspective it desirable to use independent freight forwarders even though many shipping lines themselves recommend shipping services to their shippers. They need the independent freight forwarder to continue growing and gain competitiveness advantage by being able to offer customized services. In addition, Lun et al. (2010) described how shipping lines need to treat freight forwarders as their customers to obtain synergies.

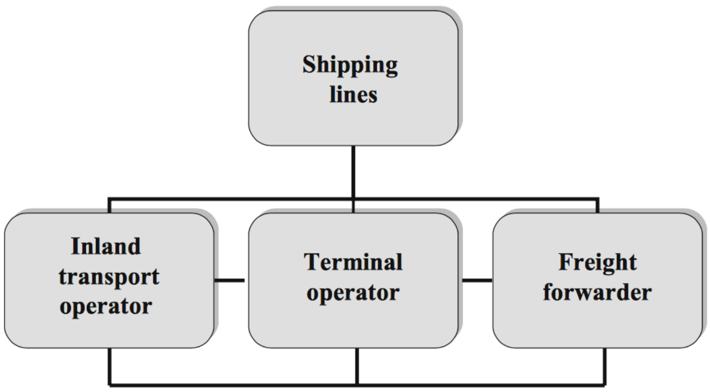


Figure 11. Key players in the container transport chain (Martin & Thomas, 2001).

3.1.6 Logistics Issues for Ports

According to Kim & Günther (2007) a container terminal is a complex system since it is highly dynamic with many different interaction points between various handling, storage units and transportation. In addition there is often incomplete knowledge about future events. Hence, there are many decisions that are difficult to make due to planning and logistic issues.

Notteboom & Rodrigue (2008, p. 171-172) compiled some main interrelated port issues since freight transportations are a volatile and costly part of the supply chains: "Managers in the logistics industry, including the port and maritime industry, are spending more and more of their time handling freight transport missteps and crises. As such, reliability and capacity issues have emerged as critical factors next to pure cost considerations." Hence, there is a need for port operators to start searching for more standardized ways of working, in order to decrease the fluctuations in workload and planning.

In addition, there also exist pressure exercised by conflicting interests in ports, shaped by many stakeholders such as port operators, carriers, ship operators and customers. Hence, it is almost impossible to create an operation plan that considers all objectives of the various stakeholders or no one has yet succeeded (Lun et al., 2010).

Another logistic problem related to stakeholder management is trying to remove the peak periods in the container handling and try to level the handling volumes. Lun et al. (2010) stated how container terminal operators might encounter problems in managing equipment and facilities during peak periods, especially for mega ships that require a lot of capacity in terms of resources. There is a limited selection of sufficient ports that can handle the size of mega vessels. Hence, the ports are preselected to secure sufficient resource allocation.

In addition, there also exist issues to coordinate the different stakeholders, since the time aspect differs for different actors, especially the turnaround time. For shipping lines, this time is valued highly and considered expensive. Hence, either the speed of the ship or the time allocated in the port should be optimised. According to Peters (2001), the speed of container handling is a crucial issue in terms of competitiveness for port authorities and terminal operators, and should therefore be treated according to its importance.

Furthermore, Johnson and Styhre (2015) described relationship between shorter time in ports and reduced vessel speed at sea. They conducted a case study, studying short sea bulk shipping company transporting dry bulk cargo mainly in the North and Baltic seas. When compiling the data over one year for two ships in the company's fleet, they found that "ships spent more than 40% of their time in ports and that half of the time in port was not productive" (Johnson & Styhre, 2015, p. 176). This reveals the unnecessary time the vessel occupies space in the port, which could rather be utilized for next incoming vessels.

There are also some logistic issues arising from internal factors such as the need for the terminals to solve how to utilize, their often-limiting area at their disposal. Space is required to be able to handle containers and it important to design the port to make the operations as efficient as possible. Both Felicio et al. (2015) and Notteboom & Rodrigue (2008) agreed that the port layout is the initial crucial issue for ports in terms of performance. Limited and a poorly designed port may lead to other potential following problems such as allocation and storage problems of containers and waiting time.

In addition, Felicio et al. (2015) discussed how customer focus is a relatively new but nonetheless critical issue for container terminal performance, because there is a need for terminals to be flexible and adapt to the customer needs as well as external market changes. The importance of a well-organized terminal layout cannot be underestimated, as it affects the performance and service quality, this is particularly prominent for large vessel requiring ample space. With land area issues comes congestion problems, a more and more relevant issue for ports as the demand is increasing (Vacca et al., 2013). Kia et al. (2000) state further which consequences an inadequate container stacking area might result in; either the extra containers must be moved for direct further distribution, or the terminal simply must be expanded.

Furthermore, Notteboom (2006) explained the need of adapting the daily operations in ports to the meet the evolving demand from the customers. He stated how customers are demanding fast and reliable delivery; often implying agile and responsive port operations. However, shipping companies are constantly searching to cut costs, causing a conflict of interest.

In addition, since the terminals usually have contracts with the shipping lines there are incentives for the terminal to plan their operation according to the shipping lines request in order to be part of the shipping route. According to Peters (2001), there are many factors the shipping line takes in consideration when selecting to ports to call at. Some of the most important once include the time of loading/ unloading and consequent vessel turnaround time. Hence, there are high expectations on the productivity of a port and it is common that the existing contracts between independent terminal operator and shipping lines stipulates the required minimum quayside productivity. For example, Notteboom (2006) suggested it is fairly common for the shipping lines to request a work rate of loading/unloading 120 TEUs per ship per hour. The request form the shipping line puts extra pressure on the coordination of the activities in the terminals.

3.1.7 Planning and logistics control issues of container terminals

In a container terminal many activities, processes and operators needs be coordinated and there are many decisions that need to be addressed at all time. Hence, good planning is necessary (Meisel, 2009). Since the container process consists of three subprocesses (the seaside, the yardside and landside), the different flows needs to be coordinated and planned to obtain and maintain an efficient and continuous flow of container (ibid.).

Meisel (2009) provided a framework over the most important planning problems and presented a model, see figure 12. The decisions needed are divided into the area of the terminal and the nature of the decision, if it is the seaside, yardside, landside and also in strategic and tactical and operational decision. As figure 12 illustrates, there are many different activities, which need to be coordinated, and where the planning of each activity is dependent upon each other.

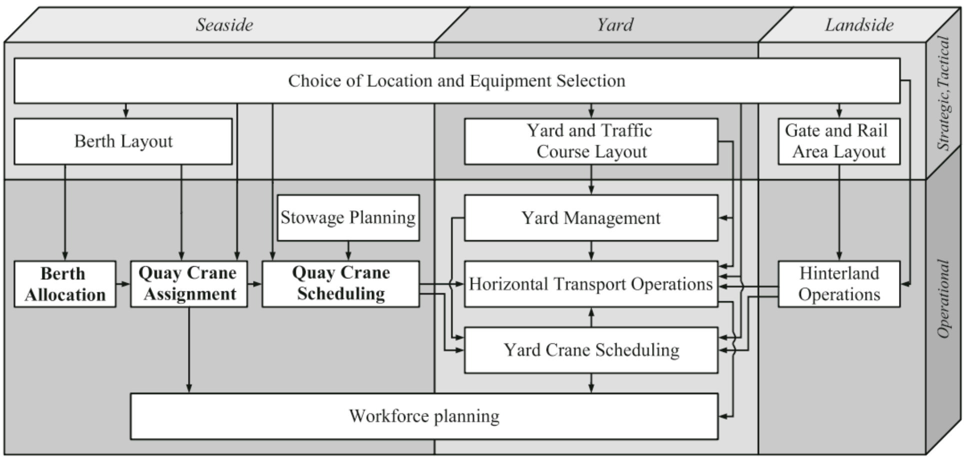


Figure 12. Planning problems in a container terminal (Meisel, 2009).

A similar model was presented by Kim & Günther (2007) (see figure 13). They chose however, to divide the planning and logistic control issues by dividing the issues into three different categories; terminal design, operative planning and real time control. Only terminal design will be presented into detail since their suggestions on an operative planning are for automated terminals.

Starting with terminal design, Kim & Günther (2007) stressed that there are many aspects and issues need to be considered and solved when planning the design of the terminal. The design of the terminals needs to be evaluated from a financial, technical feasibility and performance perspective. The main issues related to the terminal design are according to Kim & Günther (2007) multi-modal interfaces, the layout of the terminal, the berthing capacity and IT-systems and control systems.

In this rapport only multi-modal interfaces and IT-systems are discussed further. Most of the European container terminals have multi-modal interfaces, i.e. they are directly linked to railway, truck, inland navigation systems and vessels where the arrivals and delays affect the internal operations of the terminals (ibid.).

Continuing with IT-systems. The control of the logics in container terminals is complex since it "requires real-time decisions on matching handling tasks with the corresponding equipment units and the provision of detailed information about each individual container"(Kim & Günther, 2007, pp.8). Hence, there is a need of using optimization tools and different modes of software and IT support to control a container terminal.

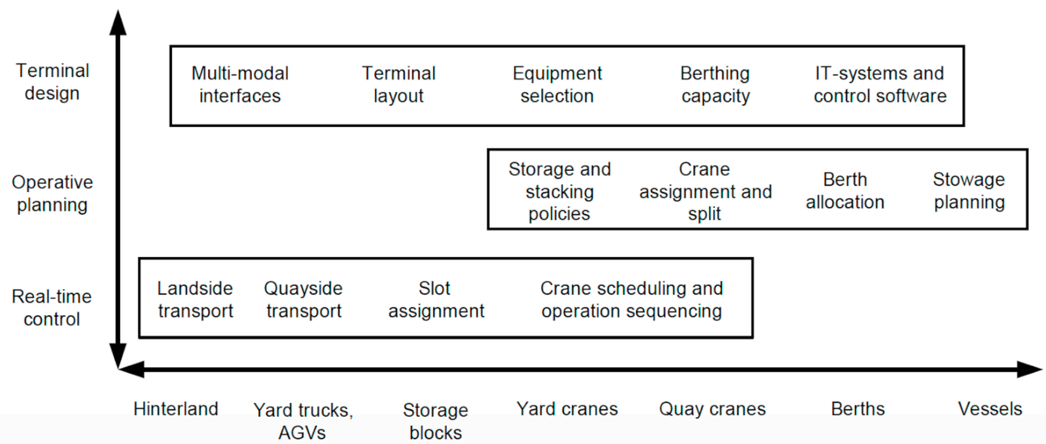


Figure 13. Control and planning issues (Kim & Gunther, 2007).

3.1.8 Delays

Notteboom (2006) suggested that the container flow is structured as hubs and spokes. The structure of hub and spokes enables economies of scale, however the system becomes more sensitive of delays in the supply chain. Since the vessels might both load and unload new containers in ports, a delayed vessel affects several other actors to make adjustment in their operations (ibid).

For the shipping company delays will, in addition to incur costs, also affect their reliability and might damage their brand. Costs that might incur when vessels are delayed include operating costs, rescheduling of vessels and costs related to unproductive vessel time (ibid.). In addition, delays can also incur cost for the customer in forms of additional inventory costs and additional production costs due to production stops of late arriving materials (ibid.).

In addition, there are many causes to delays and time losses in a vessel operation and the causes can be divided into four different groups; terminal operations, port access, maritime passages and chance (ibid). In this thesis the focus was on the first category of delays, namely delayed caused by operations in the terminal.

Notteboom (2006) suggested on page 28, "The first kind of delay could be derived to the consequence of increasing volumes in combination with capacity constraints in many ports around the world, the availability of a berth is not always guaranteed when the allocated time slots in the ports have been missed". In some cases liner service schedules can be interrupted due to port congestions. Thus, many shipping lines try to secure capacity in key ports in their service schedules to avoid congestion (ibid).

3.1.9 Port Performance

According to Chow et al. (1994), there exist many different interpretations of the term performance in the management fields, however it is commonly thought of a jargon of the industry used to evaluate an organization's success towards some level of its strategic goals. Furthermore, Feng et al. (2012 suggested, examples of key performance measurements widely used in a port environment are throughput of cargo volumes and TEUs of containers. However, as they pointed out, since the ports offer different services, it is difficult to evaluate port performance by only comparing a single measurement. Instead Feng et al. (2012) suggested, when evaluating port performance, one should compare several factors influencing port performance. Feng et al. (2012) carried out an extensive literature search and showed that there exist many different views on factors to evaluate port performance. Feng et al. (2012) selected 15 factors based on interviews. These 15 factors are summarised in table 4.

Table 4. 15 factors to evaluate port performance.

Factors to evaluate port performance (Feng et al., 2012)
1. Availability of shipping services (destinations, frequencies, price of shipping services etc)
2. Port/terminal handling
3. Warehousing charges
4. Feeder connections to the deep-seaports and major shipping lines
5. Port/shipping service is on the cheapest overall route to the destination
6. Speed of port cargo handling
7. Congestion
8. Risks
9. Port/terminal security and safety
10. Technical infrastructure of the port (handling equipment, information communication, etc.)
11. Proximity of the port to your customers and/or sources of supply, availability of skilled employees,
12. Quality of landside transport links (intermodal links)
13. Availability and quality of logistics services (warehousing, freight forwarding, cargo handling)
14. Government supports for logistics activities

15. New developments in the region and depth of navigation channel

In addition, Notteboom & Rodrigue (2008) suggest, even though the rate of container market is still growing, it is reaching the maturity phase. As a consequence, the modern terminal equipment is becoming widespread and more standardised, implying that the access increases. Notteboom & Rodrigue (2008) concluded that solely relying on the equipment to achieve a competitive advantage is not enough anymore; rather it is about having the right terminal management skills.

In addition, due to the increasing size of the vessel and the increasing trend, Parola & Sciomachen (2009) suggested how a terminal operator need to develop a fast-working maritime container handling system to cope with the current evolving trends in liner shipping in order to satisfy the customer. The larger vessels imply more containers and dramatic 'call sizes' in port, putting pressure on the terminals operators to not only offer capacity in storing but also have the right terminal management skills. The performance is here not only measured in terms of berth performance, but also the flows concerning hinterland transportation need to be well-functioning (ibid.).

As mentioned, terminal throughput may be an indicator of how well the port performs, however as Lun et al. (2010) presented in the figure 14, the operating cost increases as terminal throughout increases. Therefore, the port needs to find the optimal trade-off in order to gain the most benefits. The result was based on a regression analysis illustrated in figure 14.

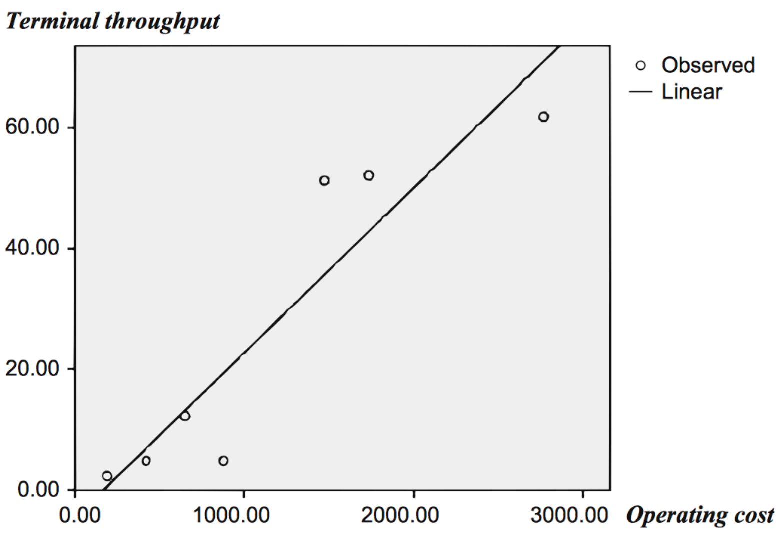


Figure 14. Relationship between operation cost and terminal throughput (Lun et al., 2010).

3.1.10 Information Communication Technology /Communication

Information, Communication and Technology (ICT) is a collective name for unified information technology (Pham, 2014). ICT plays a key role of being able to successfully integrate the supply chain (Cepolina & Ghiara, 2013). In addition, Cepolina & Ghiara (2013) suggested, ICT will play an important part in supporting the development of ports. Furthermore, Cepolina & Ghiara (2013), in agreement with Kakabadse, Kakabadse & Kouzmin (2005), suggested companies might gain competitive advantages by utilizing ICT.

ICT can also help ports to coordinate all the different actors involved in transporting a container by facilitating data availability and quality of the information flow across throughout the supply chain according to Kia et al. (2000). Even though, the port industry, has since the mid-1980s progressively adopted ICT based items (intranet, extranet, Radio Frequent Identification, communication platforms etc) it is not as developed compared to other industries such as the air industry (Cepolina & Ghiara, 2013).

Furthermore, in the project MoS24, aiming of integrating different actors connected to the port call in Genova, Cepolina & Ghiara (2013) identified four different categories of bottlenecks in the port operations that could be resolved with enhanced ICT integration. The four different categories of bottlenecks are Infrastructural, Organizational, Technical and Bureaucratic. See table 5 for examples of bottlenecks resolved by using ICT.

Table 5. Different categories of bottlenecks that could be resolved by ICT (Cepolina & Ghiara, 2013).

Category	**Examples of bottlenecks**
Infrastructural	Road access Railway capacity
Technical	Handling regulations for dangerous cargo
Organizational	Port documentation processes Financial costs of infrastructure
Bureaucratic category	Documentation process Administrative procedures Health control

In order to solve this bottlenecks there are different types of data processing systems in the container terminals. According to Kia et al. (2000) there are three types of data processing systems in port terminals; off-line central system, online multi-point system and online multipoint system with direct telecommunication to yard mobile equipment.

The first type of data processing system is centrally records of the terminal movements, often in the operation centre of the terminal. The information is recorded in the computer system. One main advantage of a data processing system compared to a manual one is that the data automatically can be validated (*ibid.*).

The second type of data processing system consists of a multipoint system and provides information about where the movements of containers take place. It provides updated information on the status of the train/truck such as travelling time, departure time and the time of arrival at destination (*ibid.*).

The third type of system, the online multipoint system, facilitates the communication of yard operations via a computer especially between the operator of the crane and container management personnel for instance with visual display units (VDU) and simplified keyboards. The crane driver receives an order via the VDU to move the container. When the order is confirmed by the driver, the system automatically updates the layout of the container terminal. Hence, "the system makes it possible to follow container movements very closely and it also facilitates execution of loading or discharging operations" (ibid pp. 334).

There are also many different electronic devices that both are and could be used a in a container terminals (ibid). Figure 15 presents some different kinds of electronic devices and information systems could be found in port terminals.

Kia et al. (2000) present two different kinds of systems; *Microcuit system* and the *Tag system*. The Microcuit system is based on Microcuit technology and it is used to track the placing and pick-up of containers by recording relevant data on tags installed on the containers. The Tag system is based on the *Microcuit system* and it includes technology can identify unique containers with help from different kinds of tags such as RFID.

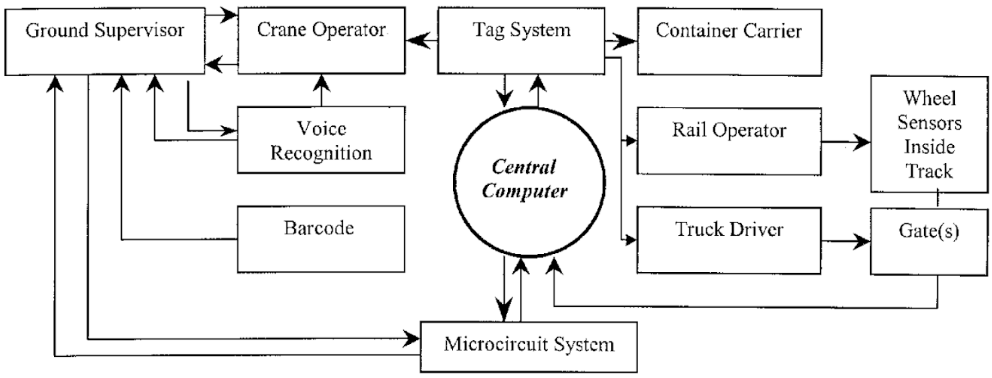
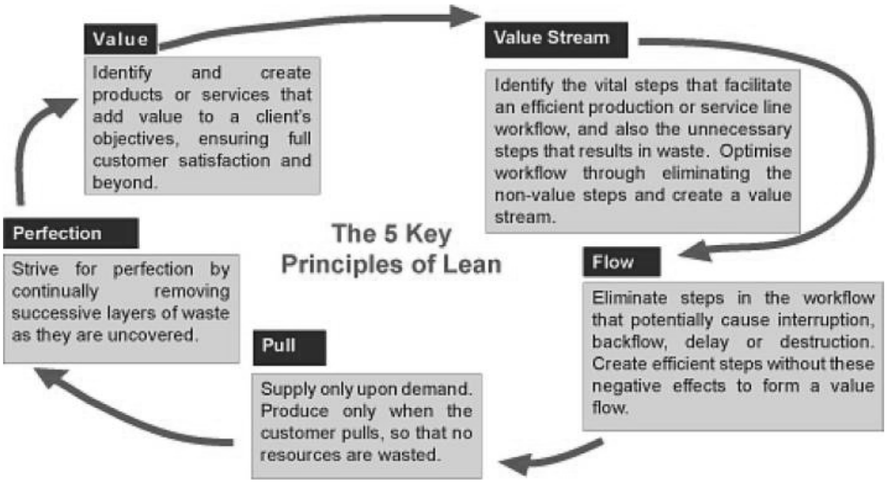


Figure 15. Some electronic devices and information systems that could be used in port terminals (Kia et al., 2000).

Other electronic devices that could be used in a port environment are voice recognition technology and barcode scanner. Barcode scanners are a type of optical character recognition are basically two automatic identification systems and may help the customs decide whether physical inspection is needed. Voice systems use recognition similar to barcode systems. However, instead of an image, the computer recognises words in a pre-programmed vocabulary. When it is activated, crane operators speak into a microphone, the machine recognises words or phrases and then converts them into electronic impulses for the micro- or host computer (Kia et al. 2000).

3.2 Lean

Lean can be viewed as a concept or a philosophy based on the principles of the Toyota Production System (Womack and Jones, 1996). The purpose of lean is to identify and eliminate all factors in a production process, which does not provide any value for the customer, simply more value for less work. It is common in the manufacturing industry. Womack and Jones (1996) presented a model explaining the philosophy of lean in terms of five lean principles, see figure 16.



Figur 16. The five key principles of lean (Womack and Jones, 1996).

In addition, Liker (2004) explained the "Toyota Way" that can be summarised into the "4P Model" (see figure 17) that is a formation of fourteen management principles. The base of the model is the philosophy, to base your management decisions on a long-term strategy. This will ensure the strength of the organization and enable to reach a higher level of realising the business goal within a company (Liker, 2004). Concerning the process, the focus is on eliminating waste through identifying different activities and make assessment on the level of value. Further, it is also important to consider the people and partners involved, to respect everyone and make everyone feel involved. Liker (2004) stated how this will help to add value to the organization.

In addition, the leaders should live the philosophy, since they are role models representing the company and can teach it to others. On a more operative level, problem solving is important to improve continuously. Lean emphases to solve the underlying problem, as well as having a managers who "walks the talk" and are present in the daily operations. Liker (2004) explained a model for problem solving where the problem first is clarified before the underlying problems, inefficiencies is identified. Then a countermeasure is executed to finally evaluate and standardize, in order to avoid the same problem in the future.

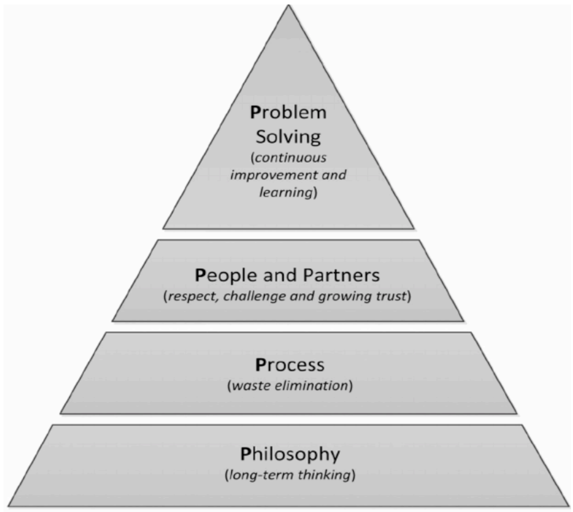


Figure 17. A modified 4P Model by Liker (2004).

Furthermore, a central aspect of lean is to remove everything that does not add any value, non-value adding operations. The non-value adding operation can be further divided into seven categories of wastes and is based on the Toyota Production System. According to Liker (2004), the seven categories central to the lean framework are:

(1) Overproduction
(2) Waiting
(3) Transport
(4) Inappropriate processing
(5) Unnecessary inventory
(6) Unnecessary motion
(7) Defects

Moreover, Liker (2004) suggested an additional type of waste, namely unused employee creativity. Liker (2004) suggested, ideas, skills and opportunities can be brought from employees simply through listening and utilize their knowledge.

3.2.1 Lean in Port Environments

Lean is developed mainly for the manufacturing industry and Olesen et al. (2015) suggested certain adaptations needs to be made in order to implement it in seaport container terminals. In addition, Olesen et al. (2015) claimed that the port environment is uncertain due to its doubly-derived demand, resulting in difficulties of implementing lean. Lean is best used in a stable and controlled environment (ibid). This claim about seaport container terminals being an unstable environment could be questioned depending on the definition of an unstable environment.

An important difference between terminal operations compared to manufacturing operations is that seaport container terminals are bi-directional logistic systems i.e. they are transporting cargo in both directions simultaneously, vessel could for instance be loaded at the same time as it is unloaded (Paixao & Bernard Marlow (2003a). A consequence of the bi-directional logistic systems the coordination between the three subflows; quayside, container terminal area and landside is complex.

However, in agreement with Ainsworth (1992) and Paixao & Bernard Marlow (2003b), Olesen et al. (2015) suggested a lean approach could result in a more efficient port through eliminating waste and creating a more continuous flow. In addition, they suggested it is important to have a well-functioning port since from the logistics perspective, a well function port will increase the degree of pull in a port. Examples gained by having a higher degree of pull along the supply chain i includes reduction of inventory levels along the supply chain, a decrease in related costs, and increased service levels with shorter lead-times.

Notteboom & Rodrigue (2009) and Olesen et al. (2015) focused on bottlenecks rather than adjusting the tact of the operations, according to the real customer demand. Even Though Notteboom & Rodrigue (2009) and Olesen et al. (2015) focused on bottlenecks rather than tact time, they identify areas in a terminal that could result in keeping a lower tact than is needed to keep the customer satisfied, The term bottleneck can be misleading since it is not the bottlenecks that determines the tact time, it is rather the customer's demand. Olesen et al. (2015) identified five areas in need of improvement, namely variations in working processes, miscommunication or lack of communications, a non-synchronized flows and lack of guidelines on how to achieve continuous improvements.

In addition, Olesen et al. (2015) also presented a framework (see figure 18) on how to improve these five area to achieve lean in a container terminal consisting of four fundamental principles to enable the improved material flow in intermodal facilities. These are waste elimination, standardization, levelling and continuous improvement. In agreement with Paixao & Marlow (2003b), Olesen et al. (2015) also suggested it is important that the four principles are supported by ICT to provide relevant information and effective communication channels (see figure 18).

The first principle is called waste elimination. However, in this framework Olesen et al. (2015) mainly point out awareness of lean. If analysing the operations of a container terminal based on the seven wastes some of these wastes are difficult to apply directly to a terminal. One example is transport, which is essential for a terminal’s operations and if all transports would be considered waste, many crucial operations in a terminal should have to be eliminated which would create a non-functioning terminal (Olesen et al., 2015). In addition, according to Toyota, storage is a waste, but for terminals this could be seen as a value adding service, since it is requested by some customers and therefore adds value to the customer.

The second principle is standardisation. Olesen et al. (2015) suggested lack of standardisation contribute to bottlenecks that affects the tact time. Ohno (1988) suggested insufficient standardization creates muda, mura and muri, namely the three Ms of waste in lean. One of the main reasons for applying standardization, seen in both the scientific literature and from empirical findings, is to reduce variability in the processes, with particular reference to process cycle times. To reduce and eliminate variations in intermodal terminal operations, standardization of procedures should be implemented both in terms of reducing variations in processes but also enabling and encouraging continuous improvement (Imai, 1986; Shingo, 1989).

The third fundamental principle is levelling. To be able to synchronize the flows, it is important to eliminate unevenness in the different operations. Olesen et al. (2015) suggested that levelling can be applied within terminals to create a more levelled schedule. A possible solution here is to distinguish between front-end and back-end operations, where front-end operations involve unloading and loading of trucks/arriving containers (external), and back-end operations involve the loading and unloading of containers that are already on-site (internal).

The fourth and final principle presented in the framework by Olesen et al. (2015) is continuous improvement. It is important to design a system to encourage the workers to contribute towards continuous incremental improvements in their daily activities. Furthermore, examples of tools that could be used to support continuous improvements are basic process mapping tools and root cause analysis to detect and develop arrival at suitable countermeasures. This can contribute to identify which operations that are value adding and to thereafter remove the non-value adding operations.

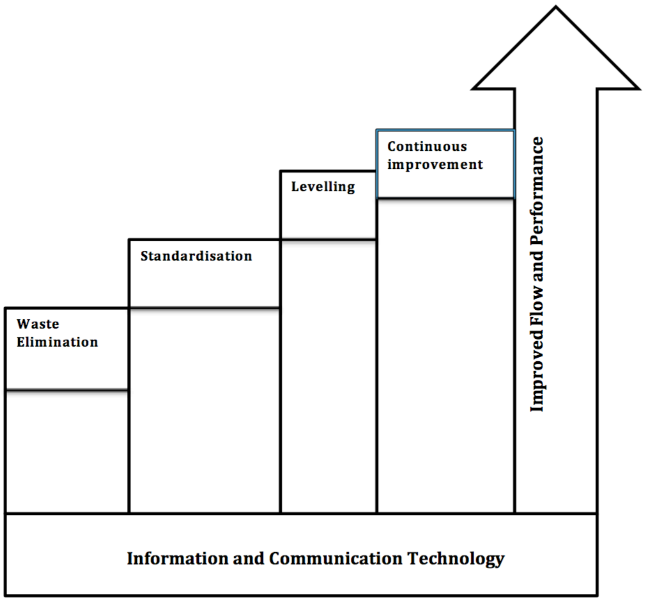


Figure 18. Modified Framework for lean terminalisation (Olesen et al., 2015).

3.3 Value Stream Mapping

Value stream mapping (VSM) is a tool to aid continuous improvement and the implementation of lean. VSM was developed in 1995 (Hines et al., 1998) and the purpose of VSM is to identify and remove non-value adding activities in manufacturing process to increase the efficiency for the company (Rother & Shook, 2003). One of the objectives is to reduce the time required for a piece to move along the entire process, from that the customer place an order until the customer has received its product, the lead time (Braglia et al., 2006).

VSM consist of three larger parts, namely a current state map, a transition between current to future, and a future state map. Sometimes a fourth part is included namely an ideal state map where the most optimal improvements are implemented (Jones & Womack, 2003). The current state map aims to identify the present and is used as the foundation for analysing the processes further. The future state map is an improvement of the current state through identifying inefficiencies in the current state and designing a lean flow. The ideal state map is a state where all actions create value and where there are zero wastes. Although this map is difficult to achieve, it can be used as a guideline for continuous improvement (ibid.).

VSM consist of two different flows; the material flow and the information flow. Information flow relates to transfer and exchange of all relevant operational information concerning the bureaucratic procedures related to the operations. The second flow, the material or material flow, concerns the movement/handling of the actual physical products (ibid.).

3.3.1 Executing a Value Stream Mapping

Before executing the actual VSM, there are two different approaches that could be used. The first approach is to first decide on which product/product matrix should be studied and what steps which are expected to be mapped. It helps to estimate the range of the map. However, this step is time-consuming and it may generate a subjective assessment when the actual mapping should be done through an inaccurate perception when sketching (Nash & Poling, 2008). The second approach is to simply map the target area, in line with Taiichi Ohno's "just do it" philosophy (ibid.). The drawbacks with this method are that the risk of forget or overlook some steps in the first mapping. This implies that more than one field study at the target area might be executed to cover the remaining parts.

Furthermore, Nash & Poling (2008) suggested that the most important characteristics to have when mapping is a strong set of observational skills. In addition, it is important to have an open mind when mapping. Hence, despite impressions from pre-studies or sketches to be able to make an objective mapping, and only map what is observed, i.e. not what other people say or think.

Finally, Nash & Poling (2008) do not recommend to use a computer or any other electronic devices when mapping, since it is too tedious in the mapping process. “Many engineers, project managers, and analysts who have conducted process-mapping exercises in the past tend to fall back on their traditional methods to document process flow” (ibid, chapter 3). Hence, the simplicity and flexibility of a pen is difficult to replace.

3.3.2 Current State Map

When drawing the current state there is a number of decisions that needs to be made. The first decision to make is which symbols should be used to present the findings, so it is easy to follow. Figure 19 illustrates common symbols and figures. It is important to state that these figures are adapted to the manufacturing industry and some will therefore not be present in the seaport industry. If there is a need of further symbols or symbols adapted to dedicated industry there are no hinders to implement new ones since the understanding of the mapping is the most crucial (Nash & Poling, 2008).

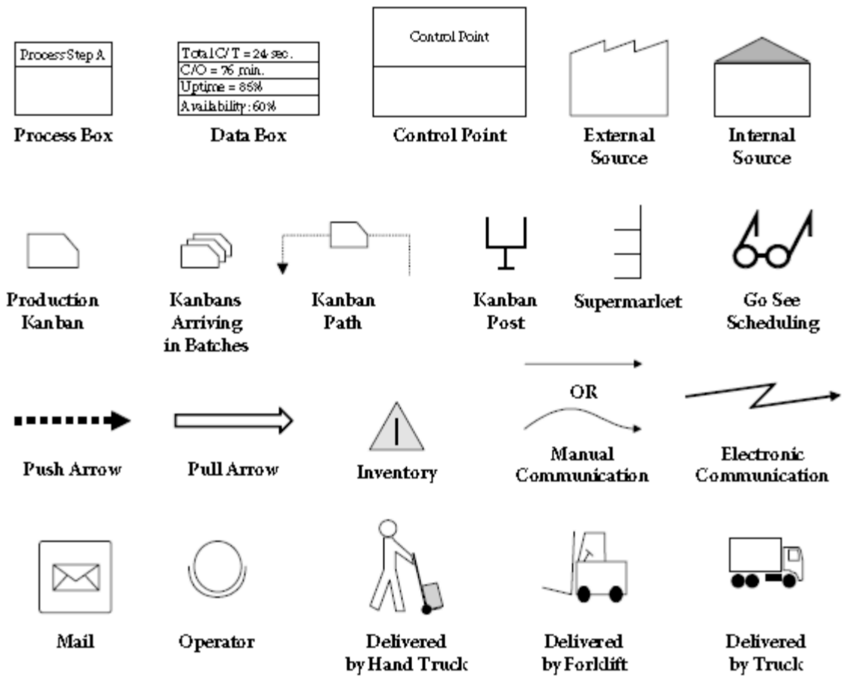


Figure 19. Examples of common symbols and figures used in VSM (Nash & Poling, 2008).

The importance of understanding is further emphasised by Hines et al. (1998) that address a case where the result was difficult to understand for the workers since the VSM was not adopted towards them. The mapping was than executed by a team of experts in the area. They were however, not involved in the daily work and their lack of the understanding of the daily work was clear in their presented maps.

Another decision that needs to be made concerns how to divide the different operations into transportation, handling, storage and administration. Transportation is the operation of moving components in order to relocate from one place to another (Finnsgard, 2016). Transportation could be seen as movement of cargo from one point to another. The difference between transportation and handling is that in handling the cargo are moved in order to hand-over and the movement is relatively short. Examples are when semi-finished products are moved a longer distance from one manufacturing station to another.

Continuing with handling, the interpretation of handling may be a bit vague and confusing since transportation has a similar definition. Hultén (1997, p. 73) chose to define handling as "the hand-over of the transport object from a conveyance, a warehouse or a means of value adding, to a conveyance. This means that one resource is relieved and another is burdened. By necessity handling will cause a movement in both space and time but neither is the purpose of the process." In other words a handling is a step where the product is moved from one point to another, in order to start a new operation. Johansson (2006, p.12) defines material handling activities as “lifting and putting down as well as packing materials”, meaning moving materials in a vertical direction. Furthermore, storage concerns storing in buffers during a longer period of time (Finnsgard, 2016). Administration includes administrative tasks such as checking the material, controlling the quality or counting the material.

3.3.3 Measurements

There are many different measurements that could be used when conducting a VSM to analyse the current map. Examples of different measurements to use are tact time, throughput time and lead-time. Ohno (1988) suggests tact time could be calculated as shown below:
Tact time = Net available time for identified time period / Customer demand for the same time period.

Cycle time is according to Rother & Harris (2001), how frequently a finished unit actually comes off the end of the process. In addition, Rother & Harris (2001) suggested, that if the cycle time is constantly faster than the tact time, this may lead to overproduction and overuse of resources.

Throughput time is defined by Johnson & Womack (2003, pp.39) “as the length of time between the release of an order to the factory floor and its receipt into finished goods inventory or its shipment to the customer”.

Lead time could be defined as the length of time between the time when an order for an item is placed and when it is actually available for satisfying customer demands. It usually consists of the following components: order preparation, order transit to the supplier, supplier lead time (defined as the time that lapses between the time an order is received by a supplier and his shipment of the items), items transit time from the supplier, and preparation time for availability (Jonsson & Mattsson, 2013).

3.3.4 Level of Detail and Boundaries

One critical decision to consider is, according to Nash & Poling (2008), to determine the proper level of detail to be included when mapping the operations. Furthermore, Nash & Poling (2008), stated that the power of VSM lies in the details. The level of details should be determined depending on what problems or issues are to be addressed and to whom the map will be presented, i.e. the stakeholders’ interests. The same applies when determining the boundaries (ibid.). The level of detail is also determined by the total operation time in relation to the total lead time in order to gain the whole picture of each operation’s share and contribution.

3.3.5 Push vs. Pull

There are many different definitions of pull and push systems and many systems are a combination of both. According to Bonney et al. (1999), there are many different definitions of a push vs. pull system. However, generally, the push operations can be described as an anticipating system whereas pull can be described as a reactive system. Hence, the pull system request some kind of signal to initiates the process with a specified quantity rather than just working from a dispatch list, as in a push system. According, to Shigeo Shingo (1989) a system is rarely purely push or pull is more interesting of talking about degree of push or pull. One important benefits gained by using a higher degree of a pull system is limiting the Work In Progress (WIP). However, a pull system is not a zero inventory system.

3.3.6 Challenges with VSM

VSM was developed in a manufacturing environment and hence adjustments need to be made when using it in another context. VSM has proved to be effective in many ways, this further support why VSM should be adopted to fit other industries (Finnsgård et al., 2011). In more recent times, the area of use has broadened for VSM where it might help to re-engineer businesses because of that it identifies unnecessary effort and resources to permit simplification and streamlining of operations processes (Sondalini, 2011).

Hines et al. (1998) stated several weaknesses with VSM, and instead suggest a more comprehensive framework, namely value stream management. The basic concepts are the same, however focusing more on key processes and a strategic review of a business's activities. Some identified weaknesses in VSM, are that there may be some wastes not stated in the current state map that should be evaluated as well. Hines et al. (1998) provided examples of wasted human potential and wasted energy. In addition, Hines et al. (1998) suggested there might be a lack of linkage to corporate strategy in the studied environment since the daily work is operative and not always connected with strategically guidelines.

3.3.7 Analysing the Current State Map

When the current state map has been made, the next step is to analyse and see which improvement should be made. The first step is to identify what activities are value adding (VA) or non-value adding (NVA) activities and the second step is to see how to eliminate the wastes and how to improve the current state by answering Medbo's 7 questions (Medbo, 2016).

3.3.7.1 Different Types of Activities

An important step in assessing the current state is to determine which activities that are VA operations, necessary but non-value adding (NNVA) operation and NVA operations.
According to Monden (1993) operations can be classified into three different categories;
(1) Value adding (VA)
(2) Necessary but non -value adding (NNVA)
(3) Non- value adding (NVA)

The first category, VA operations are the operations the customer is willing to pay for. Examples of value adding operations in the manufacturing industry include refining of materials or semi-finished products by either automotive machines or manual labour. Other examples of operations are sub-assembly of parts, painting and finishing the products (ibid.). Hence, value-adding tasks add market form or function to the product or service; simply put, "they *are* what the customer is willing to pay for" (Nash & Poling, 2008, chapter 4).

The second category, NNVA operations, includes operations that could be considered to be wasteful "but necessary under the current operating procedures" (Hines & Rich, 1997, p.47). Examples of NNVA include movements such as collecting tools and materials and to move long distances to unpack deliveries. To be able to eliminate these activities, major changes to the operation systems are needed. Examples include changing the layout, moving stations with tools, or arranging for suppliers to deliver unpacked cargo in arranged boxing (Hines & Rich, 1997). These sorts of changes are difficult to implement immediately and might require large investments.

The third categories, NVA operations, are needless operations that should be eliminated completely. According to Hines & Rich (1997), examples of activities that could be considered non-value adding are double handling, waiting time and intermediate products. Non-value adding operations may be divided into the eight wastes presented by Liker (2004) are considered non-value adding as well. Hence, NVA operations are anything the customer is not willing to pay for.

3.3.7.2 Transition to Future State

Medbo (2016) suggested, in order to create a future state map, these seven questions could be used as guidelines to evaluate the current flow and consider where improvements could be made. The seven questions are:

1. What is the real customer demand?
2. To what degree is it possible to achieve a continuous flow?
3. How can a pull controlled material flow be achieved?
4. How can a levelled material flow be achieved?
5. How can the material flow be synchronized with the real tact of the customer production flow?
6. Which process improvements are needed?
7. How can the material flow be further improved?

When creating the future state map, the current state map should be used as a baseline. One of the goals in Lean production is to only produce or do what is needed at the time it is needed, implying a pull flow with no excessive inventories (Rother & Shook, 2003). Rother & Harris (2001) also discussed the importance of obtaining and maintaining a continuous flow as the ultimate objective of Lean production. These are the objectives when creating the future state map that is an improvement of the current state map using the above questions as guidelines.

4 Findings and Analysis

In this chapter the findings and analysis are presented. The chapter is divided in five different parts. The first part (4.1) presents the contextual background including a description of fours studied container terminals and other important findings about the industry. The second part (4.2) presents the current state map generated by a merge of data from the four container terminals at seaport studied and the theory. Than an analysis of differences between the studied terminals that affect the VSM is presented. In addition, explanations and motivations to the maps are presented here, where the motivations are analysed and evaluated. The third part (4.3) consists of analysing the current state map. The part begins with a division of the operation into value added and non-value added operation. A description of the transition from the current state to the future state is then presented. The fourth part (4.4) consists of the future state map. In that part a future state map and recommendations of improvements will be presented. The last part (4.5) describes challenges with executing the current state map.

4.1 Contextual Background

In this chapter the four studied terminals are presented. The general findings from the observations of the terminals are also presented.

4.1.1 The Four Studied Container Terminals

APM Terminals Gothenburg

APM Terminals operates in the port of Gothenburg and is responsible for the largest container port in Scandinavia with 800 000 TEUs handled in 2016 (APMT, 2017). APM Terminals is a private company and a part of the Maersk group. The port of Gothenburg owns the ground where APM Terminals operates. They are a privately owned company and only conduct container operations. Around 50-60 % of Swedish container traffic is handled at the port, split evenly between exports and imports (ibid.). APM Terminals in Gothenburg handles the majority of containers and their terminal is 80 hectares. It has a capacity to handle 19 000+ TEUs vessels 24/7. In this report APM Terminals will be referred to as APMT Gothenburg.

Noatum Container Terminal at the Port of Valencia in Spain

Noatum container terminal is one of three container terminals operating in the port of Valencia, which is considered to be the natural port of Madrid. The port of Valencia was the 32nd largest port in the world in 2015 (World Shipping Council, 2017), measured total handled TEUs, and Noatum handles the biggest share of containers in the port of Valencia. Noatum group owns Noatum container terminal and owns other container terminals across Spain. Noatum container terminal handles 2.5 million TEUs/year and manages the main global container shipping lines. Noatum only carries out container operations. The terminal also manages feeder connections to other Regions (Noatum, 2017). In this report Noatum Container Terminal at the Port of Valencia in Spain will be referred to as Noatum Valencia.

Port of Helsingborg

The Port of Helsingborg is a full service port and handled 220 000 TEUs ii 2016, and is the second largest container port in Sweden (Helsingborg, 2017). The Port of Helsingborg is owned by the city of Helsingborg. It was originally built as a Ro-Ro (roll on, roll of) terminal.

Hence, the layout of the terminal is different from an ordinary container terminal. There has been a rapid increase of container handling during the last years due to a higher demand. The port of Helsingborg is an important actor in the fruit business in Sweden, since they handle the majority of imported fruit to Sweden and 100% of the imported bananas. In this report the port of Helsingborg will be referred to as Helsingborg.

Port of Norrköping
The Port of Norrköping is a full service port that handled 110 000 TEUs in 2016 (Norrköping, 2017). There has been a rapid increase of container handling during the last two years with an increase of 60 % due to a higher demand. The Port of Norrköping is owned by the city of Norrköping. In 2011 the depth at the dock was increased to 14.9 meters implying they have the capacity to manage the largest vehicles operating the Baltic Sea (ibid). In this report the port of Norrköping will referred to as Norrköping.

4.1.2 Current Documentation of Operations in the Terminals
During the data collection it was discovered that some of the terminals carried out documentation and time study of the operations in the terminals. At APMT Gothenburg they did carry out a time study and document of the different operations at the quayside but not the operations related to unloading and loading of the train. However, it is unclear of how they have carried out the documentation of the operations since this data was not shared.

The same applies for the port of Helsingborg. Noatum Valencia also carried out some sort of documentation, however as in the case of APMT Gothenburg this data was not shared (Project Manager at Noatum). The port of Norrköping had not done any documentation of their operations. It seemed that the respondents in the container terminals had little insight in how the terminal conducted the documentation and what challenges might occur during the documentations of the operations.

4.1.3 Customers and Suppliers
In the terminals studied, it is possible to distinguish four main actors that can be seen as the customers to the terminals. The identified customers are shipping lines, the owners of the cargo, and the train and road carriers. Traditionally, only the shipping lines have been considered to be the main customer and that the terminals only had contracts with them. However, more and more of the terminals have started to sign contracts with large owners of the cargo and some have also signed contract with train carriers. However, in Noatum Valencia they don't view the road carriers as their customers (Project Manager at Noatum).

The terminals have different abilities to affect their customers depending on who they have signed contracts with or not. It also affects how the transaction flows look like. When signing the contract the terminals can exert power over the customers, however, on the other hand the terminals need to deliver to the customers. If they fail to deliver, the terminals might need to compensate the customer. For instance, APMT Gothenburg have signed contracts with both shipping lines, train carriers and some large owners of the cargo. As a result, they have the ability to improve the collaboration since there exist incentives for the signed partners to collaborate since it might result in discount. However, at the same time it may become expensive if they do not achieve the stipulated terms such as the loading/unloading tact.

Even though some of the terminals have contracts with other customer categories than the shipping lines, all of the studied terminals have designed their operations to benefit the shipping line. For instance, at APMT Gothenburg, their TOS is optimizing on the shortest time for the vessels at quay. At Helsingborg, if they are at risk of not keeping the unloading/loading time for the vessel, they may create a temporarily buffer at the quay. It is understandable that the terminals prioritise the shipping lines since without them they do not have any business.

Many of the container terminals' operations are controlled by what is stipulated in the contracts. The terms in the contracts differ both between the terminals and with different customers. Examples of terms stipulated in the contracts are frequency at port calls, time for unloading/loading depending on the volumes and time in the storage. See table 6 for the type of customers the terminals have signed contracts with.

Table 6. Customers the terminals have signed contracts with.

Terminals	Contract with Shipping Line	Contract with Train Carriers	Contract with Road Carriers	Contracts with Owners of the cargo
APMT Gothenburg	Yes	Yes	No	Yes
Noatum Valencia	Yes	Yes	No	Yes
Port of Norrköping	Yes	N/A	No	No
Port of Helsingborg	Yes	Yes	No	Yes

Moving on to the suppliers of the terminal. Most of responds answered, that they view the suppliers as them who supply the equipment and services such as their TOS and maintenance service.

4.1.4 Organisation of Labour in the Container Terminals

Many terminals are both capital and labour intensive since special equipment needs to be used and many of the operations are still carried out manually resulting in high dependence on the stevedores. The stevedores are organised differently in the terminals depending on different factors including union agreements, services offered in the terminals and equipment used. The cost of the labour is rather high in the terminals; hence there exist incentives of reducing the labour force in all of the terminals.

In the studied terminal the labour force are organised often related to the areas of the terminal. Three different groups have been identified from interviews and observations namely the quay team, the train team and the truck team. The number of the team differs between the terminals and all of the team have a supervisor.

Starting with the quay team, it usually consists of a crane driver, a tally man, signal man/ men, a man removing and putting on twistlocks, drivers of vehicle transporting container to the yardside and drivers of vehicle lifting the container on and off the stacking area.

The tallyman is a person, who checks that the right containers are unloaded, the sealing off the container is on and the containers have no exterior physical damages. The tallyman usually stands below the crane. The signalman is a person who stands on the deck of the vessel and guides the crane driver and make sure none of the crew of the vessel is in the way.

Moving on to the train team. It consists of stevedores transporting the container from the yard to the train and loading / unloading the container from the train. The team also consist of a stevedore checking the container similar to the tally man when the train enter or departure from the terminal. The final team is the truck team consisting of stevedores, unloading/loading and transporting the container to and from the stacking area to the trucks. The team also includes people operating the gates of the terminals entries, if the gates are not automated.

In addition, in the terminals studied the different types of teams worked in shifts. The number and the length of the shifts differed between the terminals and the teams. Usually, the quay team worked 24/7, divided on three to four teams whilst the truck team usually worked between the opening hours of the gate, opening around seven am (+-1) closing around eight pm (+-1) and was divided on two teams. The number of the shifts for the train teams differed depending on how the slots of the train carriers were and how much was transported by train. In general, the terminals had different degree of flexibility of moving the stevedores between the different teams depending on union agreements and the level of skills required in the teams.

4.1.5 Container Size

Concerning containers, there are some different standards in sizes namely, 20, 40 or 45 feet. In the terminals studied in this case, mainly 20 and 40 feet were handled. There was no distinguish between the two sizes in terms of handling; they went through the same procedures and were handled with the same equipment. The only difference is that they need different storage space. When it comes to different types of cargo the reefer and the dangerous cargo are excluded in the findings and analysis.

4.2 Current State Map

This section presents the mapping of the current state. In addition to the maps, it contains explanations and description of current state.

4.2.1 Explanations of the Mapping

It can be concluded from literature, interviews and observations that VSM can be applicable on container terminals in seaports. The Project Manager in Noatum Valencia mentioned that a container terminal has everything a factory has apart from a roof; "we have the heavy plant, we have people, we have processes and we have a product to deliver and we have a customer to delight". The similarities between a manufacturing industry and a container terminal are many and the applicability of VSM on container terminals is acceptable.

Many symbols used in manufacturing industry, for instance as explained by Nash & Poling (2008), are considered to be useful even for the port industry. The symbols for automation and manual work are the same and also push and pull symbols can be used. Hence, there is no need to introduce any new symbols since the main operations in container terminals are transport, lifting/immersion of material and traditional information flows.

As mentioned in the frame of reference, the operations in a production can be divided into handling, transportation, storage and administration (Finnsgard, 2016; Hultén, 1997). The definitions given can be applicable for the terminal operations as well. For instance, in manufacturing the operation of lifting material with a forklift is similar to lifting a container with a reach stacker or RTGC. Explanations and symbols to the mappings are found in table 7 and figure 20.

Table 7. Explanation of the abbreviations used in the mapping.

Abbreviation	**Explanation**
Vehicle 1	Vehicle that transports between the vessel and the stacking area
Vehicle 2	Vehicle that operates in the stacking area
TOS	Terminal Operating System
Cont	Container
H	Handling
T	Transportation
A	Administration
S	Storage

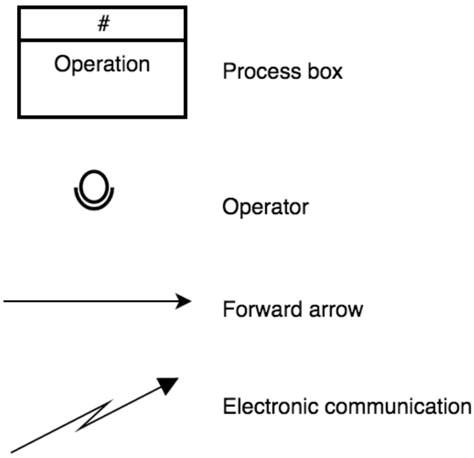


Figure 20. Explanations of symbols.

4.2.2 Mapping of Operations of Current State

The current state map is divided into two main maps to illustrate the different flows (unloading/loading). This division is made since even though the flows may be considered to be bidirectional, the flows are not identical and separated by two parameters, namely time and space. The time spent in ports are different for import and export containers for all except for Norrköping. The flows are also to some extent separated, since imported or exported containers are separated in different stacks in the stacking area. In addition, some of the operations are carried out differently depending on if it is export or import.

The general map is a merge of the data generated from observation and interviews in the four studied ports as well as literature on terminal operations. The process of VSM was carried out, as Nash and Poling (2008) suggested, by first studying the industry and operation expected to occur and then the mapping was carried out since the time spent at each terminals was limited. Due to the limiting access to the terminals interviews was used as a complement.

The mappings illustrate the operations conducted in the major part of the terminals studied. The main reason of having common maps instead of separate maps for all four container terminals is that the all of terminals performed the same operations and sequences and the main differences between them were mainly the size of the terminal and the equipment used. Any differences will be discussed in connection to the mappings.

The chapter 4.2.2.1 presents the unloading process and the chapter 4.2.2.2 presents the loading process. Figure 22-24 illustrates the flow from the vessel to truck and train and figure 26-28 illustrates the opposite flow. All of the presented maps (for loading and unloading operations in the terminals) are presented in larger scales in the appendix 1, similar to the order presented below.

4.2.2.1 Unloading

The process of unloading a vessel can be considered to consist of three different subprocesses, namely the unloading of the vessel itself at quay, transporting the container and placing it in yard. The container is then finally loaded onto a truck or onto a train at the landside. The mapping of unloading is divided in three different maps (see figure 21). The main reason of why the subprocesses quay- and yardside are mapped in the same map and the subprocess landside is divided in two maps is to facilitate the understanding. The subprocess at the quayside and yardside do not differ depending on if the containers leave the terminal by truck or train in contrast to the landside operation.

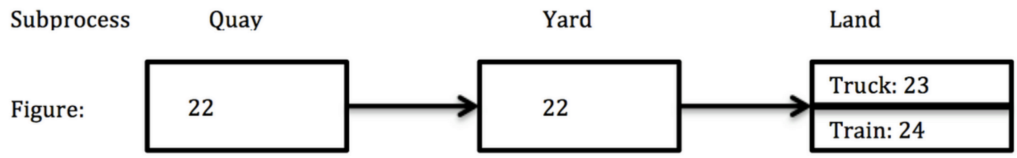


Figure 21. Mapping of the whole process of unloading a vessel in a terminal.

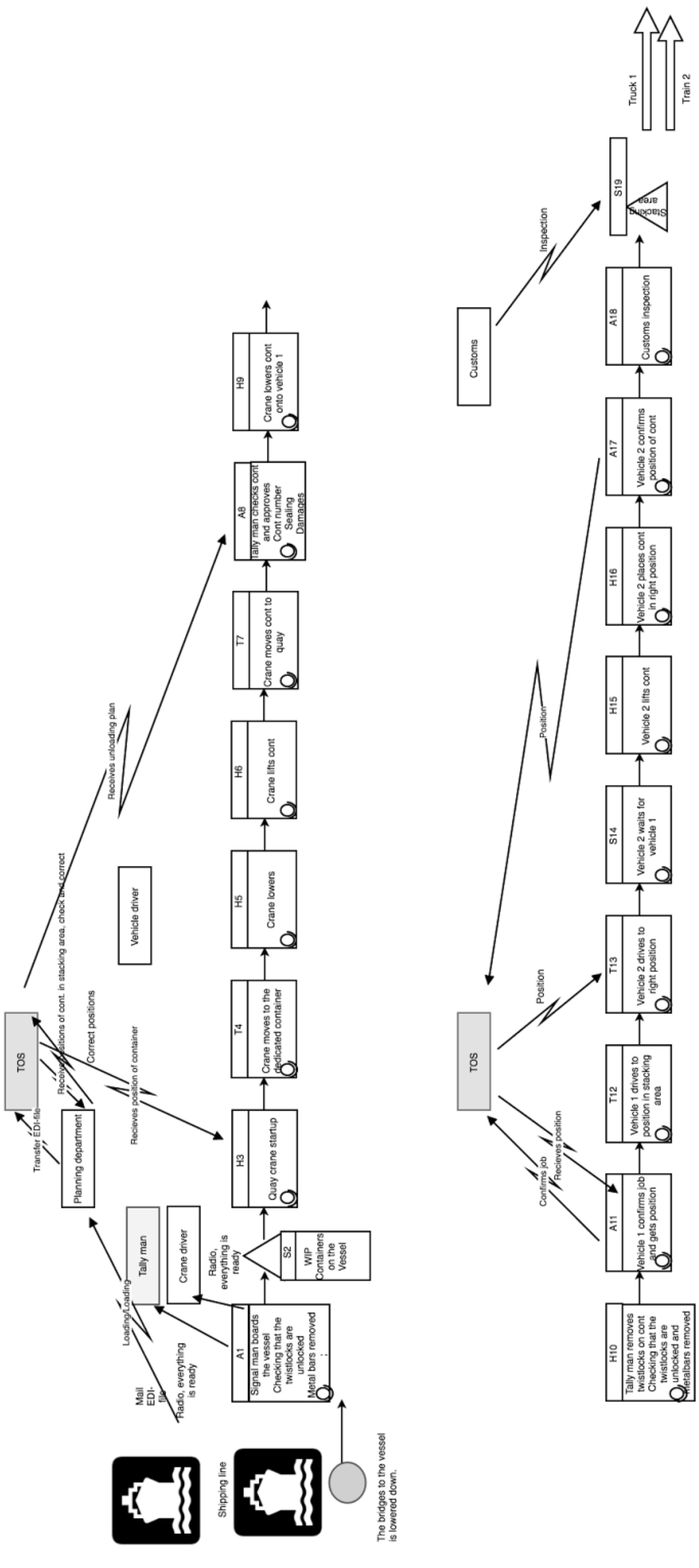


Figure 22. Mapping of the process of unloading a vessel in a terminal at the quayside and transporting it to the yardside.

For the ports studied, all of the operations are conducted similar at this level of detail, until operation H9 in figure 22. In Helsingborg, Norrköping and Noatum Valencia, the operations 9-17 are similar to the map, the only difference are usage of different vehicles. In APMT Gothenburg the operations differ and are conducted in this way: the quay crane place the container onto the quay and a straddle carrier picks up the container and drives it to it designated place in the stacking yard. The same straddle carrier unloads the container in its assigned position in the stacking yard.
In addition, the time the containers are stored in the stacking yard (operation S19) also differs between the different terminals and for import/export. The numbers presented in table 8 are only an average since the days may differ depending on agreements with different customer.

Table 8. Average days for containers in stacking area.

Terminal	**Average days in stacking area for import/export**
Noatum terminal, Port of Valencia	5.5/6.5
Port of Helsingborg	N/A/N/A
APMT Gothenburg	3/5
Port of Norrköping	4/4

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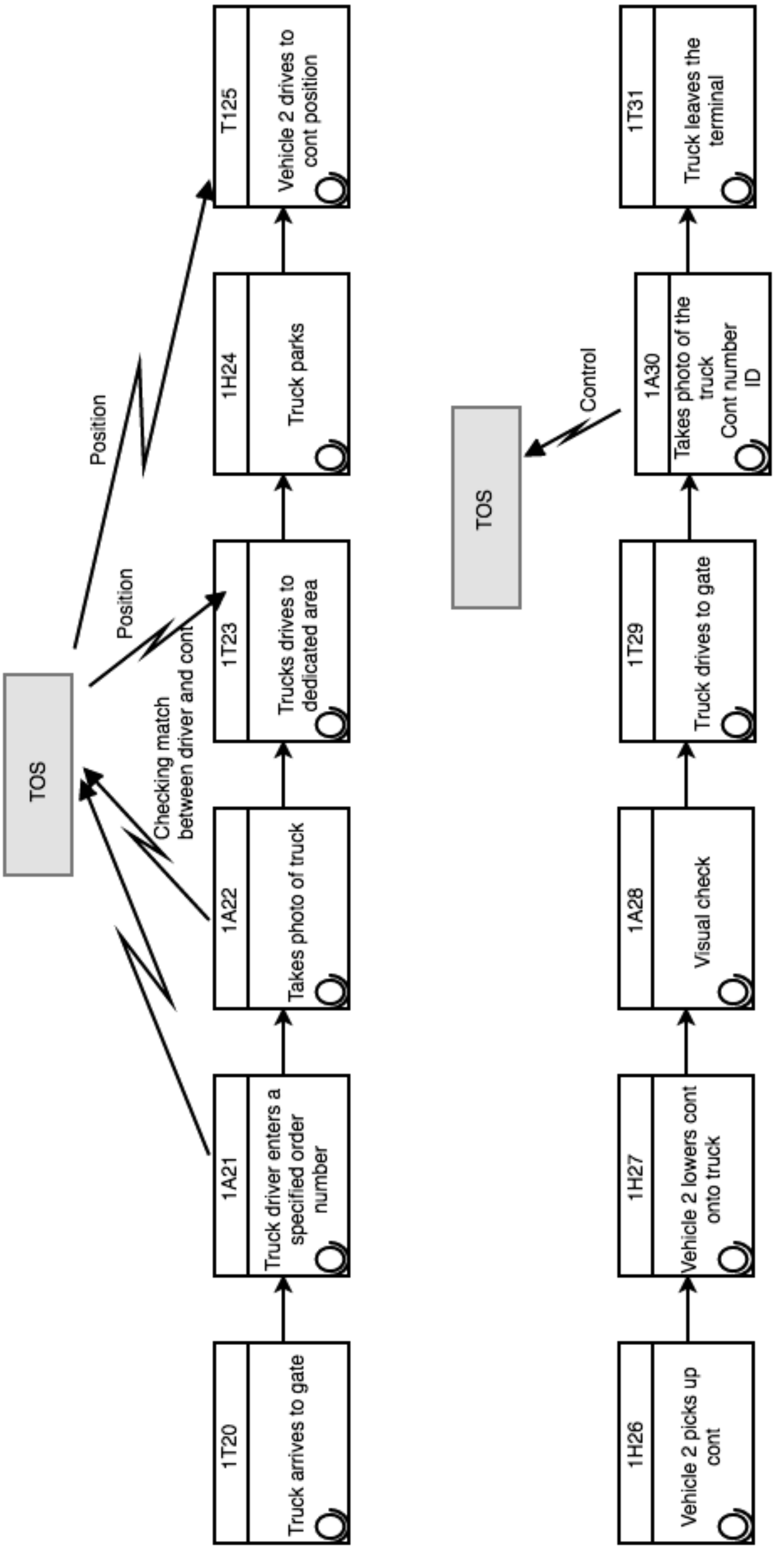

Figure 23. Mapping of the process of loading an import container onto a truck

The map in figure 23 illustrates the operations carried out in Noatum Valencia and Helsingborg. The central gate was fully automated both in Noatum Valencia and Helsingborg. In Helsingborg they were currently trying out an automated gate and it was decided to map the operations as if they were automated. At APMT Gothenburg and Norrköping the processes at the gates were operated manually and differed from the map.

Starting off with APMT Gothenburg; the processes started off with the truck driving to the building for ID control. In the building their papers were checked and, for new drivers, a quick test concerning on how to behave in the port and some safety regulations were conducted. If the paperwork was in order they received a code and a queue number. The driver drove down to a parking space close to the gate of the terminal. The driver waited there, until their queue number showed up and droved than to the gate of the terminal.

The driver then entered its code and the bar at the gate was lifted up. The driver then drove to an instructed place for loading and unloading. The drivers then turned off the engine and entered a white box where they pressed a button. A straddle carrier received the signal and a working order and drove to the container and picked it up and drove to the truck. The container was then placed on the truck and when the container was loaded, a light in the white box was turned green and the driver entered the truck and drive out of the gate.

Continuing with Norrköping, if the truck was pre-advertised the trucks drove down to the gate of the terminal and the driver walked into the gatehouse where the driver entered the booking number and their identification. The driver than received a map of where they should drive to pick up the container.

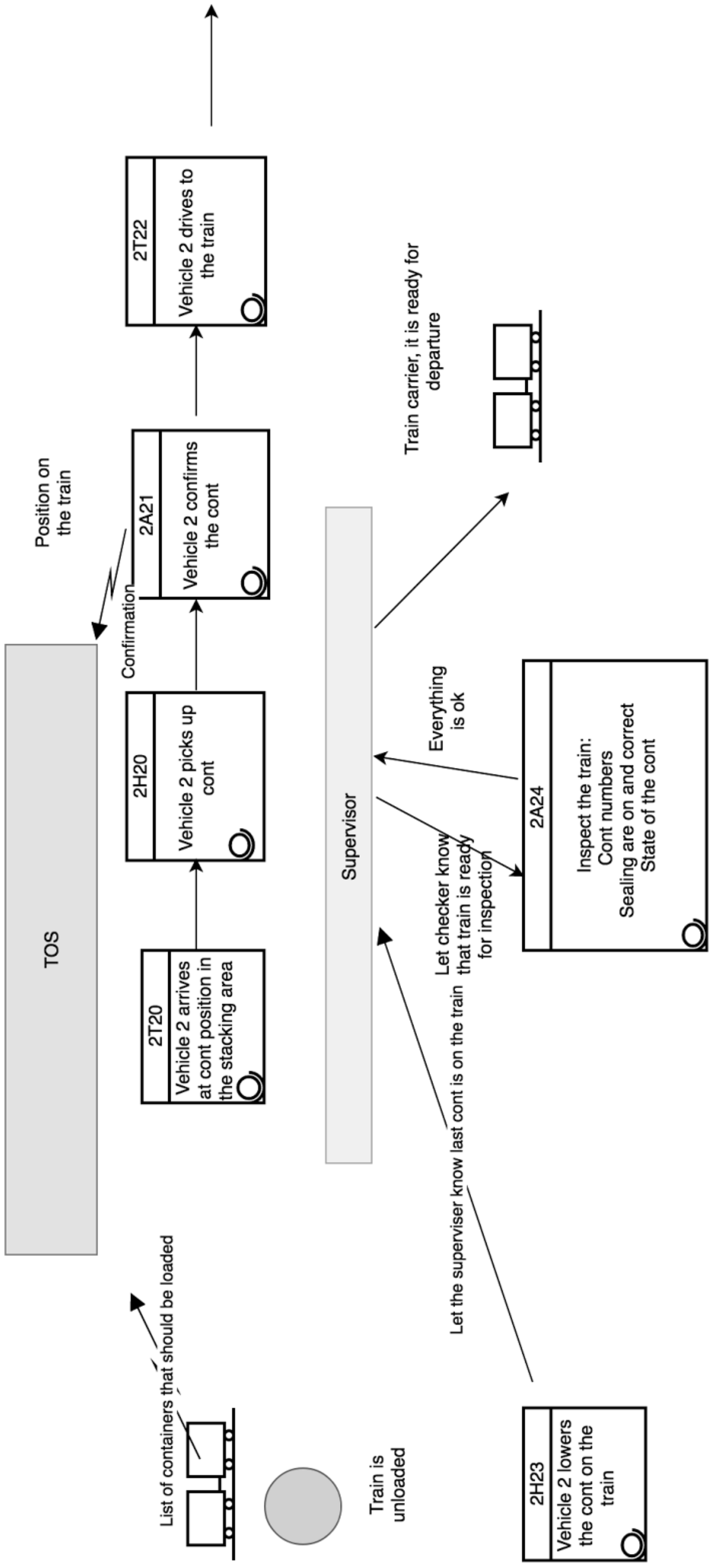

Figure 24. Mapping of the process of loading an import container onto a truck

Figure 24 illustrates the process of loading a container onto a train. The subprocess started when the train is unloaded. The map presents how the operation of loading a train was conducted in AMPT, Gothenburg, Noatum Valencia, Helsingborg and Norrköping. The only difference between the terminals was the distance the container is transported from the stacking area to the train.

To summarise, figure 22-24 illustrates the process of unloading a container and the process starts with the berth of the vessel and the container was than unloaded by a quay crane. Then some type of vehicle transported the container to the stacking area. From the stacking area the container was then loaded onto a truck, train or on a feeder vessel. All of the ports studied have the similar operations but used different vehicles as vehicle 1 and 2. See table 14 under 4.2.3.5 Equipment for more details.

4.2.2.2. Loading

The maps of loading the vessel follows the same logic presented under the chapter loading for the same reasons mentioned previously. An overview of the process is presented in figure 25.

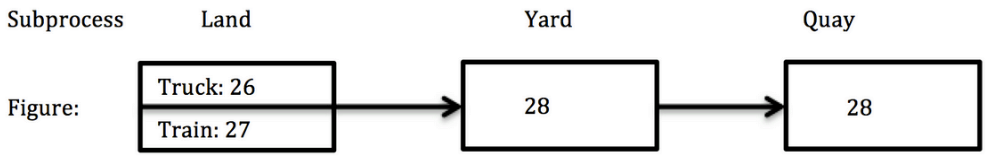

Figure 25. An overview of the whole process of loading a vessel in a terminal.

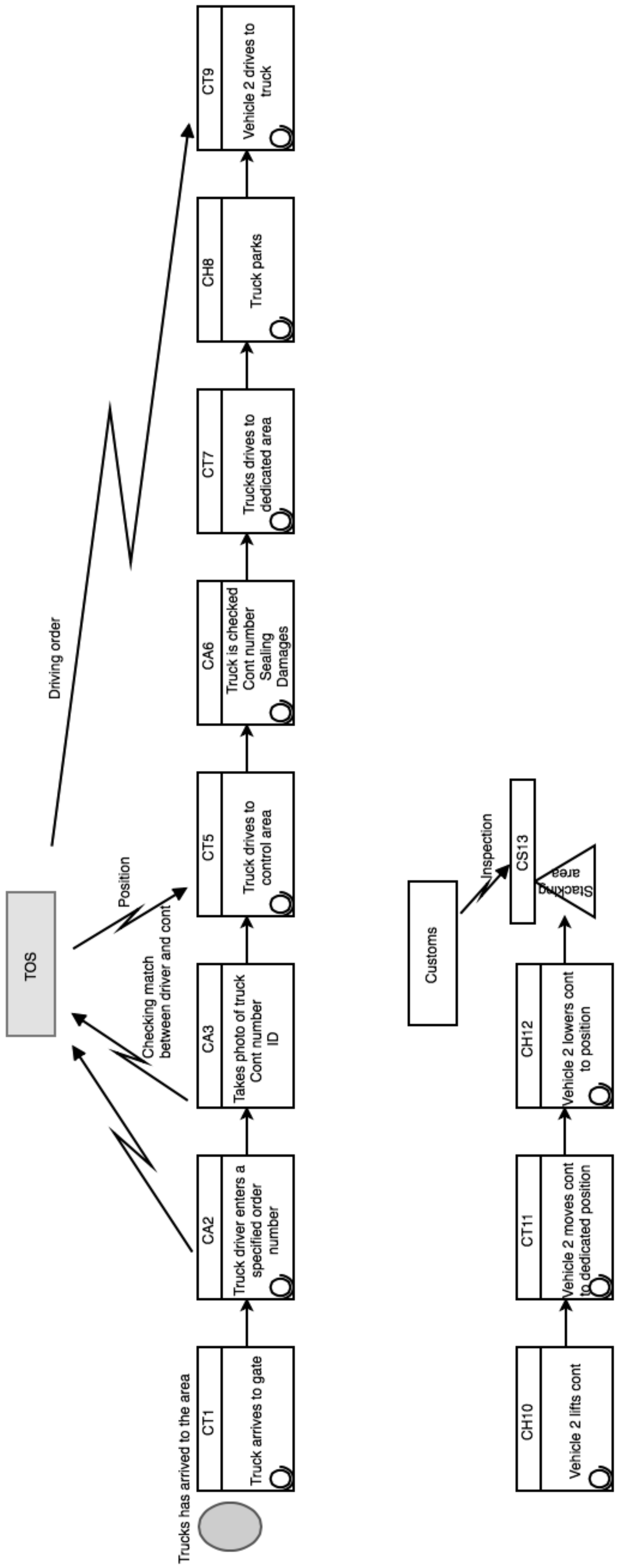

Figure 26. Mapping of the process of unloading a truck in a terminal.

The map 26 illustrates the operations carried out in Noatum Valencia and Helsingborg. The central gate was fully automated both in Noatum Valencia and Helsingborg. At APMT Gothenburg and Norrköping the processes at the gates were operated manually and differed from the map.

Starting with APMT Gothenburg; the processes started off with the truck driving to the building for ID control. In the building their papers were checked and, for new drivers, a quick test concerning on how to behave in the port and some safety regulations were conducted. If the paperwork was in order they received a code and a queue number. The driver drove down to a parking space close to the gate of the terminal. The driver waited there, until their queue number showed up and droved than to the gate of the terminal.

The driver then entered its code and the bar at the gate was lifted up. The driver then drove to an instructed place for loading and unloading. The drivers then turned off the engine and entered a white box where they pressed a button. A straddle carrier received the signal a drove to the truck. The straddle carrier lifted up the container and drove the container to it dedicated position and place it in the yard. When the container was loaded, a light in the white box was turned green and the driver entered the truck and drive out of the gate.

Continuing with Norrköping, if the truck was pre-advertised the trucks drove down to the gate of the terminal and the driver walked into the gatehouse where the driver entered the booking number and their identification. The driver than received a map of where they should drive to drop up the container.

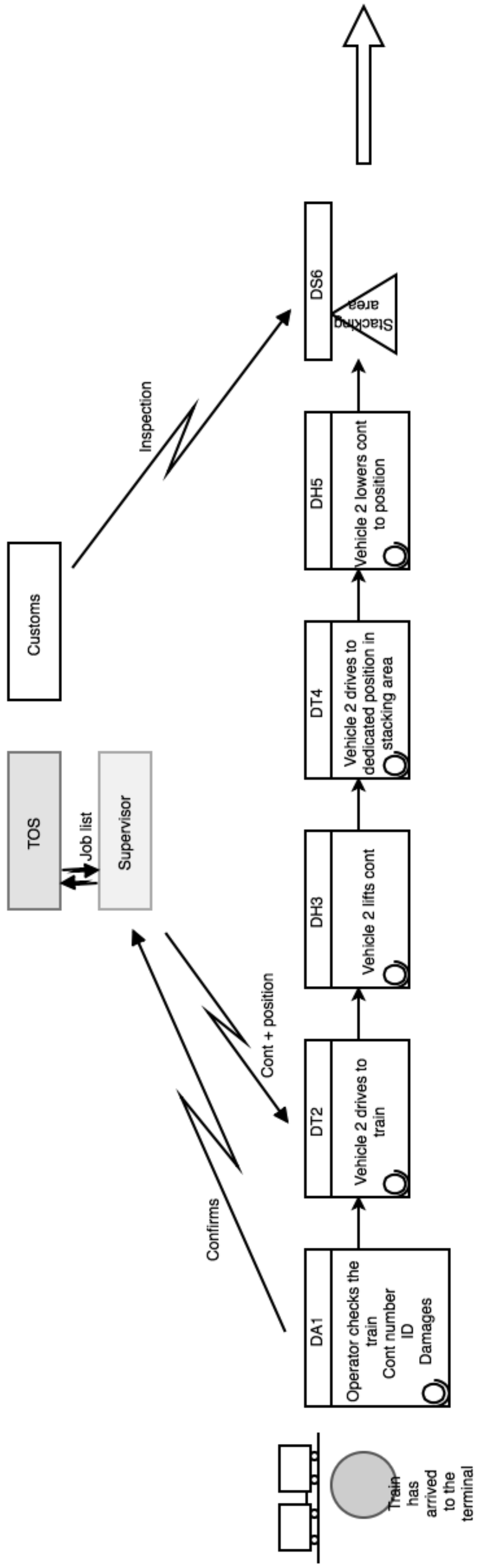

Figure 27. Mapping of the process of unloading a train in a terminal.

The operations of unloading a train, in figure 27, were performed in the same way in all four terminals. There may be differences if the arrival of the train was known early in the process, then the operators had time to prepare the loading process of the train through putting out the dedicated containers at the train tracks in advance. This will imply that, when the train arrived, the vehicle 2 loaded the containers right beside the train tracks onto the train, speeding up the loading process. This preparatory work was more prominent at APMT Gothenburg compared to the other terminals.

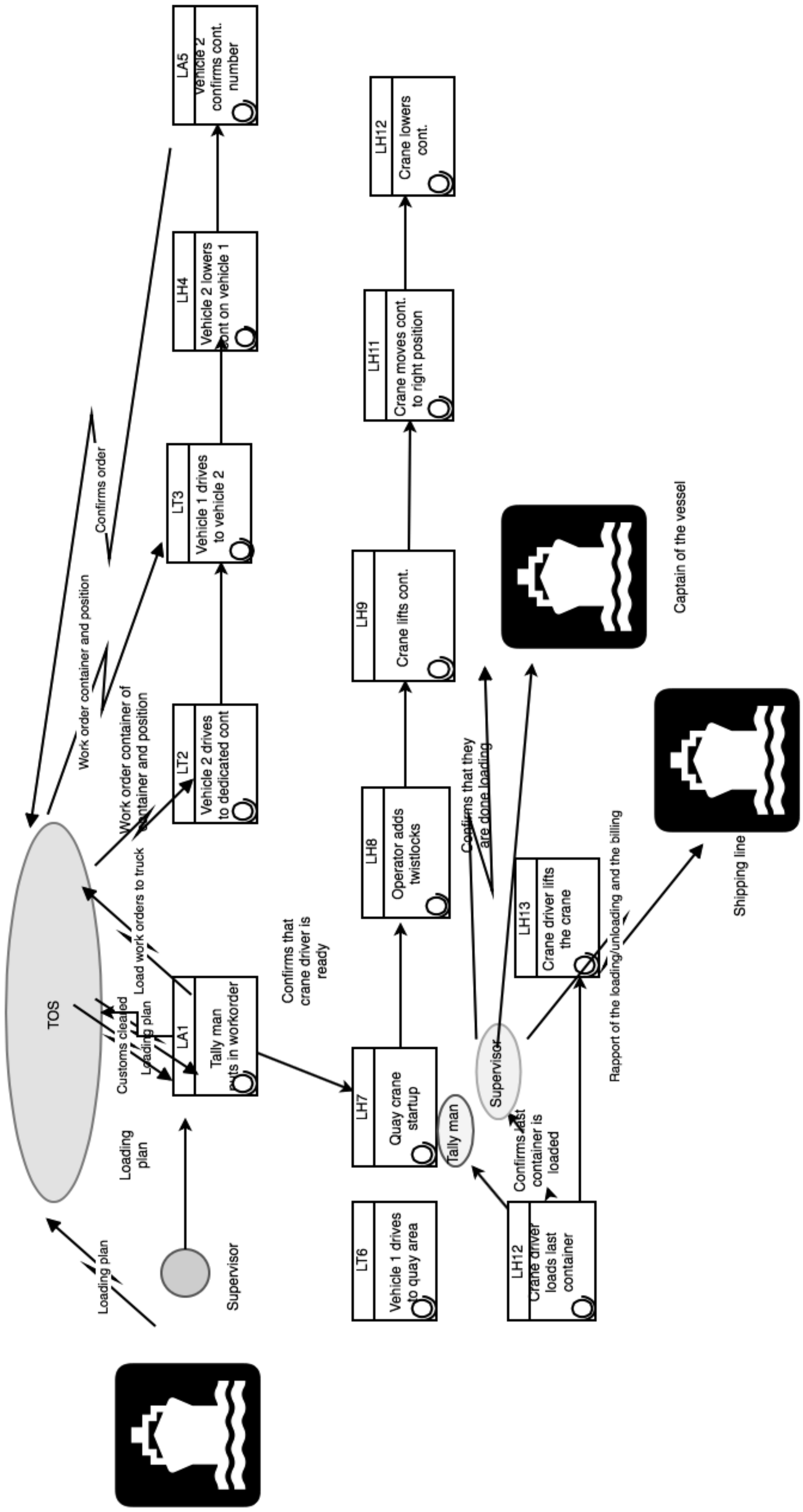

Figure 28. Mapping of the subprocess of loading a vessel in a terminal.

The supervisor initiated the subprocess of loading a vessel in a terminal, seen in figure 28. The maps illustrated how the operations were conducted in Helsingborg, Norrköping and Noatum Valencia. The operations were conducted differently at AMPT, Gothenburg since only one vehicle was used instead of two.

To summarise, the figures 26-28 start with the arrival of the feeder vessel, train or truck, arriving with a container. The container was then transported with some type of vehicle to the stacking area. The container was then transported to the quay area and loaded onto the vessel with a quay crane.

4.2.3 Description and Motivations to the Current State Maps

In this section, the motivation behind certain decisions, such as the level of detail and where the boundaries for both the material and information flow should be set in the current state, are discussed. In addition, descriptions of the information systems, KPIs and equipment used in the terminals are presented.

4.2.3.1 Boundaries for Material- and Information flow

Nash & Poling (2008) suggested that the scope of the VSM should be decided based on the stakeholder who the mapping is aimed for. Since this mapping should be made primarily for the employees of the container terminal, only activities that they can control should be mapped. First the boundaries of figure 22-24 are discussed and then the boundaries of figure 26-28 are described. In table 9 you can find the decisions on when the starting and ending boundaries appear for the unloading process.

Table 9. Starting and ending boundaries of material and information flows for unloading for all terminals.

Unloading	**Quay**	**Truck**	**Train**
Material flow Starting	The land bridge is placed on the quay	N/A	N/A
Material flow Ending	N/A	When they pass the gate	When they start to leave the area of the
Information Flow Starting	When the operators of the terminal receive information about the specific loading/ unloading	Either when the truck driver has pre-announced its arrival or when they put in their order number	When the terminal receives a list of which container that should be loaded
Information Flow Ending	N/A	When the driver has confirmed that everything is in order	When the terminal has confirmed that everything is in order

Starting off with figure 22-24, the container arrives with the vessel and the container leaves the terminal either by truck or train.

Based on interviews and observation from all of the four terminals, the material flow should considered to start when the landbridge is placed on the quay, since it is first then the container terminal is in control. This starting point is considered to be valid for all of the four terminals. Concerning, the ending boundary of the material flow should be set using the same logic as for the beginning of the boundaries, namely when the container terminals are in control of the operations. Therefore, the ending of the maps for the material flow should be set for the trains, when the train start to leave the area of the terminal. The same applies for the trucks.

Continuing with the information flow, it was more difficult to set a specific boundary since a port is a part of a transport chain. In addition, since regular shipping lines operates the container vessels, they arrive on an agreed day. This means that the container terminals have contact with the regular shipping lines regularly concerning the volumes and time of arrival and it can sometimes be difficult to know the starting point of the information flow concerning a specific vessel operation. Often the berth planner carries fist out some sort of preliminary plan on estimated volume, than contacting them at a later time and then a final time to confirm the order.

AT APMT Gothenburg the berth planner makes a preliminary plan on estimated volume for the next two weeks. He contacts the shipping line to confirm the preliminary orders on Friday the week before and then the shipping lines have until ten o'clock the day before arrival to place a final order of volume and estimated time of arrival. The berth planner then answers with a departure time for the vessel. However, the volumes and the split between import/export and loaded/empty containers may have changed when the vessel arrives.

In Helsingborg and Norrköping the production manager makes a rough planning the week before and do not have any specific time for a final order. Hence, it is suggest that the starting boundary of information flow should be set when the terminal has the first contact with the shipping line concerning the specific unloading. Continuing with the ending boundaries of the information flow, it is suggested to be set when the port no longer can affect any decisions regarding the cargo.

Starting with the train, the end boundary should be set when the containers have been checked to make sure that everything is in order, hence when the train driver receives information that everything's in order since the terminal do not have any more responsibility of the cargo. Concerning the trucks, the end of the information flow is recommended to be set when trucks leave the gate after it is confirmed by the port that the driver have picked up the right container.

Continuing with figure 26 and 27, the container arrives by, either truck or train to the terminal and leaves the terminal with a vessel. Table 10 presents a summary of the starting and ending boundaries of material and information flow for loading.

Table 10. Starting and ending boundaries of material and information flow for loading.

Loading	Quay	Truck	Train
Material flow Starting	N/A	When the truck arrives at either a central gate or a gate in the terminal	When the train has stopped within the terminal
Material flow Ending	When all of the containers are loaded and placed in its right positions	N/A	N/A
Information Flow Starting	N/A	Either when the truck driver has pre-announced its arrival or when they put in their order number	When the terminal receives a list of which container that should be loaded
Information Flow Ending	When the terminal has sent the rapport of the loading/unloading process to the shipping line	N/A	N/A

Starting with the boundaries for the material flow, the starting point for a truck should reasonably be drawn when the container terminals have control of the operations similar to the logic used for unloading. In Noatum and Helsingborg, the starting point for the material flow should reasonably start when the trucks are at the gate in the terminal. In APMT Gothenburg, the most reasonable starting point for them is when the drivers announce themselves at the central ID control. In Norrköping, assuming that the drivers have put in the order in advance, it should be set when the driver is standing in the queue on the terminal. Regarding the trains, the starting boundaries for the material flow should be when the train has stopped within the terminal.

The ending boundaries of the material flow should also follow the logic that the container terminal should have control over the boundaries. Hence, the ending boundaries of the material flow should be put when all of the containers are loaded and placed in its right positions in the vessel. However, this last step depends on if the containers has automated twistlocks or not or if it is the crew of the vessel or the operators of the terminal who secure the twistlocks.

Concerning the information flow, the starting boundaries for trucks depends on if the truck drivers/road carriers inform the terminal in advance of their arrival or if they just show up at the gate entry. Furthermore, the starting boundaries for trains depend on when the operators receive information of the containers carried.

4.2.3.2 Level of Detail

According to Nash & Poling (2008), the purpose of the VSM should be the focused on the detail that stakeholders are interested in. Hence, the stakeholders' interest should determine the level of detail. However, there is a trade-off between how detailed the map should be and how easy it should be to overview. In this project some areas are considered more interesting and has been described more thoroughly than others in the mapping. If all operations were to be described equally detailed, the map should be very extensive and thus difficult to follow.

Therefore, areas, that are more interesting from this perspective, should be described in more detail. Areas that can be affected or improved are those that are the most logical to describe more in detail in the mapping since one of the purposes of lean is to improve (Serrano Lasa et al., 2009). This recommendation is given for production and transactional industries, however it works for the shipping industry, as well as out of the author's' own observations in the four studied ports.

One example is the operations around placing a container at its dedicated area in the stacking area. Either it can be seen as one single operation, namely movement of the container to the right place including the immersion. However, it can also be described more detailed consisting of several operations namely the lifting of the container, movement of container, immersion of container to its dedicated place and then releasing the vehicle. This decision should be based on what is interesting to evaluate.

The same problem applies for crane operations. If the crane is not automated it can be important to map smaller operations around the crane affecting the downtime and replacement time i.e. the time spent for crane drivers to prepare for their shift and to climb up to the crane. The stakeholders might have an interest in shortening downtime and replacement time to reduce costs.

4.2.3.3 Information Systems

Container terminals have become a more complex environment (Charlier and Ridolfi, 1994) where information needs to be exchanged between involved actors in real time thus there is a need of a good terminal operating system. The studied ports use different terminal operating systems, however it seems the systems are not satisfying and therefore additional information systems are required, such as radio communication.

The terminal operating systems should be so reliable that no extra informal information system will be needed, however the difficulty lies in stating the right parameters for the terminal operating systems. This makes the mapping of the information flow difficult to get an overview of and understand how it is happening. This applies both to the contact with the external actors as well as internal communication between the staff.

All studied ports used truck computer to communicate which containers should be picked and suggested a place for a container in the yard, however, in all of the ports manual changes could be made and was used frequently. Walkie-talkies and radio were also used in all ports to communicate in the shift. Table 11summarises the different TOS used in the terminals and their functions and what the systems are optimising on.

Table 11. Different TOS used in the terminals.

Terminals	TOS	Functions	Optimising on
APMT Gothenburg	NAVIS	Yard planning	Time at quay for vessels, distance for equipment.
Helsingborg	PortIT	Yard Planning	Shipping line, type and size.
Noatum Valencia	CATOS	Yard planning	Don’t optimize on anything.
Norrköping	PortIT	Yard planning	Don’t optimize on anything.

The four studied container terminals used different IT systems as presented in table 11. At APMT Gothenburg, there has recently been a change in system from CATOS to NAVIS, however, this new system is not as appreciated by some stevedores, mainly since new system lacked a graphical interface to gain an overview of the container park. This implies that it is more difficult to visualize where the container is. However, this can be a matter of habit since it is still possible to use the new system, and it can be seen as resistance to learn a new system due to built-in resistance to change.

Both in Helsingborg and Norrköping the system PortIT is used. In Norrköping there appears to be a satisfaction with this system, except the built-in GPS system since sometimes it presented incorrect coordinates of the vehicle’s position. The main reason why the GPS showed incorrectly coordinates was, as a tally man in Norrköping explained, the ground in the container park was not completely horizontal. The heavy vehicles torn the ground causing minor slopes that, affected the position of the container. The stacks might tilt a few degrees and the GPS position might then be a bit different.

In Helsingborg they are becoming more and more controlled by the IT system, however the stevedores are more used to place containers completely manually causing some resistance of letting the IT system control their work. Noatum is currently using a ten year old version of CATOS which does not have all the functions they need for their operation systems today. For instance, the system lacks an optimizing tool. There are, however, some indications that they are starting to search for a new IT system such as NAVIS.

Changing to a new TOS is a long and complex process both in terms of changing the operations in the terminal according to the system but also to be able to convince the employee to adapt to new routines, as always when change is implemented, supported by Kia et al. (2000).

4.2.3.4 Key Performance Indicators

Common Key Performance indicators (KPIs) used in VSM in the traditional industry are lead -time, cycle time and tact time (Notteboom & Rodrigue, 2009; Ohno, 1988). Many of the traditional KPIs related to VSM were not used in the studied terminals, seen in the table 12.

Table 12. KPIs used in the terminals.

Terminals	Lead time	Tact time	Cycle time	Throughput time
APMT, Gothenburg	No	No	No	Yes
Noatum Valencia	No	No	No	Yes
Port of Helsingborg	No	No	No	Yes
Port of Norrköping	No	No	No	Yes

It was indicated from the interviews that lead-time is not among those KPIs that is thought of as the most important one, and was not mentioned at all in the interviews. One of the reasons of not measuring lead-time is, since the terminals are in the middle in the supply chain, they do not receive customer orders similar to the manufacturing industry.

Continuing with tact time, in the manufacturing industry the tact time is a hot topic, namely to produce in line with the customer demand (Ohno, 1988). In the container terminal one should view the rate containers are handled, required by the customers compared to the cost of operating in that tact to determine the optimal tact of handling the containers. Hence, all off the terminals should measure the tact time.

Moving on to the cycle time, according to the respondents, this measurements was not used in none of the terminals and since it measured, how frequently a finished unit actually comes off the end of the process it might be tricky since the end of the process may be counted to 3. The end of the loading process, can be viewed as when the vessel departs and the end of the unloading process can be viewed when a container departures by the train. It might be difficult collect and monitor all of the three different and compare them since the vessels and trains departure on time schedule less frequent than trucks, but carries more containers compared to the trucks. Hence, cycle time might not be an appropriate KPI to use.

Finally, all of the terminals measures through-put time, how long time it takes for a container, from when the container enters the terminal until till it departures from the terminal. This measurement is important to measure, even if the time mainly consisting of the time in the stacking area, since it affects the filling rate of the container terminal.

Instead many of the respondents from the interviews stated that they consider other KPIs, presented in table 13. All of the terminals used some sort of measurements relating to the movement of the containers by the quay crane per hour. This measurement provides information concerning the time needed to a loaded/unloaded a container vessel. The main reason of using this measurement is that this is what the customers are paying for. In Noatum one important measurement is moves per hour, namely GMPH (Gross Moves Per Hour) namely how many container that is moved per hour, and GMPH measures the cranes' performance. Other measurements used to evaluate the performance at the BMPH (Berth Moves Per Hour).

Table 13. Examples Used KPIs in the terminals divided on the areas of the terminal.

Terminals	**Quayside**	**Yardside**	**Landside**
APMT Gothenburg	GMPH	Filling rate Number of moves	Queue time for trucks
Noatum, Valencia	GMPH BMPH Percentage of delays	Percentage of unproductive moves Utilization of equipments Equipment moves per hour Ratio of equipment dedicated to cranes Filling rate	Truck turn-around time Transactions in a period of time Peak factor
Port of Helsingborg	Crane moves per hour	Number of lifts	N/A
Port of Norrkoping	Crane moves per hour	N/A	N/A

Continuing with KPIs at yardside, all of the terminals apart from Norrköping use some sort of measurement of counting the total number of lifts required handling a container. In addition, APMT Gothenburg and Noatum Valencia also keep track of the capacity of the yard area. The capacity of the yard is usually measured as the filling rate and is an important measurement since it depends on how many containers that are in the stacking in relation to empty places. According to the Business Development Manager and Commercial Manager Rail in APMT, the optimal filling rate of their stacking area is 75-85 %. If the filling rate is higher it is difficult to operate, and if the filling rate is lower it is an indication that either the volume handled is lower than expected or that the containers stay shorter time in the yard than expected. The decreased volume of the containers may depend on less volume in total or a delayed vessel. Hence, it seems to be a trade-off between the capacity of the port and how many containers that are managed within the port.

For instance, in APMT Gothenburg the area of the terminal is relatively limited since the area is expensive and there is a large competition with other actors interested in renting the area. At the same time APMT Gothenburg manages a relatively large amount of containers each year (about 800 000 TEUs/year). This implies that the challenge is within optimising the utility of the existing available surface. However, in Helsingborg the area is no limiting factor. The container operations have increased recently, and the limiting factor is rather the assortment of equipment and vehicles.

Continuing with KPIs at the landside, both APMT Gothenburg and Noatum Valencia use measurements to evaluate the performance of at the landside operations, primarily KPIs related to truck operation. However, from the interviews and observation no KPIs related to the train operation could be found. This might considered to be strange since the terminals usually have signed contract with them. However, since the containers arriving or departure to the terminals corresponds to a minor share in all terminals except in APMT Gothenburg where the share of containers transported by the train corresponds to a larger share.

4.2.3.5 Equipment

In the mapping of the current flow it was decided not to state any vehicles used since it varied for the four studied ports, thereof the use of "vehicle 1" and "vehicle 2" in the maps. The ports have different characteristics where certain vehicles or equipment fit differently well due to working load, space, tact, flexibility, cost etc. It can be concluded from Kozan (2000) that the choice of equipment in a terminal is an important decision that should be matched with the terminal's characteristics. Therefore the choice of equipment has been evaluated further.

Table 14. Equipment used in the different terminals.

Terminal/Process	APMT Gothenburg	Helsingborg	Noatum Valencia	Norrköping
Lifting to and from vessel	STS crane	STS crane	STS crane	STS crane
From quay to yard	Straddle carrier	Yard truck	Yard truck	Yard truck
Lifting to and from yard	Straddle carrier	Reach stacker	RTGC	Reach stacker
From yard to truck	Straddle carrier	Reach stacker	Reach stacker	Reach stacker
From yard to train	Straddle carrier	Reach stacker	RTGC+Reach stacker	Reach stacker
Lifting to and from train	RMGC	Reach stacker	RTGC+Reach stacker	Reach stacker

Another aspect to consider when it comes to equipment is the size of the yard of a terminal and the height of the container in the stacking area. The height of the staple of the containers depends on the volume of containers handled, the available area in the yard, the equipment used in the terminal, how much pressure the quay can handle and how often shifting containers are required.

For instance, by using a reach stacker the terminals are able to stack the containers rather high, however they require much space to manoeuvre. By stacking more containers on top of each other the space required to store container decreases, though the need for shifting containers may increase by the increased height of stapled containers. Shifting containers results in more time-consuming operations and slows down the flows.

The equipment used in the terminal also affect how interfaces, namely how many points in the process where the equipment used for transporting, the container is changed in the handling process. An increased number of vehicles used to handle containers in the process results in an increased number of interfaces resulting in increased difficulties to coordinate the equipment in order to achieve a continuous flow.

The figures 29 illustrates how the choice of different equipment affects the number of interaction points and thereby the number of interfaces between the subprocesses.


= Flow of Equipment


= Flow of containers

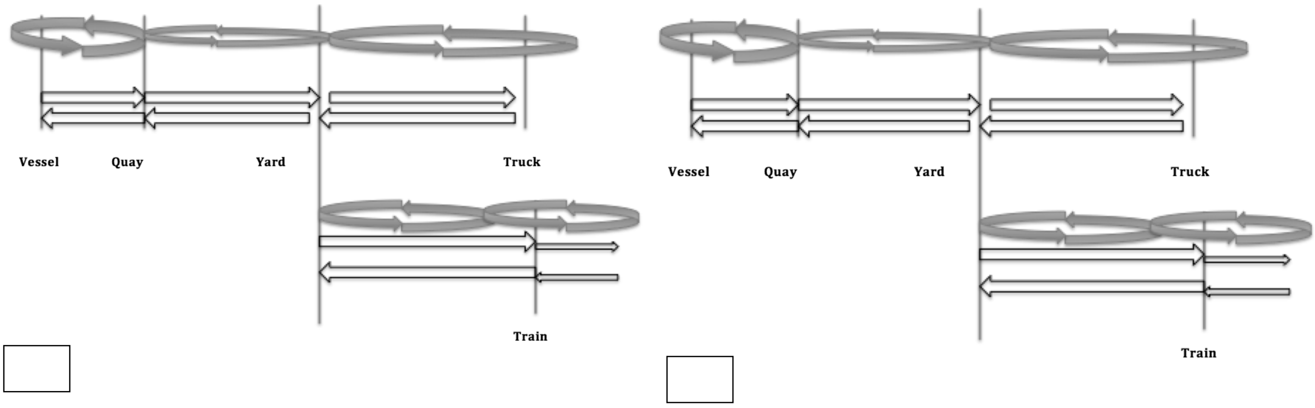

Figure 29. The flows of equipment and containers and the numbers of interfaces in APMT Gothenburg (1)

Table 15 provides a summary of the number of interfaces in each terminal is presented to demonstrate the differences depending on the number of vehicles used.

Table 15. Number of interfaces in each terminal.

Terminal	**Number of interfaces, quay to yard**	**Number of interfaces, yard to truck**	**Number of interfaces, yard to train**
APMT Gothenburg	1	1	2
Noatum Valencia	2	1	1
Helsingborg	2	1	1
Norrköping	2	1	1

4.3 Assessment of Current State

The assessment of the current state can be considered to consist of the two different parts. The first parts consist of the division of operation into value adding operations, non-value adding operations, and evaluation of waste and identification of inefficiencies causing the wastes. The second part consists of the transition from the current state to the future state.

4.3.1 Analysis of Value Adding operations and Non-Value Adding Operations

In this section the different operations are divided into value adding operations and non-value added operations according to Hines & Rich (1997). However, in Hines & Rich (1997) division, necessary but non-value adding operations are included, however it is excluded here since the necessary but non-value adding operations are often referring to the wastes resulting from current structures that are difficult to eliminate in the short term. In a terminal environment, many of the changes required are long term solutions such as changes in the area and the change of equipment.

4.3.1.1 Value Adding Operations

Value Adding (VA) operations can be considered as operations that are value adding for the customers, namely operations that the customers are willing to pay for. From some of the interviews (COO at Helsingborg, Production Manager at Norrköping, Project Manager at Noatum, Berth Planner at APMT and Operations Execution Manager at APMT) it can be concluded that the lifting from the quay to the vessel and the opposite are what the customers are paying for. The same applies for the storage time of the containers in the stacking area as mentioned by several respondents (Sales Manager at Norrköping, Project Manager at Noatum, Berth Planner at APMT and Operations Execution Manager at APMT), since this is included in the terms and price negotiated with the shipping line. In addition, some of the respondents mentioned that they also charge the shipping lines of the number of moves they need to move the containers within the terminals with the purpose of transporting the container from one transport mode to another (Berth Planner at APMT Gothenburg, Project Manager at Noatum and COO at Helsingborg).

Other operations considered to be VA operations in terminals, are checking the state of the container, the sealing and control that the correct containers enter and leave the port, either by the gate, by the vessel and by the train. This can be considered to be value adding since it ensures a correct transfer of the cargo. The sealing of the container is generally checked when the container enters and leaves the terminals however, it is not checked in all cases. From the terminals' perspective this might be of interest if wanting to ensure that the container was correctly handled in the port, i.e. that no one in the staff at the terminal tampered with the cargo. However, it is even more interesting for the train carriers, the shipping line and the road carriers to make sure that everything is in order when they take over the responsibility. If the next transporter in the chain wishes a more careful checking of the sealing, it needs to be developed in collaboration with the terminals to minimise the disturbances of the flow.

Other operations considered to be VA operations are weighing and container repair, extra services offered by all of the studied terminals at an additional cost. Since last year, a new regulation regarding the containers weight was imposed. The consequence of this regulation is that all containers need to have a confirmed weight on beforehand since extensive cheating occurred earlier, jeopardizing the security on the vessels. The weighing took place when the container was lifted to the stacking area by various equipment.

The terminals usually had an external part in connection to the terminal, performing container repairs and the terminals were paid for the extra lifts and transported to and from the stacking area. This can also be considered as VA since it is a service that the customers have chosen to pay for.

4.3.1.2 Non Value Adding Operations

NVA operations are operations that do not add any value to the customers and can be considered to be pure waste. The NVA operations are analysed from the eight wastes identified by Liker (2004). In addition, the underlying problems, inefficiencies causing the wastes are evaluated.

(1) Overproduction

There are different perspectives on the term overproduction in a container terminal. One perspective is that the real customer demand can be considered to be the number of containers the terminals handle annually. Since all of the cargo was passing through the container terminals is requested by someone there is never any overproduction in a container terminal. However there may occur an underproduction when containers are not loaded/unloaded on vessels, trains or trucks as requested due to the inefficiencies in the internal handling.

Another perspective on overproduction in a container terminal is to view the terminals as production sites where containers are produced in that sense that they are loaded and unloaded on the vessel. In this perspective, overproduction may occur if the terminal works in a faster tact than requested from the customers.

Overproduction is therefore here defined as working in a faster tact in the terminal than the optimal tact time that can lead to overstuffed yards and unnecessary shifting situations. Overproduction may be a symptom of inadequate forecast and lack of system understanding. The inadequate forecast, namely poor anticipating or not knowing the future demand may cause inadequate resource allocation resulting in working either too fast or too slow in comparison to the optimal tact.

In addition, overproduction might be seen as a symptom of the lack of system understanding when not taking the current resources available or the optimal tact time into consideration when signing contracts. Furthermore, the terminals need to communicate the need of working at a constant tact to the stevedores. However, since delays of vessels occur frequently the working pace needs to be adjusted in these situations in order to keep the optimal tact. Figure 30 presents the inefficiencies causing overproduction.

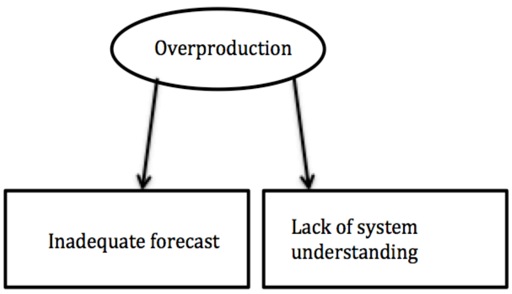

Figure 30. The waste overproduction and its derived causes.

(2) Unnecessary Waiting
In the operations of handling container, unnecessary waiting was identified, caused by both external and internal factors.

External factors
The waiting time derived from external factors include delays of vessels and train. Delays of train and vessel compared to estimate arrival time can be considered a waste since it difficult to start up anything without them in place. As a consequence, the labour force is paid for not producing anything. For instance, if the delay is less than an hour it might not be useful for stevedores to carry out any other tasks in the meantime. In addition, if the delay is more than a couple of hours, it might be difficult to find other meaningful tasks. The terminals possibility of utilize its labour force depends on how their collective agreement is stipulated and if the terminal has other businesses such as stuffing and stripping or the stevedores can help out in other areas.

Continuing with delayed train, preparation work may be carried out by moving the containers besides the train rails. However, this only worth doing if container are a bit further away as it is the case in APMT Gothenburg and does not require an extra lifting or do not save any time. Waiting time may arise depending on when the trucks arrive to the terminal. This could happen in four cases. The first case is if the truck that should deliver a container that should be loaded onto the vessel and is either placed on the vessel in such manner that they cannot continue to load the others until it arrives. The second case is if all of the other containers are loaded and the vessel is waiting for this last container that is delayed and is preventing the stevedores to start with other tasks.

The third case is when the terminal experiences a low peak and the stevedores need to wait before they can serve a truck. The same problematisation applies for when a train or vessel is delayed. The fourth case is when the truck drivers are not driving correctly in the terminal and prevent the employee from operating.

Another external factor, that can contribute to unnecessary waiting is waiting for electronic documents to be approved, both custom clearance, the customer fills in on the web, and the release order that needs to be approved by the shipping lines. The containers are not allowed to leave the terminal if these papers are not approved. In some cases, if there are not ready in time, the vessel or the train excludes the containers, however in some cases they wait for them. If they decide to wait for the container this can prevent the stevedores to finish the loading process of a vessel or a train resulting in unnecessary waiting time. From interviews with all the terminals it was noticed that this happens but it was not clarified how often this occurs. Other external factors contributing to unnecessary waiting time are when the crew of the vessel are not finished with the preparation, such as unlocking all twistlocks and slow down production speed by being in the way. This problem was identified both in Helsingborg and Norrköping.

Internal factors
Internal factors contributing to unnecessary waiting are mainly found in the interfaces, namely when the equipment handling a container should be changed. Starting off from the vessel, it was observed that the crane driver in Norrköping needed to wait for a yard truck before the crane driver could continue working. The next interface where unnecessary waiting occurred was when the reach stacker need to wait for the terminal tractor to arrive with the

container. The problems was observed all of the terminals except in Noatum Valencia. However, the same problems also occurs there.

In addition, depending on how the processes for loading the train is carried out, this interfaces may arise to unnecessary waiting time. For instance, if the crane in APMT Gothenburg needs to wait for the straddle carries to receive a container in order to be able to continue the loading process.

Furthermore, waiting time may occurs for vehicles at the quay , if problems arise if the manual twistlocks are stuck in the locking position and takes longer time to remove them. Transportation also affects the waiting time since insufficient planning in transports will lead to queues and extra time spent for vehicles in a certain position. Another internal factor causing unnecessary waiting time is if the stevedores are not ready in their positions when a train/vessel or trucks are ready to be unloaded/loaded.

Unnecessary waiting can be derived from lack of synchronisation, causing waiting time in the interfaces, lack of communication and information resulting in unutilized labour force and insufficient resource allocation i.e. too few vehicle serve the vessel/ train compared to the pace. Figure 31 presents the inefficiencies causing unnecessary waiting.

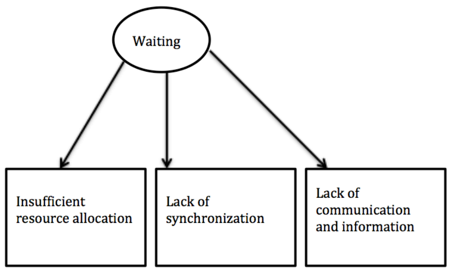

Figure 31. The waste waiting and its derived causes.

(3) Unnecessary Transportation

Transportation is here defined as all transfer with vehicles, with our without a container. It has been concluded that some transportations are necessary in terminals, due to the need of internal movement of containers. However, transporting longer distances than necessary is considered a waste. This can appear either when a container is not in the right position, meaning that the vehicle must drive and search for the container. In addition, the same situation can also appear when container should be placed in the stacking area. There is a risk that the dedicated position is already taken due to human or system error and when the vehicle needs to search for another free position.

As stated before, transport is included in the offered services at terminals, and cannot be considered waste due to its dependence and connecting purpose. In every terminal an optimal stacking layout can be obtained where all sections are placed according to shortest distance to next step in the chain. In that case an optimal stacking layout is obtained, no waste should exist in the transport as long as all transports are performed correctly without any re-routes or mistakes. However, in some of the cases, the terminals does not know the next step in the chain, especially concerning the import flows. This hinders the terminals from placing the container in the most optimal space.

Unnecessary transportation may be seen as symptom of the underlying problem of an inadequate TOS, either that it does not take the driving route into consideration when providing jobs or if the TOS do not take into consideration of how the container is leaving the terminal. In addition, unnecessary transportation may arise as result of lack of system understanding, for instance when the stevedores deviate from TOS. The main reason why the stevedores deviate from TOS is since they may believe the new position of the container is better than the one suggested by TOS.

Another factor contributing to unnecessary transportation is lack of information and communication. For instance if a stevedore makes a decision of placing a container in the positions that he or she considers to be best way but has no idea when the container and how the container is going to leave the terminal. This results in unnecessary transportation later.

Furthermore, another important factor that causes unnecessary transportation is if two drivers take the same job and drives to the same container due to lack of communication. In addition, if the terminals should be able to place the container in the most optimal position they need to know which transport mode the container should be transported further. However, currently they often lack this information. Finally, the terminals do not often know the precise time when the trucks will pick up a container or leave a container; if they had the information they would be able to place the container in a better position. Figure 32 presents the inefficiencies causing unnecessary transportation.

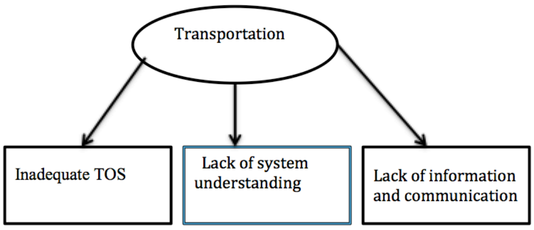

Figure 32. The waste transportation and its derived causes.

(4) Inappropriate Processing

Inappropriate processing in a terminal environment can be considered as either having excessive equipment or using the wrong type of equipment. From the interviews and the observations it was observed that some of the terminals had purchased an excessive number of quay cranes based on the volume terminal handles. This may result in that a quay crane is not used most of the time. In some cases, for larger vessels or for more urgent orders, more than one crane might be needed to operate faster, and in these cases there is a need for the complete fleet of equipment. If these cases occur frequently, there is a need for more than one crane. However, if these cases only happen on rare occasions, having an excessive and expensive crane that is not used much may be considered to be inappropriate processing. This applies to all excessive equipment in a terminal.

Inappropriate processing can be seen as symptom of inadequate forecast and insufficient resource allocation. Inadequate forecast implies not knowing the volumes of the future demand, and hence not knowing how much capacity the terminal must offer to the customers. For a smaller terminal, the depth at the quay is limiting them to serve larger vessel and miss out of volumes even though they have invested in solid and many cranes. The equipment fleet should be adopted towards the future demand generated by an adequate forecast.

Concerning insufficient resource allocation, there is a risk that available equipment is not utilized in the most optimal manner. If several options exist with different characteristics on lifting capacity and driving distance, insufficient resource allocation may imply that more vehicles are used than necessary and thereby creating critical interfaces. Figure 33 presents the inefficiencies causing inappropriate processing.

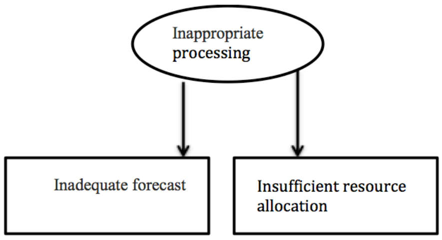

Figure 33. The waste inappropriate processing and its derived causes.

(5) Unnecessary Inventory

In a container terminal the unnecessary inventory can be identified in the storage in the stacking areas, buffers at the quay and along the train tracks. Starting with the unnecessary inventory in the storage area. The container terminal is paid indirectly to keep the container a number of days before and after they are loaded onto the vessel and this storage time can been seen as value adding. However, if the container is kept longer than stipulated in the contract, this extra storage time can be considered as a waste even though the terminals is paid for the extra days by the shipping lines. This extra income may considered to be a penalty rather than the income since the extra days increases the filling rate, resulting in increased difficulty to operate.

Continuing with the buffers at the quay, they arise if the crane is operating faster than the next equipment collects it. One example of this is at the port of Helsingborg. In some cases the stevedores need to keep a higher tact than the terminal tractors manages to pick up containers to be able to keep the departure time for the vessel. This is a consequence of that the distance that the container should be transported is longer compared to the number of vehicle used in that process. Hence, a buffer is created along the quayside.

In addition, buffers along the train tracks arise when the stevedores starts to prepare for the arrival of the train by placing the container along the tracks or when containers are being loaded besides the train tracks waiting for the equipment to transport them to the stacking area. An example of when this occurs is at the landside in APMT Gothenburg (Operations Execution Manager at APMT Gothenburg). The buffers arises since it takes longer time for the straddle carriers to fetch or leave the containers in the stacking area compared to the time it takes for the RMGC to load/unload the train.

There are many reasons to this time lag, one is that the distances are rather long in comparison to the number of straddle carriers used and that it is not always known if the container should leave the terminal by when it is unloaded off by the vessel. As a result the container may be placed unnecessarily far from the rail tracks.

The main reasons identified of why these unnecessary buffers arise are lack of synchronisation, insufficient resource allocation and lack of communication. If synchronisation between truck drivers and stevedores is functioning poorly, containers may be placed in inconvenient positions that may limit the accessibility to certain places. In addition, by insufficient resource allocation is referring to the situations when utilizing too few equipment for the operations in question to maintain the desired tact time to avoid temporary buffers.

Finally, lack of communication can refer to the situation arising if the terminal isn't informed enough by truck or train carriers about for instance delays, the containers may be placed in a poor position for upcoming containers since it was anticipated to be transported further. Figure 34 presents the inefficiencies causing unnecessary inventory.

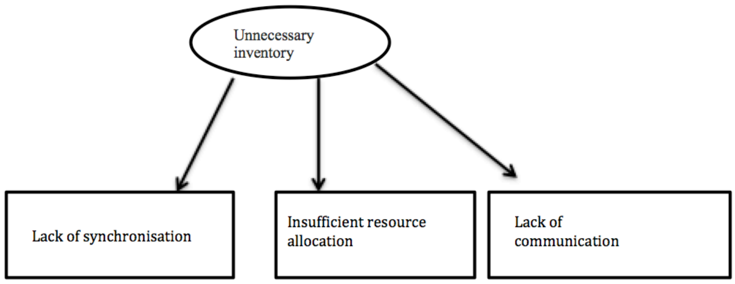

Figure 34. The waste unnecessary inventory and its derived causes.

(6) Unnecessary Motion

Motion is in this context referred as both any movement without a vehicle and the movement of a container in the horizontal way. In a container terminal most of the transportation is made in different equipment and vehicles, however there are a few situation where unnecessary motion do occur. Many examples of unnecessary motions are related to some of the tasks carried out by the tally man.

One of the tasks was unnecessary motion do occur is the removal of the manual twistlocks from the containers when unloading (this is needed for all containers that are placed above the lid on the vessel that is on top of the deck). In Norrköping, the tally man was assisted with another stevedores who removed the twistlocks from the other side of the container. If the assisting worker has to leave the position, the tally man must remove all twistlocks, causing an additional movement to the other side of the container.

In addition, another unnecessary motion identified was when there was a need to shift the containers. Shifting containers is the operation when a specific container is placed below another container and the blocking containers need to be moved to be able to reach the requested container.

Furthermore, unnecessary motion can be seen as a symptom of the underlying problems of lacking standardised working procedures, an insufficient TOS and lack of system understanding. In some of the terminals there was either lacking standardise working procedure or the stevedores did not follow them. As a result, the stevedores perform their tasks as they like and not in the most efficient manner. A result of a non-functioning algorithm in the TOS was when the container need to be shifts.

In addition, lack of system understanding may appear as the need to shift containers since this may be seen as a result of when the stevedores do not follow the TOS and instead putting the container where they think it is an optimal solution. However, at this moment they lack the information to evaluate if their opinion is better. Figure 35 presents the inefficiencies causing unnecessary motion.

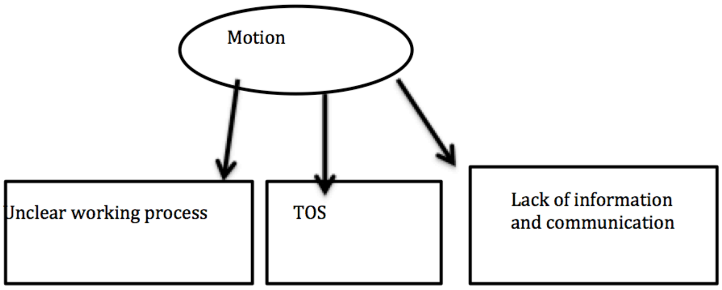

Figure 35. The waste motion and its derived causes.

(7) Defects

Defects in a terminal environment may be divided into security issues and too careless handling. In both cases, lack of system understanding is the source since it creates a general lack of understanding and perception of why it is important to consider security and to be more careful when handling the containers.

Starting off with security issues, during the observations and from the interviews in the terminals, it was noticed that problems with the sealings or container numbers do not happen often. However, if a damaged sealing was discovered within the terminal it may lead to consequences such as careful control of the content to make sure it is not tampered or denying the container off entering/leaving the terminal. This quality check should be performed for every container, however it was observed that exceptions appeared due to the human error and since it was not prioritised when there was much work to be done.

Continuing with the damage of the exterior of the container, the most common damages to the container was damages to the corner of the containers, caused by careless handling. If the container corners are damaged, it becomes more difficult to move them since the equipment lifts the container in the corners. Figure 36 presents the inefficiencies causing defects.

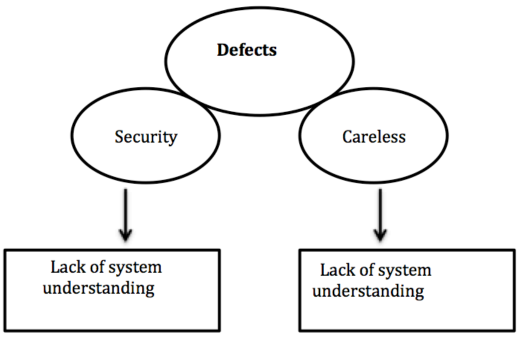

Figure 36. The waste defects and its derived causes.

8) Unused Employee Creativity and Knowledge

The eight waste suggested by Liker (2004) refers to not utilizing employees' creativity and knowledge. The underlying problems causing unused creativity is identified as lack communication between different levels in the organisation, where there tends to be a segregation between some levels complicating the ability to communicate.

The first examples of this waste, noticed in interviews and during observation was, in many of the terminals the stevedores did not have a structured way of either evaluating the work of the shift, or passing on important information to the next shift concerning on how the work had proceed or if any deviation had occurred. This may seem a bit strange since, even though the new shift workers can continue the work in the terminals without knowing certain details, exchanging information may also bring up some new ideas or changes that can improve the work further.

In addition, in Norrköping the stevedores do not have personal work mail, they have one mail in common, resulting in tedious collection of the feedback. In addition, Norrköping tried to have structural meeting once a month, however the collection of feedback on those meeting did not work as well as they could. This eighth kind of waste can be more difficult to evaluate than the other seven kinds of wastes since the judgement may be subjective and it is partly about perception. Figure 37 presents the inefficiencies causing unused employee creativity and knowledge.

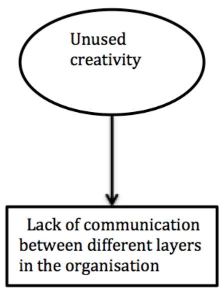

Figure 37. The waste unused employee creativity and knowledge and its derived causes

To conclude, the eight wastes and the inefficiencies are presented in the figure 38 to illustrate the connections. The eight wastes are stated and the surrounding boxes represent the main causes to the identified wastes.

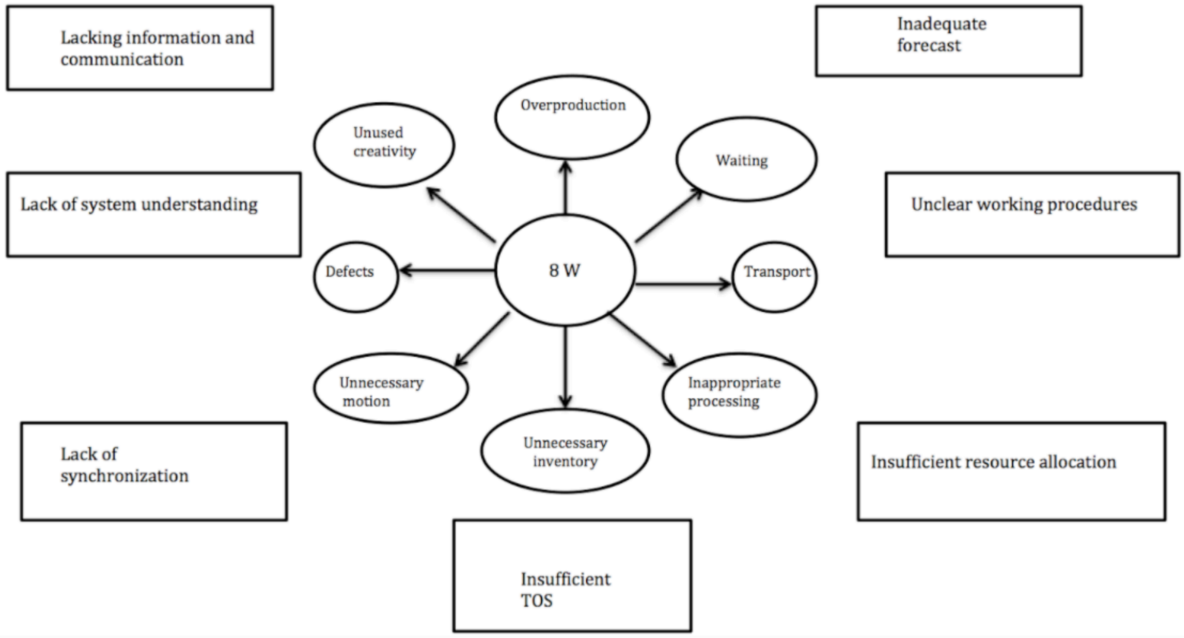

Figure 38. The eight wastes and identified inefficiencies.

4.3.1.2 How to Solve the Inefficiencies

The identified inefficiencies causing the eight wastes are; lacking information and communication, lack of system understanding, inadequate forecast, unclear working procedures, insufficient resource allocation, insufficient TOS, and lack of synchronization.

The identified inefficiency, lack of information and communication, is caused by lack of system understanding. Having a common system for all involved processes will facilitate the understanding of the processes in the terminals that automatically implies a need of a well-functioning TOS-system for all involved actors. Many operations in a terminal are depending on the success of other operations, which can be performed by someone else, demonstrating the importance of an information exchange between operations where interfaces appear.

Generally, a standardised way of working will help to reduce any undesirable variations through more unified communication channels and standard procedures. An effective way to reduce variations is implementing automatic processes, the automatic equipment can be set to certain stable values meaning fewer human errors and no deviations. Synchronisation of driverless vehicles or equipment is often easier than synchronising humans since less resistance may appear among vehicles or equipment. In addition, vehicles are more easily adopted to the workload. Despite the power of automation in container terminals, each terminal needs to benchmark the large investments required towards the gain and effects of the change.

Concerning problems with lack of well-functioning information and communication, a suggested solution is to ensure an including information exchange between actors or operators. Receiving the right information at the right time is a crucial factor for successful transitions of information and material, since the information and material flows are interconnected. Through collecting all directions of information into one channel will contribute to a decreased need of intermediaries and a better overview. Shipping lines and train carriers should be able to access the IT system used in the container terminal to place orders and make changes, instead of conveying this to an operator of the terminal who has to manually insert the values into the system afterwards. This will also help to easier identify missing information, if the system is well structured and easy to overview.

Another situation where additional information is desirable is when containers are to be stacked in the yard. One suggestion is to inform the IT system and thereby the operators where the current container is going to be moved in the next step in the process. This will contribute to a better understanding of why a container is placed in a certain way and also shifting containers can be avoided to a larger extent since containers are placed more strategically on a longer time basis. It will also contribute to a less uncertain approach to the containers where in the current situation containers can be placed on certain places in anticipation of the next movement. For instance, when containers are prepared for being loaded on a train, they are moved to beside the train tracks. With a well-functioning IT system and in addition information exchange each container can be dedicated an exact position on the train and thereby the containers can be placed directly along the train tracks according to their dedicated position on the train.

4.3.2 Transition from Current to Future state

The transitions from the current map to the future map is analysed based on the seven questions from Medbo (2016).

1. What is The Real Customer Demand?

In a container terminal the real customer demand is the handling of container demanded at the optimal tact. As stated before, the tact of handling container is specified in contracts with the shipping line. As a result it is difficult for the terminals to work in a slower tact requested by the shipping line even is if is more beneficial for the terminals.

2. To what Degree is it Possible to Achieve a Continuous Flow?

The flow in a container terminal is considered to be a continuous flow to a high degree. The process of unloading and loading a container and moving them to and from the stacking area can be considered to be a continuous flow. Likewise, the processes to and from trucks. To achieve a more continuous flow in terminals and to reduce the labour cost, implementing automation may be a good solution to remove the variation caused by humans. Grunow et al. (2004) believe in the potentials of automated vehicles in terminals as a mean to eliminate human failure causing temporary stops and waiting times and complicates the possibility of continuous flows. In Helsingborg, the only operation automated is the central gate for trucks. When requesting, the production manager in Helsingborg was skeptical of further automation of quay cranes and yard trucks for instance, as there was concern over whether something would go wrong and there would be no human being nearby. However, the Project Manager suggested that the tally man's tasks would be suitable to automate.

None of the terminals studied had any automated vehicles. This can be considered a bit surprising, especially for Noatum Valencia, since the terminals is relatively large and important terminal with a high demand, implying a need for continuous flow to level out the work load.

As Ioannou et al. (2000) claimed, many larger ports use automated vehicles in their daily work since it has been proven to improve efficiency and they recommend more ports to pursue this innovating transition. Therefore, primarily Noatum Valencia is considered to be suitable to implement automation to cope with the increasing demand and also to keep some bargaining power through offering a more guaranteed continuous flow. What is concluded to be one of the main reasons for not investing in automated vehicles or equipment is that Noatum is already up and running, and this kind of project would imply shutting down parts of the business to be able to implement the new parts.

It is simpler to automate a new terminal under construction than a terminal that is already up and running with ongoing operations, both from a cost and time perspective as the director at Lighthouse points out. Having to shut down parts of the operations in the terminal implies a decreased production during the implementation time, perhaps also at the initial phase of the new routines, since it is capital-intensive and there is a risk of losing customers due to the decreased production. In addition, there may exist resistance to change in a current terminal since there is a risk that some manual jobs will be removed.

3. How can a Pull Controlled Material Flow be Achieved?
At present the main part of the container flow is pull controlled, namely that a container is first moved when a signal is received. However, at the rail division in APMT Gothenburg, they prepare for the train by transporting the containers that are departing with the train to the train racks. This preparation can be seen as a push controlled flow. At that moment the rail division is not aware of the exact position of the containers since it depends on how much the train wagons are allowed to carry and where the container is going. By having a better information exchange with the train carriers and more vehicle in place this preparation would not be needed.

4. How can a Levelled Material Flow be Achieved?
In order to be able to achieve a continuous flow the incoming and outgoing volumes of containers needs to be levelled out. There are many factors that need to be taken into consideration when trying to level the container flow. The fluctuations of the volumes of containers that are handled can be viewed on different time horizons and depending on which horizon that is analysed. This rapport mainly deals with the weekly and daily fluctuations.
In the long term the volumes of container in terminals depend mainly on the end-consumers' demand. The demand depends on many different factors including the general trade between countries, geographical location of customers, suppliers and manufacturers, and attitude towards free trade. In addition, other factors such as choice of transport route and choice of shipping route is contributing to variations in the demand.

Looking at the long term the terminals must analyse trend patterns among the main exporters and importers passing through their terminal and how their demand and supply vary. Considering a year, the terminals needs to observe how and if the important customers have seasonal fluctuations to identify high and low peak periods. The fluctuations over the week depend on when the vessels and trains are scheduled to arrive in combination with the arrival of the trucks. Even significant fluctuations over the day occur depending on the peaks of arrivals and pickups of container by trucks in combination with the arrival, volume and the split import/export of the vessels and trains. The terminals have different opportunities to influence the peaks. The possibility to influence the peaks depends on numerous factors, namely the contracts stipulating the terms and conditions of the handling of containers, which actors the terminals have agreement with and what bargaining power the terminal has compared to its customers.

For instance, APMT Gothenburg, Helsingborg and Noatum Valencia also have contracts with the owners of the cargo apart from the shipping lines. APMT also have contract with the train carriers. Norrköping has only contract with the shipping lines. This affects to what extent the terminal can affect the peaks of the trucks. If they do have contact with some of the owner of the cargo that ships significant volume, the terminal can offer them better service or lower price if they can come during the low peaks to level out the flow. APMT display estimated waiting time for the trucks to be served depending on arrival time on their webpage, to try to influence the time of arrival to level out the flow. Concerning the shipping lines and train carriers, they are more difficult to influence since they have their routes and may have bargaining power since the terminals are dependent upon them.

To conclude, the terminals have various opportunities to try to level out the volumes of containers, however they need to cooperate with the owners of cargo, shipping line and train carriers to level out the container flow.

5. How Material Flow can be Synchronised with the Real Tact of the Customer Production Flow

This question is not suitable to apply directly to the container operations due to the lack of consuming material when producing containers. However, coordination between the different interfaces of the different flows in the terminal is needed. The number of interfaces is directly correlated to the number of equipment and organisation of the operations. During the observations and interviews it can be concluded that the more interfaces resulting in difficulties of coordination the flow and keeping a constant tact. In addition, the distance to and from the stacking area to the vessel, the trucks and trains affect the vulnerability. Hence, the decreasing of the number of interfaces do not automatically improve the stability of the flow.

6. Which Process Improvements are Needed?

The suggestions are divided into the internal and external actors. Concerning improvements for the internal actor, a better TOS would contribute to a better overview of the processes and an enabled planning for the terminal operator. An implemented function in TOS could be to be able to log any deviations such as mismatch in container positions. This would result in better control over the performance of the system and any bugs would be more visible.

To speed up the lifting operation in the terminals, it is possible to lift more than one container at once. In Helsingborg it is possible to do a twin lift, i.e. is to move two 20 feet containers with the quay crane at once. However, this requires more time spent on the manual twistlocks per lift. According to the tally man in Norrköping, implementing a twin lift function for the quay crane would speed up the movement of containers from vessel to quay, however the yard trucks would have to operate twice as fast (if still three yard trucks would be used) or more yard trucks would be needed, implying extra labour leading to an extra labour cost for the port. Still, as long as the customer demand is satisfying, there is no need to work faster than what the customer has paid for.

Concerning process improvements among external actors, a better exchange of information between shipping lines or truck or train carriers and the terminal would enable a better control over the coordinating processes and could imply a better control over the arrival of trucks and the processes of unloading and loading containers.

7. How can the Material Flow be Further Improved?
Ideas to consider are implementing more efficient transportations of containers and better tracking systems for containers. Some sort of transport conveyor could be implemented that mainly could be used in the yard area to move containers to the right positions depending on when the containers is to be moved further. This would remove all need of shifting, however such as system doesn't exist in any container terminal yet and it would imply major changes in layout and structure. In Norrköping, GPS positions are used for each position in the yard areas. An improvement could be to implement GPS position on containers, or barcodes to be able to trace every container. The limiting factor is to decide who will pay for the implementation of this system.

4.4 Future State Map

In this chapter the future state map is presented with the suggested improvements divided into short and long term improvements.

4.4.1 Mapping of the Operations of the Future State Map

The future state map is structured in the same way as the current state map, namely the same divisions of unloading and loading processes. The usage of symbols is the same for the current state map and the same level of detail and the same boundaries for the information and the material flows are used.

Many of the main improvements of the future state map, such as more and better integration of different IT systems among the most important external actors of terminal are not shown in the maps, however they are set as pre-condition of the future state map. It is assumed that the algorithm in TOS works better and the stevedores only use TOS to govern their work. In addition, the supervisor's role changes, from handing out orders caused by deviations from the system, the supervisor now receives a role of handling unforeseen events and becomes more of a support function. As mentioned before, the future state map is divided into two different maps; unloading and loading. All of the presented maps (for loading and unloading operations in the terminals) are presented in larger scales in appendix 2

4.4.1.1 Unloading

The unloading process consist of three different maps, figure 40-42, where figure 40 illustrates the operations from the vessel to the stacking area, figure 41 illustrates the operations from the stacking area to trucks and figure 42 illustrates the operations from the stacking area to the train. Figure 39 illustrates an overview of the different maps of the unloading process.

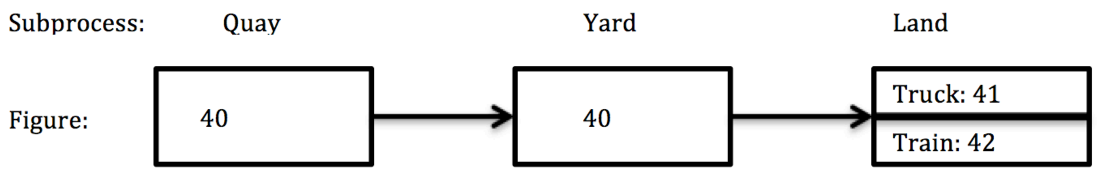

Figure 39. An overview of the different maps of the unloading process

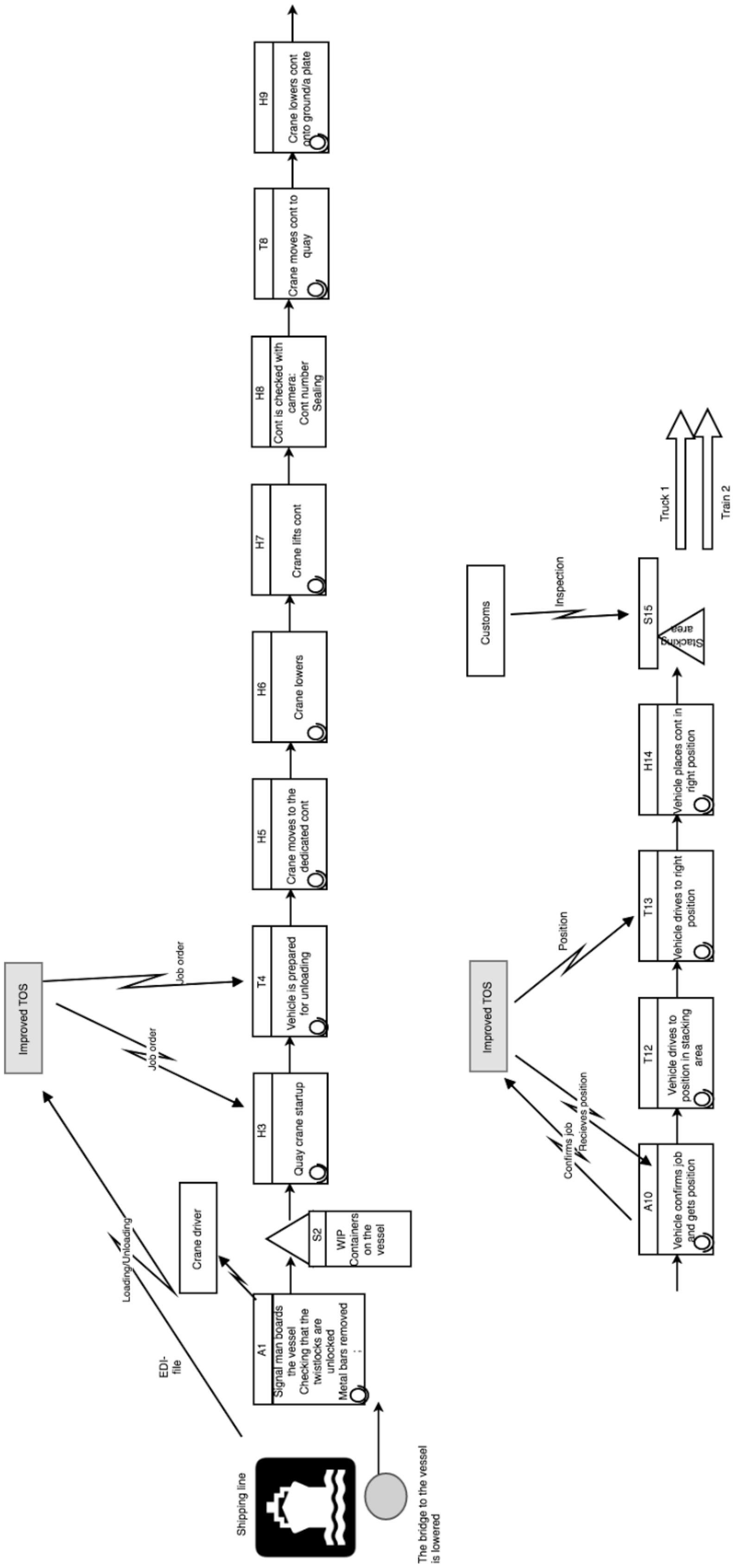

Figure 40. Operations of unloading a vessel from the quay to the stacking area.

The main differences of the operation in this map (see figure 40) to the corresponding map in current state (map 22) are that the crew of the vessel stay out of the way of the crane driver to reduce the quay team by one person. Another improvement, especially concerning Helsingborg and Norrköping, are to collaborate together with the shipping lines to remove the manual twistlocks and change them to automatic in order to be able to remove another member of the quay team.

The next improvement recommended is to automate the tallyman's tasks by introducing scanning functions, that can read the container number and match it to the a register of the incoming containers. The system needs also be able to scan the sealing of the container to make sure it is not tampered with and that the sealing number corresponds to a number put in by the customer. There must also be an image processing program that are able to determine if the container has any physical damage on the exterior.

Another improvement suggested is that all of the terminals except APMT Gothenburg (since they already have these vehicles) should consider investing in straddle carriers to limit the number of interfaces and thereby limit the unnecessary waiting time.

Furthermore, another improvement related to improved information exchanges between the actors are that the terminal requires that either the shipping lines or the owner of the cargo put in the next transportation mode in the terminals system so that they are able to dedicate specific stacking areas for container's leaving by train and trucks. This improvement would potential reduce unnecessary transportation.

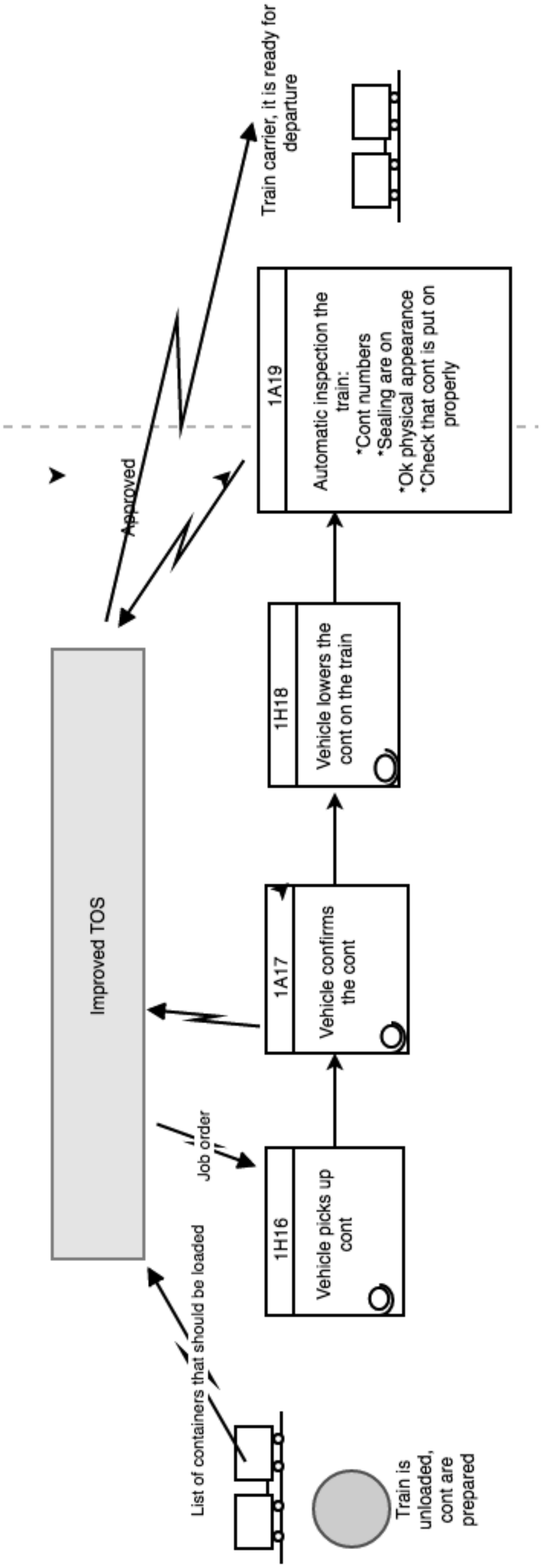

Figure 41. Mapping of the process of loading an import container onto a train.

The main difference of the operation of loading a train in the future state map (figure 41) compared to the map in current state (figure 23) is the automated inspection carried out before the train leaves. The requirement for this expectation is the same as for the automated system replacing the task of the tally man. Another important precondition for this new improved subprocess, is that the exchange between the train carriers and the terminal improves so the terminal know how the train wagons is placed and how much weight they can carry.

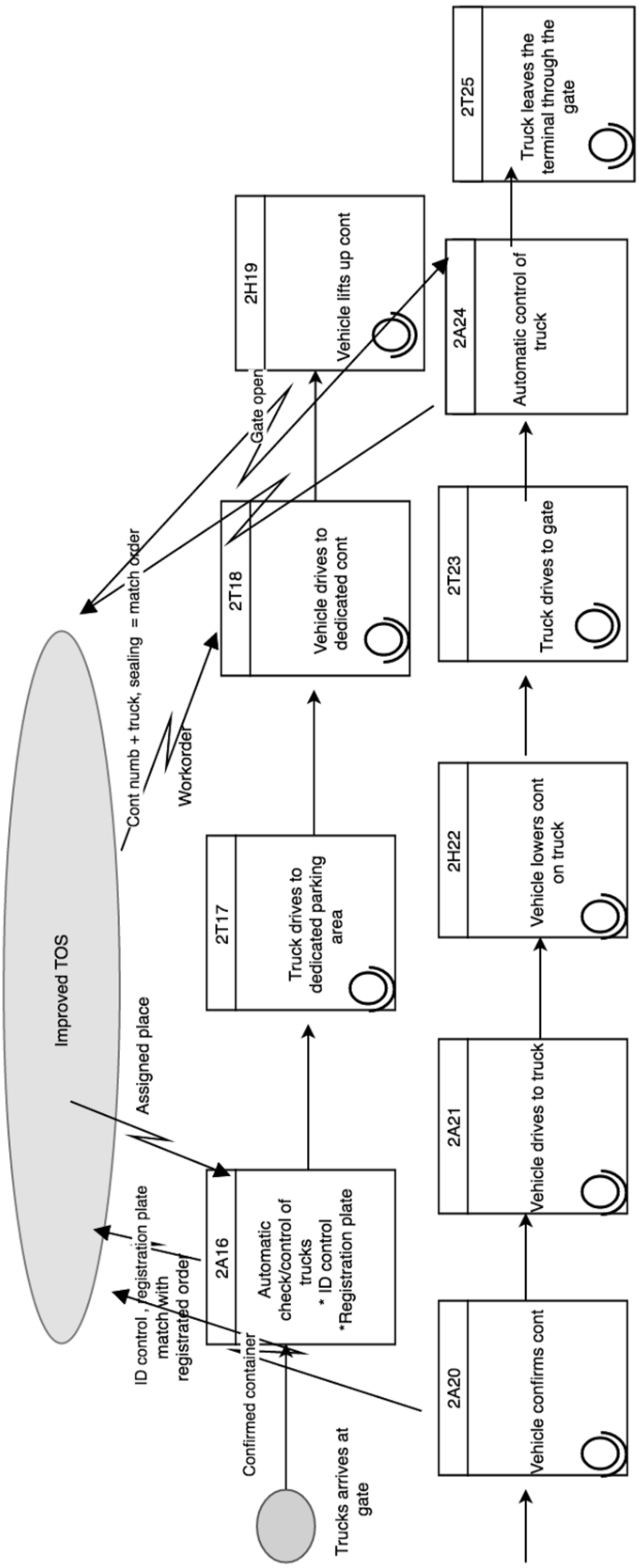

Figure 42. Mapping of the process of loading an import container onto a truck.

The main difference of the operation of loading a truck in the future state map compared to the map in current state (figure 24 is the gate into the terminal should be automated and the system should be able to check identification, registration number and be able to compare this with the order placed in the system. The system should also be able to carry out a quality check consisting of two factors, both being able to scan the exterior of the container to make sure that there are no physical damage and check the sealing. The system needs to make sure that the sealing is not tampered with and to match the number on the sealing with the number.

4.4.1.2 Loading

Figure 43 illustrates the overview of the future maps of loading the vessel

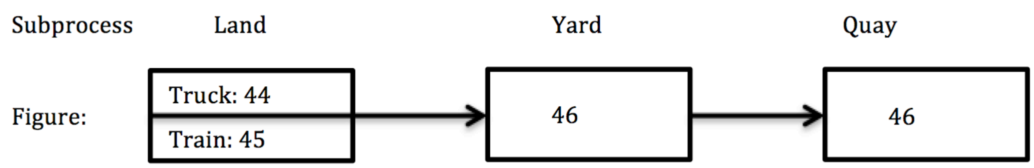

Figure 43. An overview of the future maps of loading the vessel

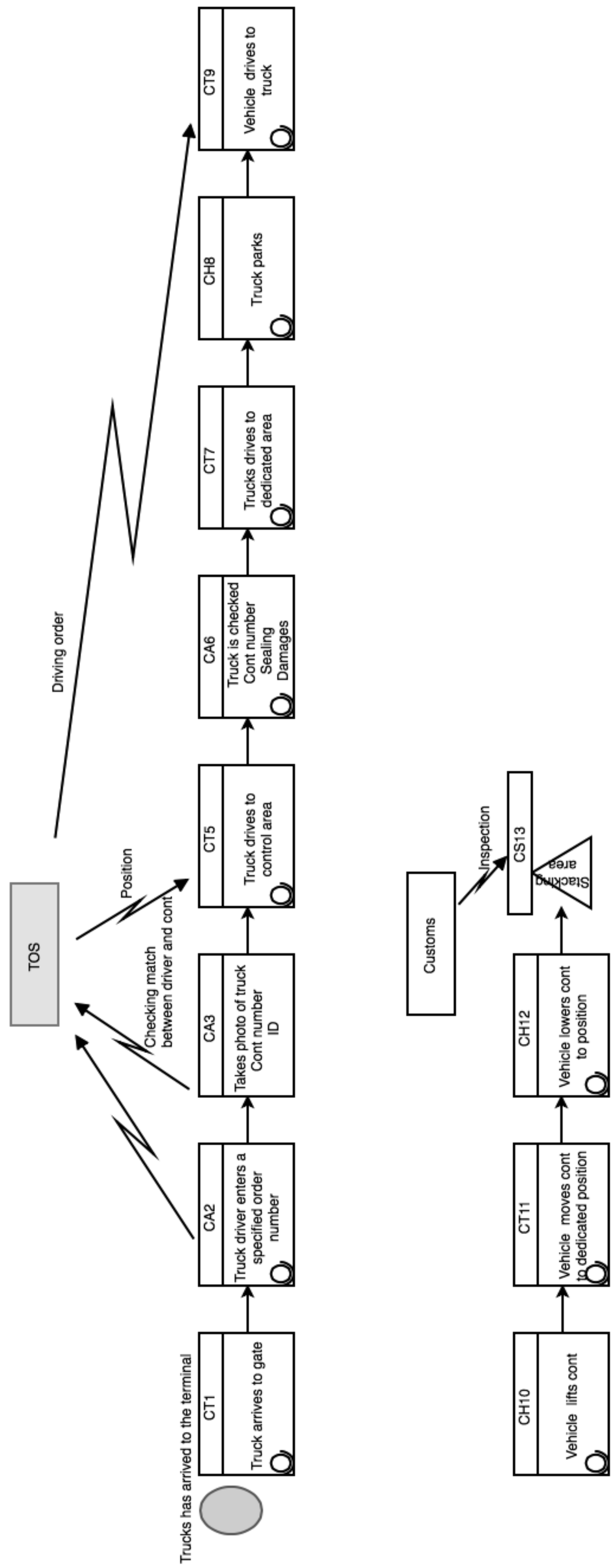

Figure 44. Mapping of the process of unloading a truck in a terminal.

Figure 44 illustrates how the improved subprocess at the landside for trucks would look like. The suggested improvements are similar to figure 26 including automated gates and separation of the area where trucks drives into a container terminal.

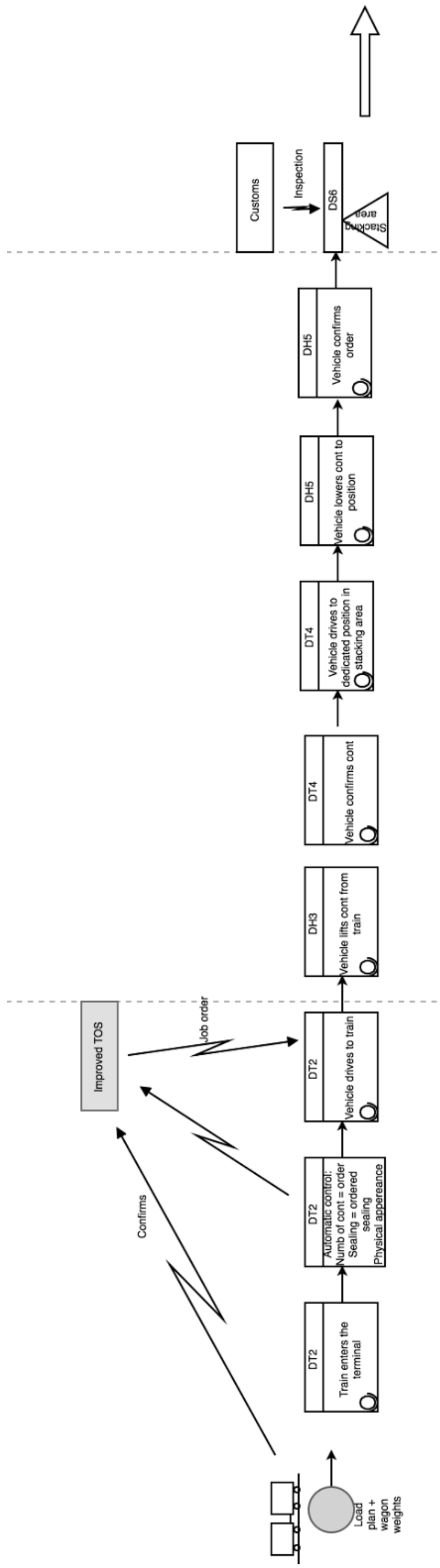

Figure 45. Mapping of the process of unloading a train in a terminal.

Figure 45 illustrates how the improved subprocess at the landside for trains should be performed. The suggested improvements are similar to figure 42 including automated gates.

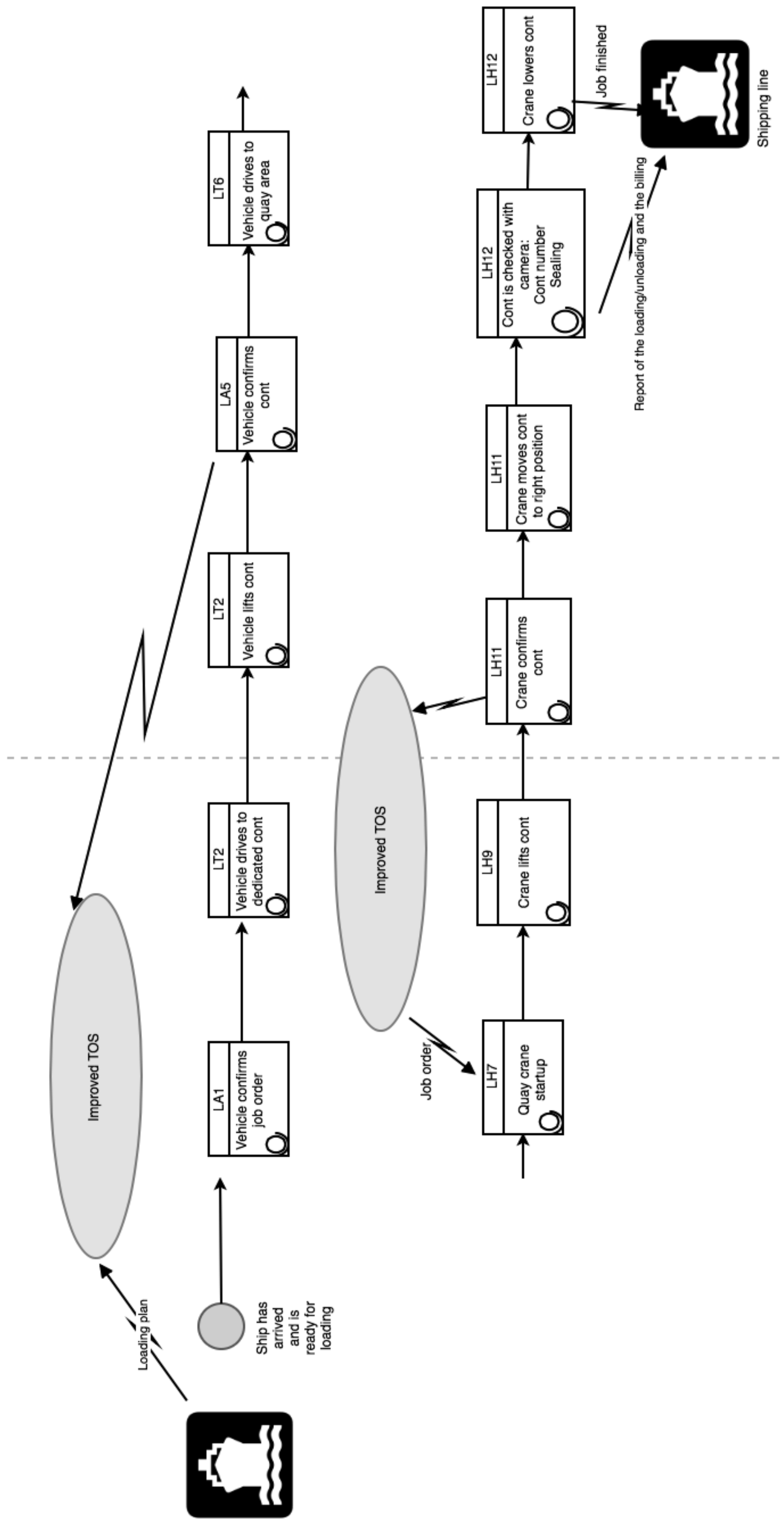

Figure 46. Mapping of the process of loading a vessel in a terminal.

Figure 46 illustrates how the improved subprocess at the quayside for trucks should be carried out. The improvements made are similar to figure 39.

4.4.2 Short-term and Long-term Improvements

In this section the suggested improvements are divided into short term and long-term improvements. The short-term improvements are improvements that are considered to be implemented within three years and long- term improvements are considered to be implemented in more than three years.

4.4.2.1 Short-term

The short-term improvements identified for the four terminals can be divided into the following groups, equipment efficiency, standardisation and levelling and a better TOS system. Concerning the improvement of equipment it is suggested that all of the terminals start to map how much they utilize their different equipment to know if they need to optimise the usage or if they should sell off unused equipment. For instance, in Helsingborg it could be a better idea to use two yard trucks where one of them carries an extra trolley instead of using three yard trucks, if it is discovered that the usage of three yard trucks results in many unnecessary transports.

Continuing with the operations in the terminals, more standardised and levelled working procedures are desirable to keep a better control over the processes. For every operation in the terminals, there should be clearly stated certain standard working procedures to make sure all of the stevedores work in the same way, in order to avoid any errors or misunderstandings. Also more standardised ways when communicating is important to clarify and avoid any mistakes.

Levelling out the flows should be obtained through making sure that the working pace follows the tact time generated from the customer demand. To obtain this, there is a need of synchronised processes in the chain and also between actors. One example of an action to improve the levelling is to sign contract with the owner of the cargo in order to have more control over the trucks, when they should leave or pick up containers. To minimize seasonal variation it is important to map the large owner of the cargo to know the peaks and to try to balance the promises concerning capacity over the year. Hence, there is a need to have a overview of their customer base.

In all of the terminals there seemed to be a need for an improved TOS. For Helsingborg and Norrköping the first step is to find a structural way of collection data on the errors of placing the containers in order to know if the algorithm in the system are poor or if the perceived malfunction system is a consequence of not following the system's recommendations.

Since it has been observed that GPS systems exist for positions in the container yards, it should also be possible to implement a similar GPS system for the containers themselves, meaning that every container should have a tracking and tracing system in the shape of a barcode or chip attached. This is the proposal that should be in the most near future due to the simplicity of implementing barcodes for instance. There is a limiting factor though, and that is the decision on who should be responsible for the payment since it is not clear. That is, who will benefit the most from this solution and who would pay for it?

In addition, it is also suggested that the terminals implementing an automatic tally man and checker at the train to obtain a better flow and to increase the quality by checking the sealing, exterior of the containers and container number. Currently there exist several suppliers offering these services, one example, is the supplier Camco technologies (Camco technologies, 2017).

4.4.2.2 Long-term

The long-term improvements require more planning and larger investments due to the scope of the suggested improvements. In more developed and innovating terminals such as one of the largest container terminals in the Netherlands (Maasvlakte), automation is implemented to standardise the operations. In general implementing automatic vehicles or equipment can level out the flows and decrease the amount of human errors, also they are easier to control and demand.

If areas where automation is difficult to implement exist, a change in equipment or vehicles should be discussed in order to improve performance and increase capacity. Norrköping and Helsingborg should overview if they can gain a better flow by changing their container trucks and reach stacker to straddle carriers to minimize the number of interfaces.

Another suggestion is to implement a conveyor system for transporting the containers in the stacking areas. The containers would be placed conveniently on the conveyor, and then the conveyor should transport the container close to the next step in the chain (either close to the truck or train area). This would eliminate all need of shifting containers since the containers always should be placed at the most appropriate location at that time. This conveyor system could be divided into different layers to keep the stacking function. This solution hasn't been applied in any terminal yet to the author's knowledge.

Another long-term improvement is changing the type of equipment. It is suggested that both Norrköping and Helsingborg should change to straddle carriers to minimise the number of interfaces in the flows. It is also suggested that they separate the loading and unloading of the trucks similar from the terminal's operation, similar to APMT Gothenburg to avoid the trucks from interfering the terminals operations.

The area of a terminal is valuable since it as a measurement of capacity. One example is in Helsingborg where the large power plant of Öresundskraft is located. From the ports perspective, the area could be used to store containers instead in a more efficient way and this could shorten some distances to the container stacks, but it is unlikely that the power plant will move since it would probably require much resources to move Öresundskraft. The same applies for the area where the factory of Lantmännen is located in the port of Helsingborg.

Finally it is important for all of their terminals to increase both the information and communications between all of the external actors in order to receive information when needed and to be able to conduct better forecast.

4.5 Challenges with Executing the VSM

In this chapter the main challenges encountered during VSM are presented.

4.5.1 Challenges with Executing the Current State Map

During the executing the current state map challenges were encountered. The main challenges identified are; difficulties to gain an overview of the terminal, difficulty of observing the flows by foot, the challenge of following a container since the containers are stored for a various period of time in the stacking yard and the flows are affected by the weather.

Usually a container terminal is rather large, there is much traffic and there are high stacks of containers. These characteristics contribute to difficulties to gain a good overview of the flows without missing out on important steps. One of the best places, depending on the terminal layout, is to start off by observing the flow from a quay crane since the high position provides a good overall view of the terminal.

When following a specific container, there is a risk that the container will be left behind in the stacking area for several days, implying the mapping will be delayed and unnecessary waiting time arises. Due to this reason the mapping should be planned in advance and preferably a container that the port plan not to have in their stacking area for so long should be chosen to study. However, this may lead to a skewed and biased result since it is not illustrating the real flow.

Concerning delays, the arrival of a vessel may be postponed several hours the same day the vessel should arrive resulting in postponed mapping. The delays of the vessel may be a result of bad weather such as windy conditions forcing the vessel to wait or go on a detour. In Helsingborg, there is a wind restriction on 22 meters per second - if it is windier the cranes cannot operate since they will commute and it is therefore very hard to grab a container. In Norrköping this limit is the same. Yet again, when planning the mapping it is good to look at weather forecasts and allow plenty of time to the mapping to be able to wait for the vessel.

Other observed challenges are the difficulty of simply walking when mapping, since there are safety regulations requiring visitors to be transported in vehicles in the terminal. In addition to this, a vehicle may not be able to stop where the sight is the best and is instead directed o a dedicated parking area to avoid disturbing the operations. The best way to carry out a mapping of the container flow is to join the vehicles that are performing the operations.

When mapping a certain container, it may be difficulties of following a specific flow the entire process since other operations are taking place simultaneously and thereby creating a structured chaos. All operations affect each other causing congestion and queues that, is interesting to map. However, it is difficult to present in a map only presenting a static picture of the process. In this project, this has been solved by describing the operations individually and then maps the process in two different maps for import and export due to the bidirectional flows with differing characteristics.

4.5.2 Challenges of Executing the Assessment of the Current State Map and the Creation of the Future State Map

There were several difficulties encountered when assessment the current state map. They can be derived from the purpose of the nature of the container terminals. The purpose of the container terminals are to transport and move containers from one transportation mode until one other and to store the container for a period of time. Hence, some of the transportation and storage are needed and can be consider to be value adding operations. Thus, caution needs be applied when determining which transports may be considered to be value adding or not. The same applies for storage.

In addition, two of the descriptions of the categories of wastes need to be adjusted to be applicable in a seaport container terminal environment, namely overproduction and inappropriate processing. In a seaport container environment overproduction should be referred to working in a higher tact than required and inappropriate processing should be viewed as using the wrong and possessing to many vehicles or equipment.

Continuing with problems encountered when creating the future state map. One of the main challenges when creating the future state map were that many of the improvements were difficult to illustrate since many of the operations were not possible to remove. Many of the improvements are thought to reduce the time of handling and transportation of the container. Since it was difficult to collect the different cycle times of the operations, it was difficult to evaluate the possible reduction of the total time.

5 Discussion

5.1 Conducting the Current State Map

VSM is considered to be applicable in a terminal environment. As the project manager of Noatum stated, the terminal operations can be seen as resembling operations corresponding to the manufacturing industry where lean is more incorporated, where the production corresponds to the movement of containers. In addition, Marlow & Paixao (2003) agree upon the applicability of lean in terminals where it could be used effectively to improve efficiency, which seems reasonable due to the similarities.

Still, there are some challenges with executed Value Stream Mapping and they can be derived to the issues that may affect the flows in the terminals. Notteboom (2006) especially states the time issues, such as delays in arrivals of vessels, and since the operations concerning the movements of containers cannot be initiated until the vessel arrives. This implies an uncertain start up time for the process and hence deteriorates the reliability towards the shipping lines. In addition, an uncertain arrival time obstructs the control over the cargo level in the terminals. Due to the limiting access to the terminals interviews was used as a complement. Even though some of the mapped observation was not observed and only discovered through interviews as Nash & Poling (2008) suggested, it is still considered that the maps on this level of detail present a realistic view, however it is recommended that the terminals themselves tries to document their operation themselves.

A delayed vessel automatically means a delay in arrival of cargo to the terminal, and if another vessel will arrive the following day, resulting in a higher filling rate of the terminal For a smaller terminal with less load capacity, the effect of a delayed vessel will have a larger impact on the stacking area, still delays impacts on many levels such as availability of stevedores and equipment, the arrival of trucks and trains as well as the need of shifting containers. Olesen et al. (2015) claimed, the environment in container terminals are considered to be unstable making it difficult to implement lean. However, it could be argued that this is not the case since the demand is relatively stable and the operations in the terminal are performed in the same way every time.

Another interesting finding is the importance of the relationship between involved actors concerning the terminals. Martin & Thomas (2001) stated how a good relationship between shipping lines and terminals will contribute to a more secure time horizon and hence, better planning. Many operations of containers related to customers are predestined and controlled by contracts that in a way facilitate the terminal. However, there tends to be a perception that some predestined guidelines can hinder the natural flow in the terminals. The authors also reached this conclusion. However, a good relationship and good exchange of information are also needed to the other actors especially the train carriers and the owners of the cargo.

Pham (2014) expressed the importance of a well-functioning information system, and even though the studied ports use different types of relatively modern IT systems such as Navis and PortIT, it can be concluded that further development can be carried out in order to cope with the development in the world.

Another factor, complicating the optimisation of the terminal operations further, is that the terminals do often not know the loading plan, when the containers are entering the ports. In

Norrköping for instance, the containers generally enter the ports four days before they are loaded onto vessel but the loading plan for the vessel is received in best cases 24 hours before. This means that when a container enters the port it is not possible at that time to know where on the vessel a certain container is placed. A consequence of this is, in the worst case it is placed in a wrong position. Another difficulty identified in all of the ports is, information in order to optimize their operations, is not known at the time they needs to be, such as next destination for containers or loading plan.

Regarding applicability of existing symbols used for VSM, there are no indications, more symbols have to be developed since the operations taking place in the terminal environment can be derived to manufacturing operations to some degree as stated earlier. The project manager of Noatum explained how the operations in the terminal site can be compared to a production line with the exception that no processing of the material is performed.
The definitions of handling, administration and transport are in some respects difficult to distinguish, however not crucial for the performance and reliability of the mapping as long as a uniform system is used.

Concerning implementation of VSM as Hines et al. (1998) addressed case where the maps was not understood by the operators since the external consultants conducted the map lacked understanding of how the work was conducted on a daily bases. Therefore, it can be concluded the stevedores or employees at the company should conducted the mapping, rather than hiring a professional external team since they understands the operations.

The most commonly used KPI in the studied terminals is moves per hour, i.e. how many containers the crane moves per hour. Lead-time is not included in the daily calculations in the terminals, unlike in the manufacturing industry where lead-time is a crucial measurement that is often used to measure performance (Notteboom & Rodrigue, 2009; Ohno, 1988). It is perceived a bit monotonous to rely on this measurement as a measure of performance, since performance in terminals can be measured in many other ways such as filling rate and total number of moves in the terminal. Feng et al., (2012) presented some other factors used to evaluate a port performance, which were not used in the terminals studied. This report demonstrates that VSM is an effective way of evaluating performance, which hopefully can be used in terminals.

Furthermore, what can be alleged by the authors and further supported by Kozan (2000) is that the choice of equipment is a crucial performance indicator. The choice of equipment is directly related with the amount of interfaces and hence the amount of subprocesses, and overall the more interfaces - the more critical points where valuable time can be wasted.

5.2 Analysing the Current State Map

The current state map was analysed by analysing the value and non-value adding operation according, to Monden (1993). As mentioned in the frame of reference, necessary but non-value adding operations are excluded since many of the suggested improvements in a terminal is based on changing the current structure. The value adding operation, the transportation and handling of a container between different and storage of a container seems to be accepted as value adding operation, for instance Olesen et al. (2015) also mentioned this. However, checking the sealing and assuring right container is entering and leaving the terminal may also consider to be value adding to ensure correct handling. However, this is not mentioned in the literature study.

The non-value adding operations was analysed accordingly to Liker's (2004) eight wastes. It was concluded Liker's (2004) eight wastes could be used in contrast Olsen et al (2015) suggestion. It is true, transport and storage are needed and are value adding, however, buffers and unnecessary long transports are wastes.

Furthermore, some of the wastes need to be re-defined to be able to apply them on a terminal environment. For instance, overproduction in a container terminal should be defined as working in a faster tact requested by the customers than producing too many products. In addition, in appropriating process could be seen as possessing too much equipment and too many quay cranes.

The main underlying insufficiencies causing the wastes are lacking information and communication, lack of system understanding, inadequate forecast, unclear working procedures, insufficient resource allocation, insufficient TOS, and lack of synchronization, this insufficiencies are similar to the once Olesen et al. 2015 discovered and presented in his framework. One differences Olesen et al. (2015) suggested is that ICT is a prerequisite for the framework, whilst the authors, although agree to some extent, suggests lack of communication and information exchange between the external partners needs to be resolved in order to have a well-functioning ICT.

In addition, the transition from current to future state, the seven questions by Medbo (2016) can be used for production environment. In this project, all seven questions could be answered despite the seaport container terminal environment with it characteristics however, the term production have to be considered. It can be alleged from the observations that there is no production in terminals as in the manufacturing industry, since containers are simply moved from one point to another often without any changes of the container's appearance. However, in Helsingborg they refer to the business in the terminal as production, implying that the meaning of a production can be subjective.

5.3 Suggested Improvements

Possible improvement for the future state can be stated given the characteristics of the four studied terminals. The recommendations are quite general, and more precise solutions are difficult to state due to the lack of quantitative data that should be evaluated and thereby difficulties of calculating the effect of the given recommendations. The recommendations are given both for the short and long term. The short term recommendations consist of evaluating the current equipment fleet and develop a system to evaluate the how well TOS is performing as this is crucial for further improvements of the flow.

The long-term improvements consist of working towards implementing automation in the daily operations and let the IT systems control a larger part of the flows. Well-functioning synchronisations between involved actors are important to perform well in the interfaces. This is also facilitated through integrated IT systems where all necessary information is shared and a unified system to handle the information is clearly stated.

5.4 Future Research Areas

Additional research in this area is encouraged, especially research concerning the interaction between the external actors the of container terminals including the operations, actors and synchronisation. Concerning innovation, inspiration should be retrieved from the automotive industry where the efficiency performance is measured and evaluated frequently and where traditional approaches are eliminated if better solutions are found, as is the purpose of lean.

5.5 Transferability, Reliability and Validity

The findings could be used to carry out VSM (both conducting and analysing the VSM) in other terminals in their processes of continuous improvements. As can be concluded from the observations of the four studied terminals, terminals operate in a similar way using similar equipment. However, there is a challenge when observing larger terminals (with operations taking place on a larger area) since the area will be more difficult to overview. The easiest ways to solve this is, through spending a longer time in the terminals and ask comprehensive questions about the daily operations.

The level of reliability of the thesis is considered sufficient for supporting the findings. Interviews have been performed with people involved in the operations in the terminals, implying they have a comprehensive level of knowledge and understanding concerning the terminals' operations and associated areas.

The case study has been performed on four different container terminals, providing a broad and faceted understanding and insight in the terminal operations. This strengthened the conclusion that VSM can be applied on terminals since the mapping is based on observations from all four terminals.

It would have been appreciated if more time could be spent in the terminals to gain a deeper understanding of the operations. For instance, in Noatum container terminal, only a quick car tour was performed where a snapshot of the operations was observed. A more thoroughly visit would contribute to a better understanding of the operations and it would have been easier to see how the vehicles were used.

There were some difficulties in receiving quantitative data (time measurements, distances etc.) from the terminals, therefore it was decided not to involve any of these kinds of measurements even though average measures were obtained from the observations. For instance, in the maps of VSM, it is common to present a timeline over all operations, however the average time measurements obtained are hard to evaluate due to their uncertainty. Despite the lack of the time line, it is possible to conduct VSM in the terminal environment.

6 Conclusion

A container terminal has many similarities to a manufacturing environment. They both have a dedicated area to operate, both have customers to satisfy and supply with cargo and services both have equipment to facilitate the operations and both have employees to execute the operations. The main difference between the manufacturing and seaport container terminal environment is instead, of refining raw materials compared in the production in a manufacturing environment, in a container terminal the production consists of transferring cargo from one mode to another. However, due to many similarities of a manufacturing it can be argued that lean can be implemented as well as the tool VSM in a container terminal.

However, there are challenges when conducting a VSM in a container terminal due to its characteristics. The challenges can be divided into both practical and analytical challenges. The practical challenges of the execution of the mapping include difficulties of gaining an overview of the container flows resulting in difficult to follow a single container flow, delays and uncertainty of arrival of the different transportation modes requires dedicated time. Another challenge is that the flow of an individual container can vary a lot depending on the storage time, implying long waiting time for the mapping.

There also exist challenges when analysing the current state map. The main challenges include difficulties to understand information flow and the planning, only by observing the material flow. In order to overcome this challenges, interviews concerning these areas were conducted in order to understand these factors in the container operations. In addition, when classifying the operations in a container terminal it is necessary to know that type of operation could both be considered as value adding and non-value adding, depending on its function.

Furthermore, the non-value adding operations can be divided into different types of wastes derived from Toyota Production System, however some of them needs to be re-defined to be able to apply them on a terminal environment. For instance, overproduction in a container terminal should be defined as working in a faster tact requested by the customers than producing too many products. Transport is another kind of waste that needs to be redefined since the container operations are dependent on essential transportation.

As a result of conducting a VSM in the different terminals, several inefficiencies were identified, however many of them were connected to specific terminal characteristics, for instance in Helsingborg the design of the terminals resulted in unnecessary transportations due to unnecessarily long distances. However, some of the inefficiencies were the same for all of the terminal, including an inadequate TOS, limited resource allocation due to labour regulations, lack of synchronization, lack of system understanding, insufficient forecast and lack of information and communication both internally and externally.

The general recommendation solving the inefficiencies could be divided into short-term and long-term solutions. The short-term solutions include collecting data of errors in TOS to improve the system, investigate the utilisation of the equipment fleet and initiating better collaboration with the external actors. Long-term improvements include automation to minimise variation, changing vehicle types and better collaboration between external actors.

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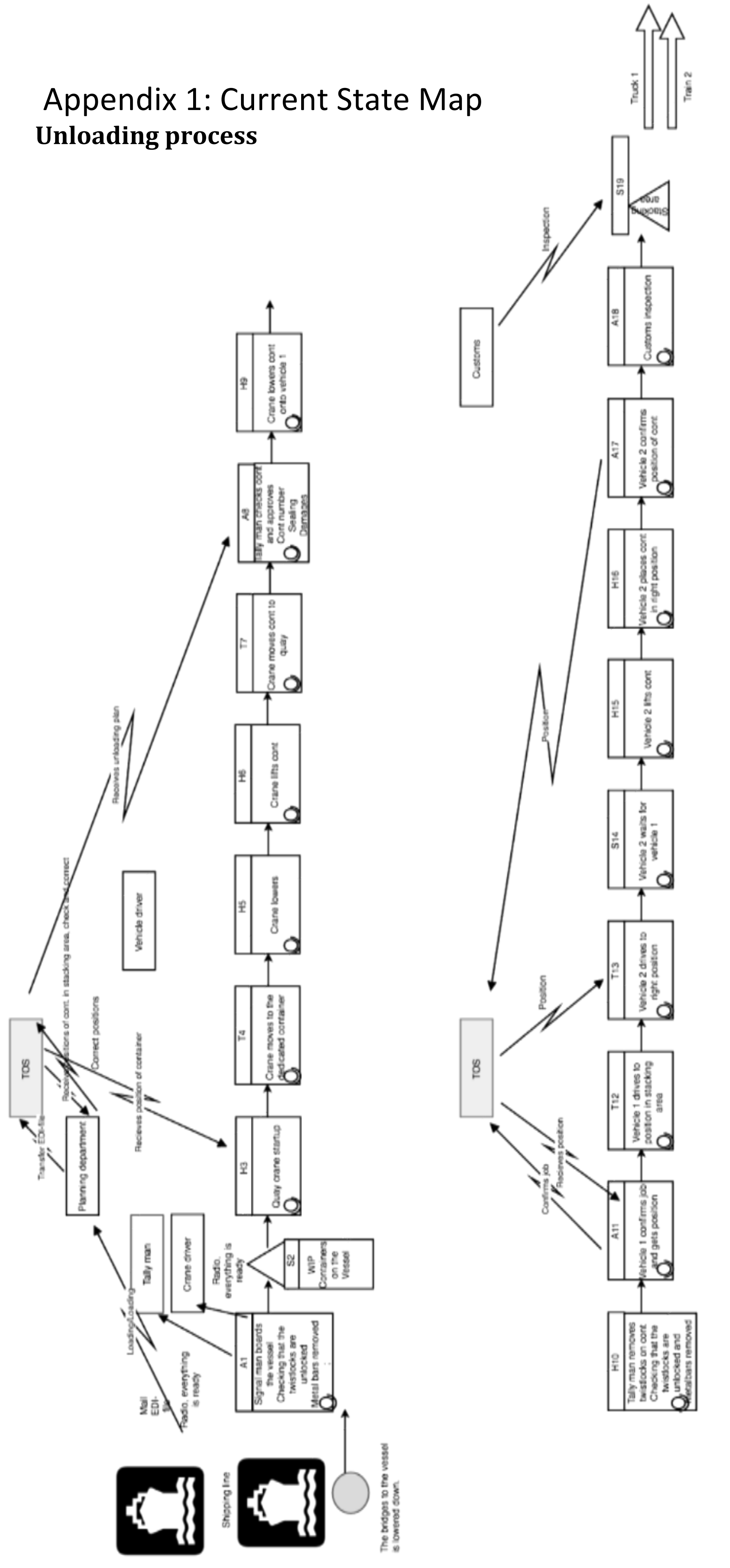
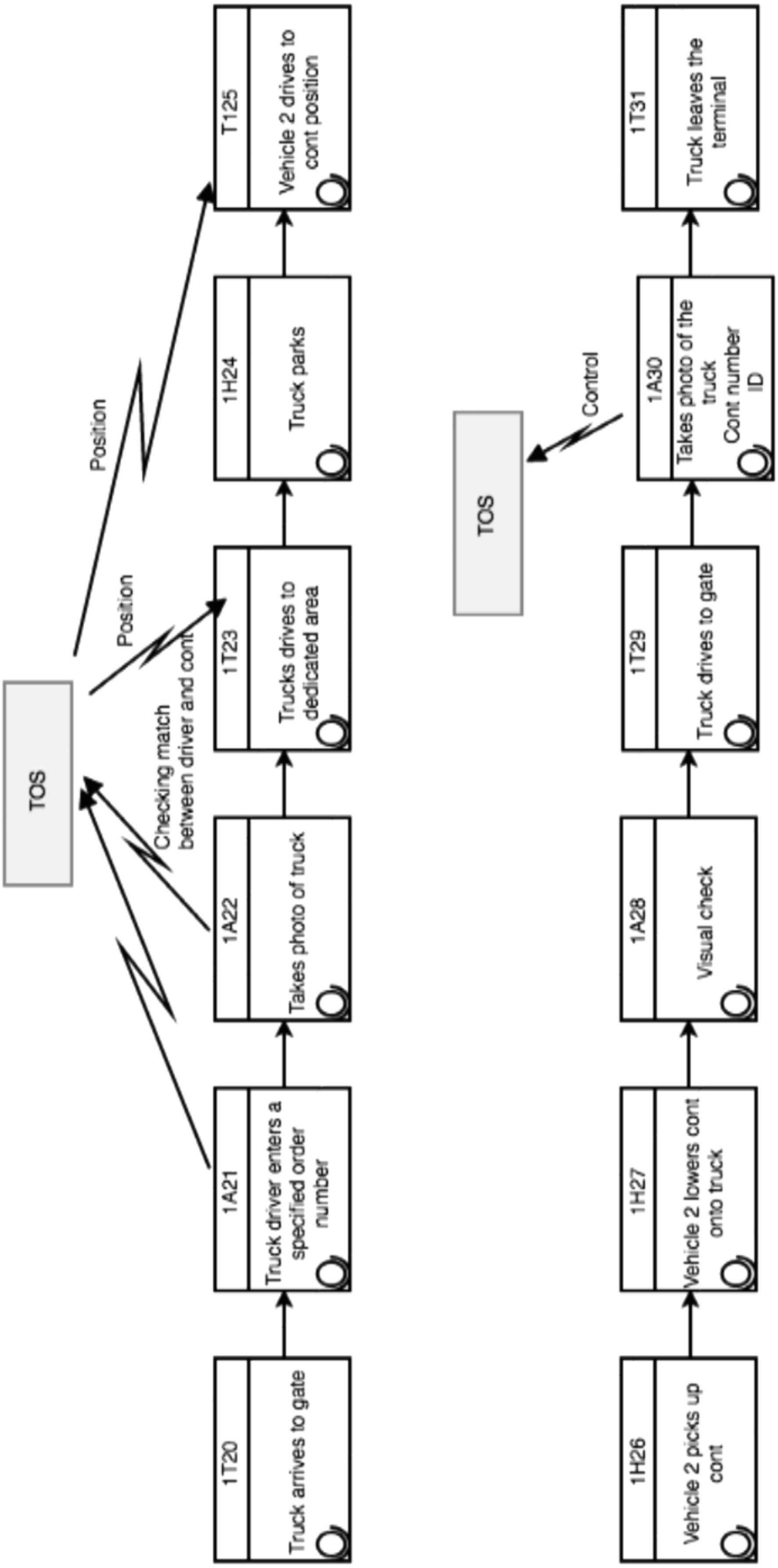
Appendix 1: Current State Map

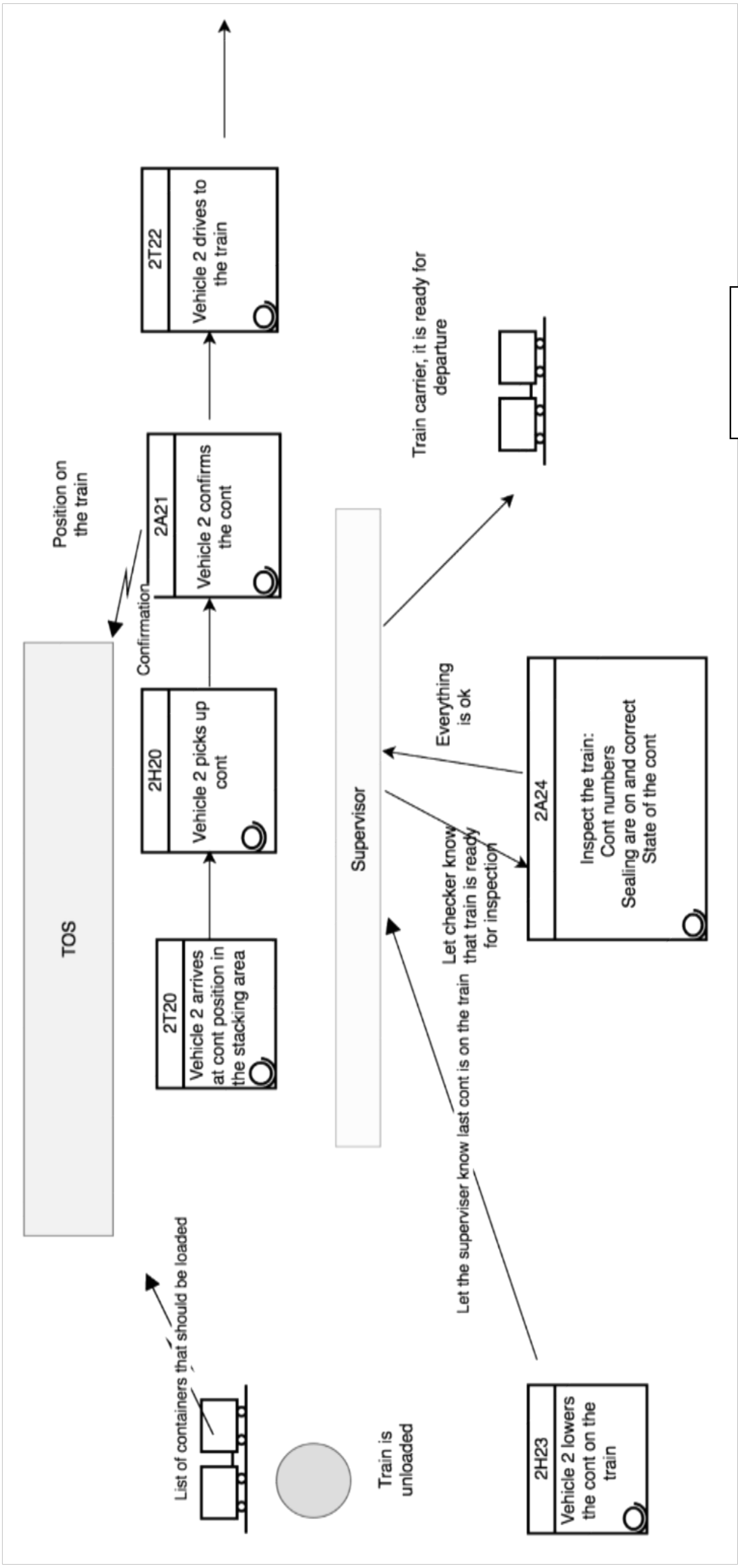
Unloading process



Mapping of the process of unloading an import container of a vessel and transporting it to the

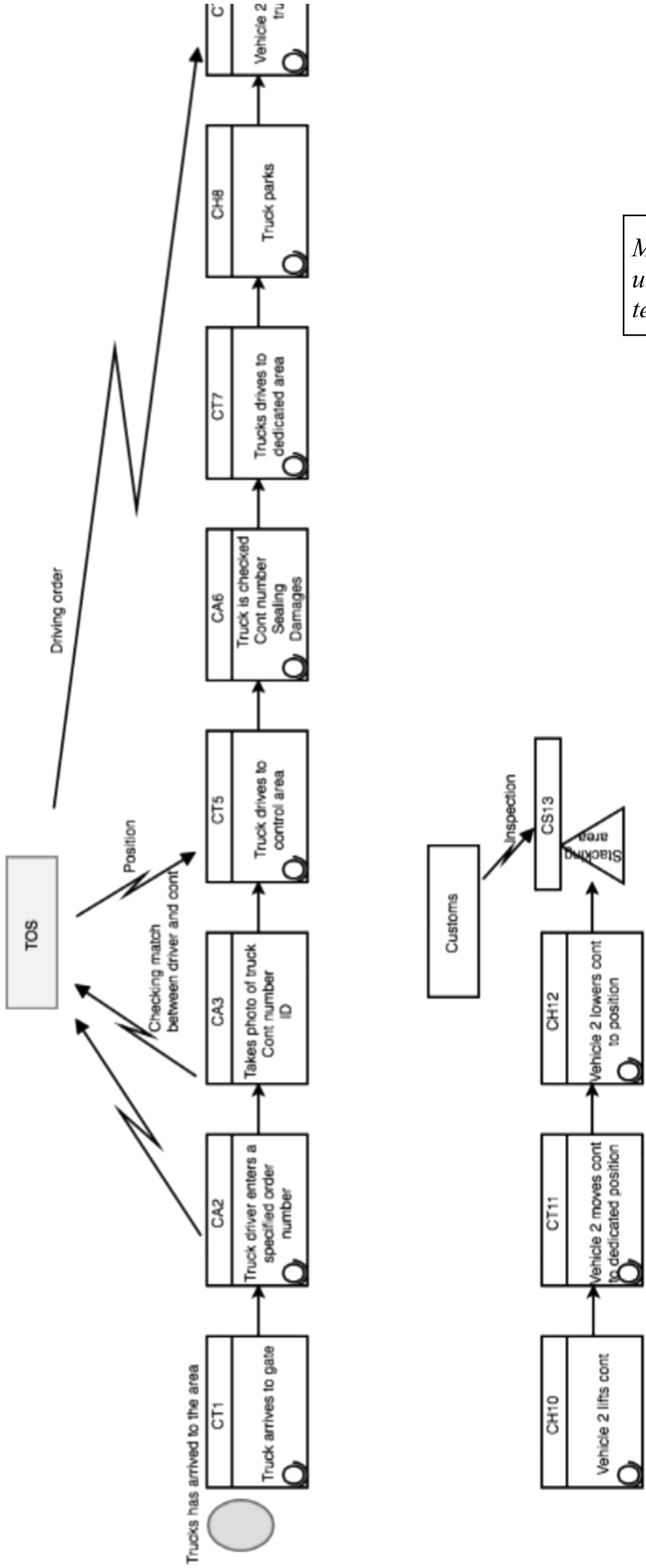


Mapping of the process of loading an import container onto a truck.

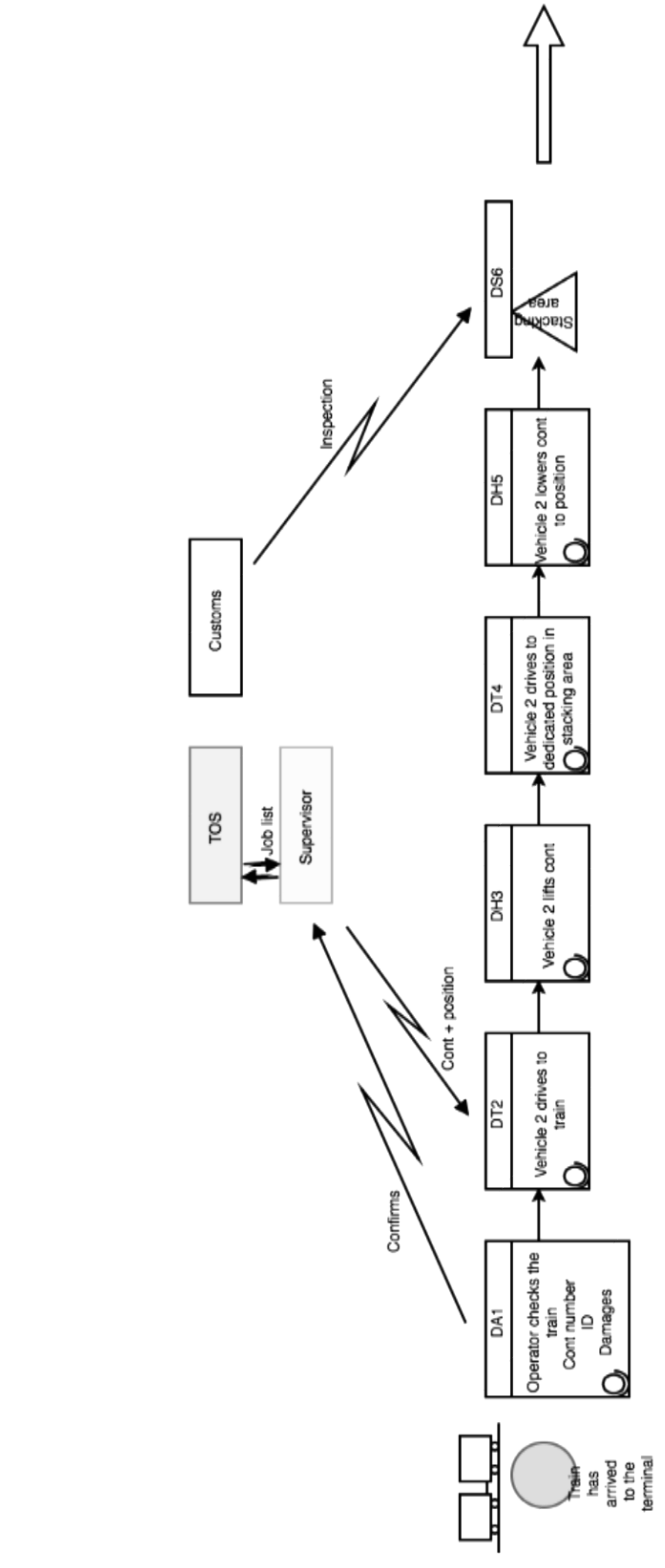


Mapping of the process of loading an import container onto a train.

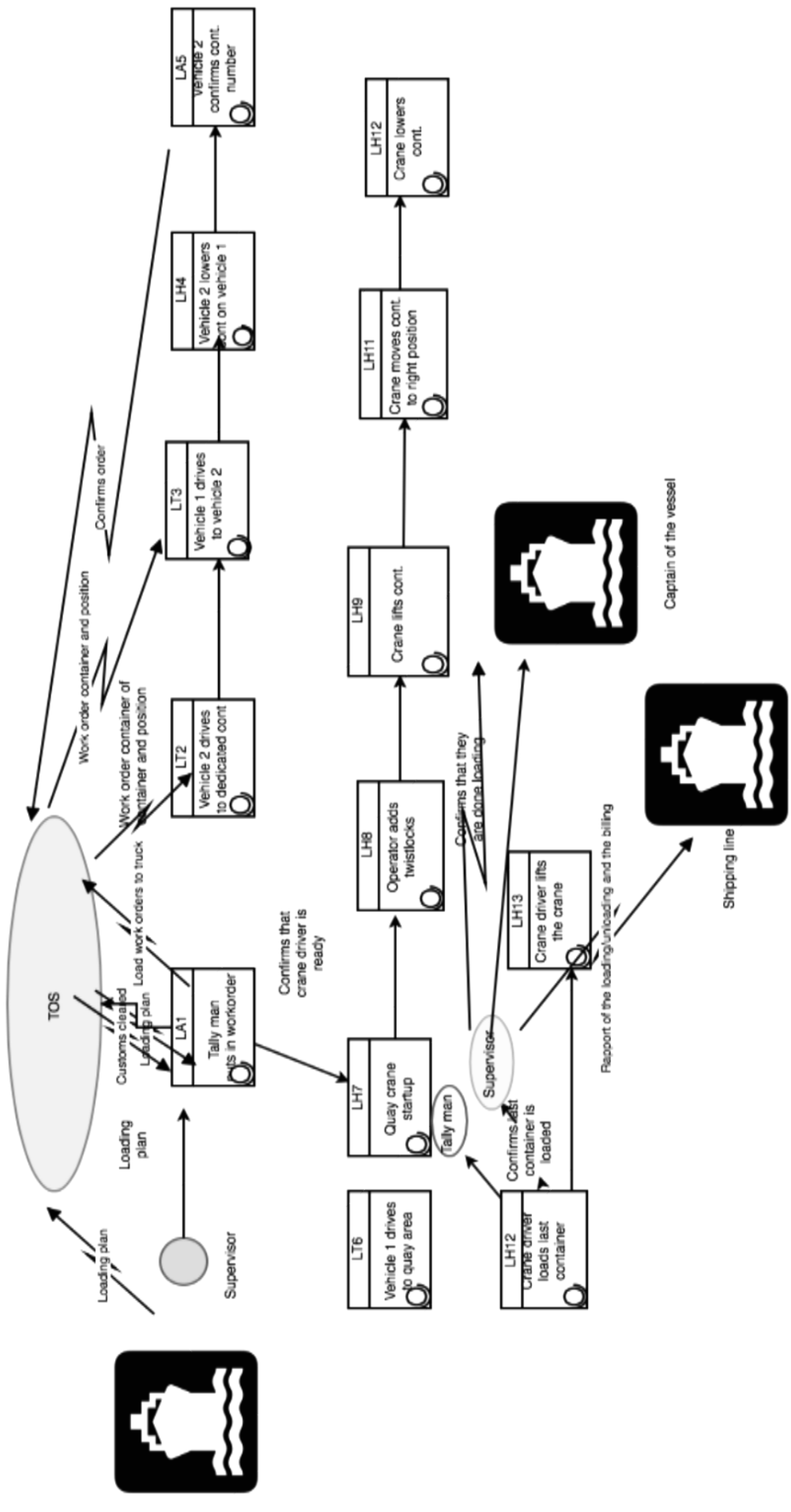
Loading p



Mapping of the process of unloading a truck in a terminal.



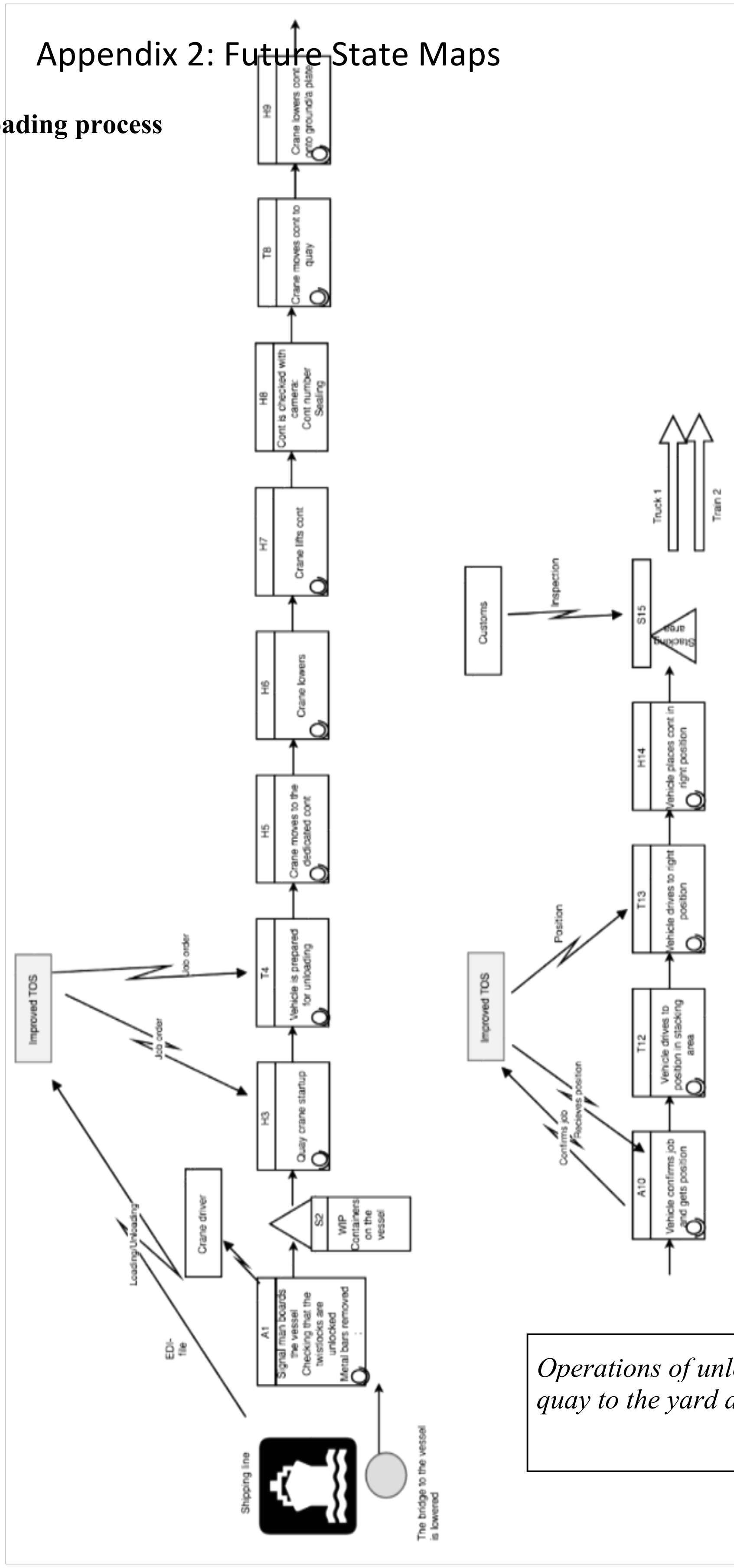
Mapping of the process of unloading a train in a terminal.



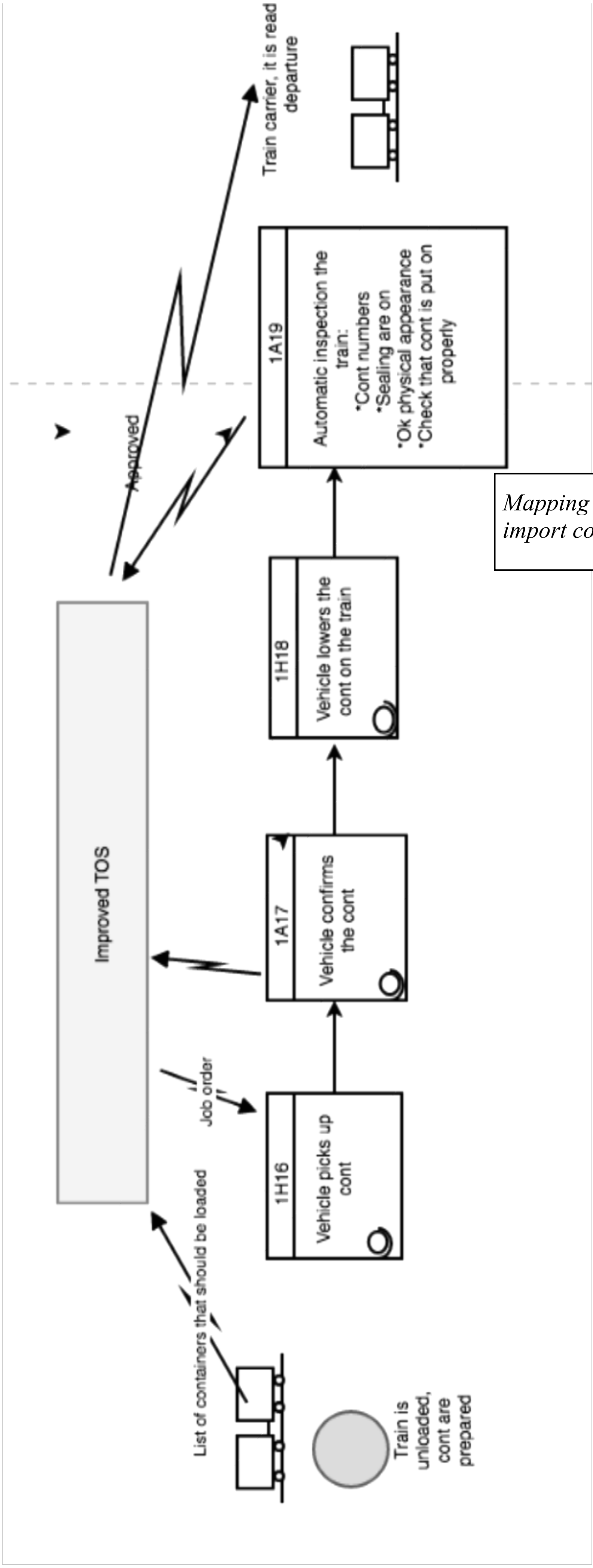
Mapping of the process of loading a vessel in a terminal.

Appendix 2: Future State Maps

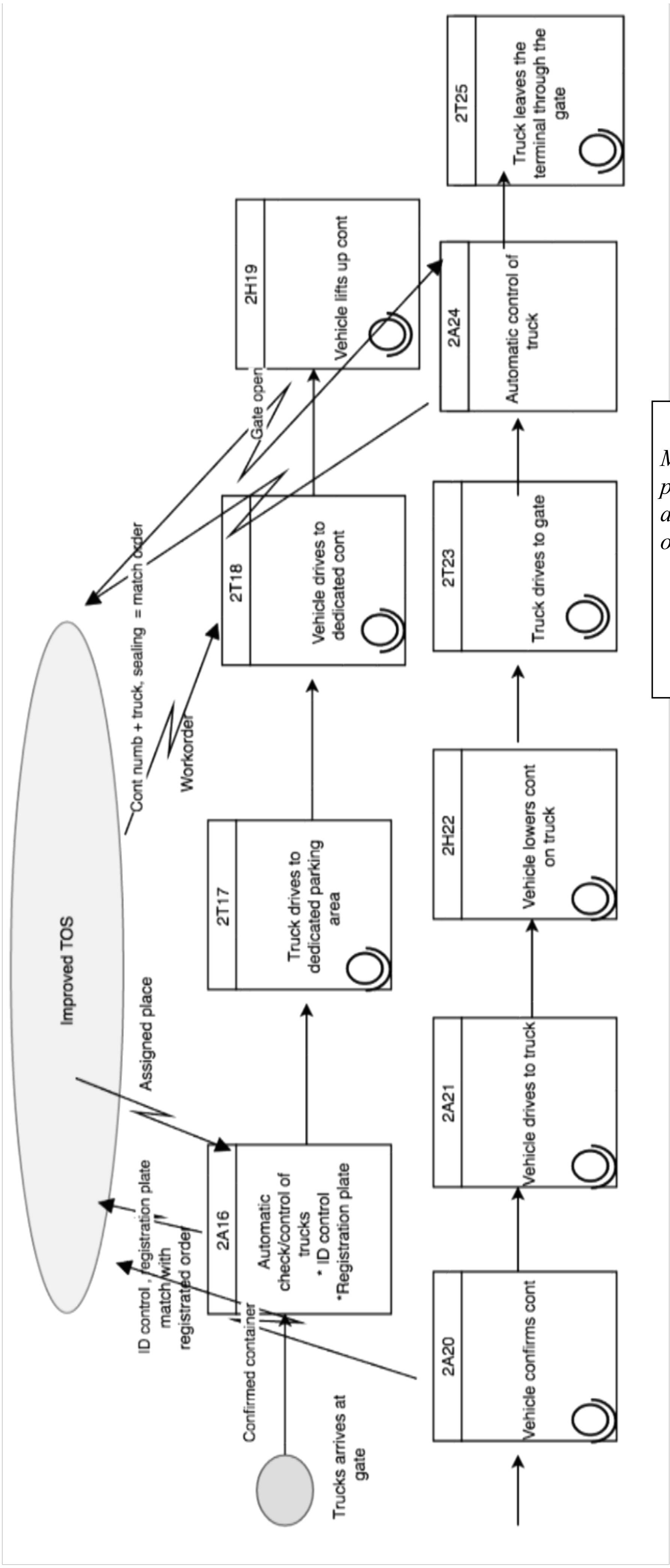
Unloading process



Operations of unloading a vessel from the quay to the yard area.

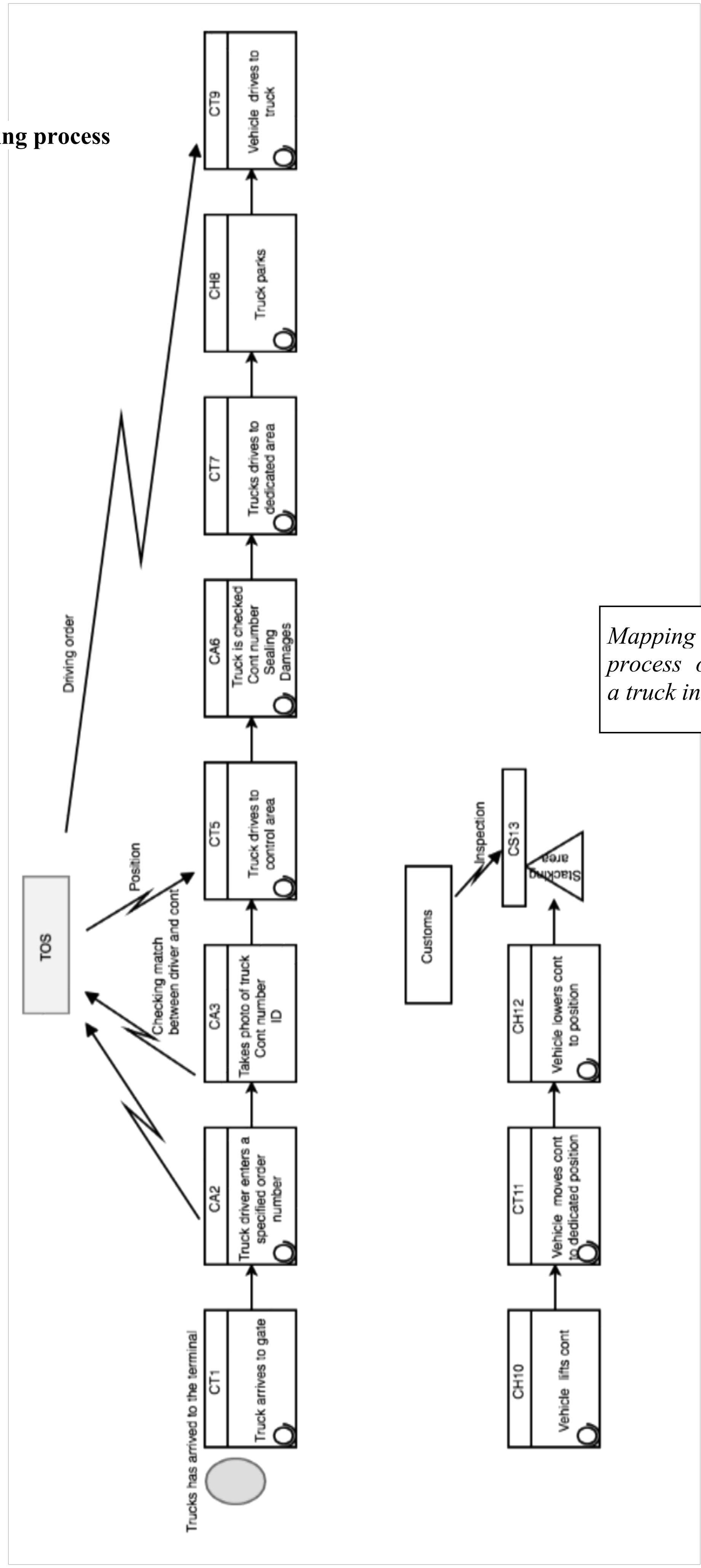


Mapping of the process of loading an import container onto a train.

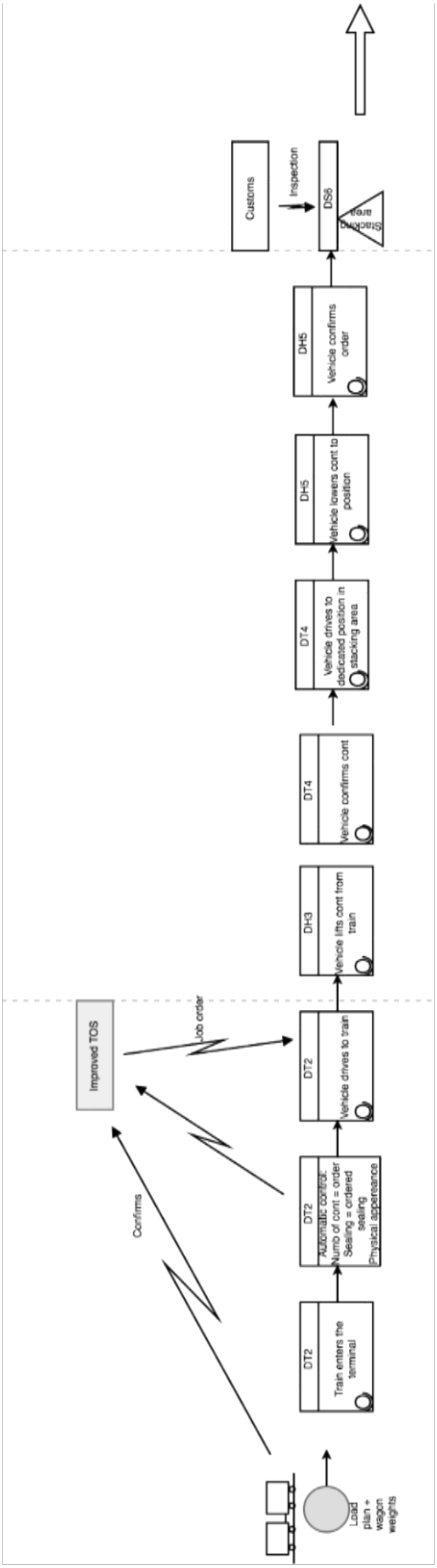


Mapping of the process of loading an import container onto a truck.

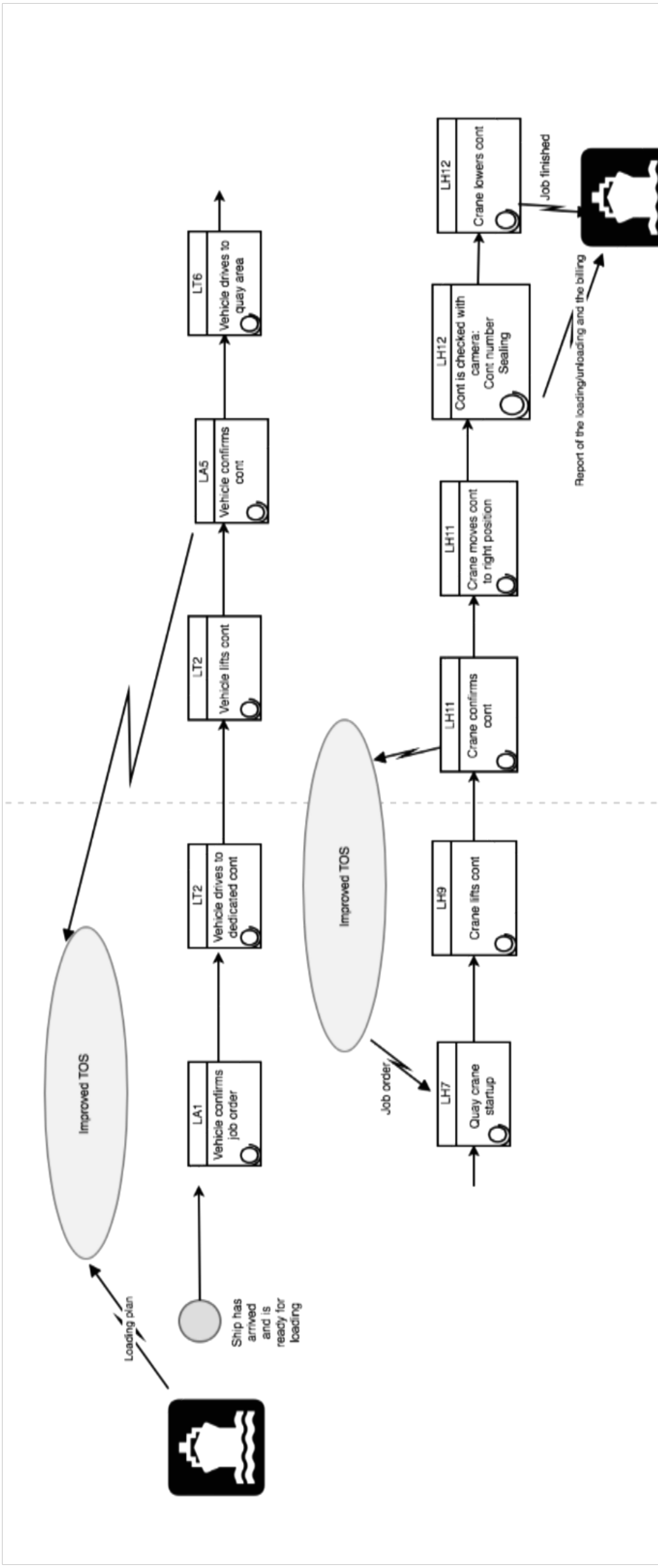
Loading process



Mapping of the process of unloading a truck in a terminal



Mapping of the process of unloading a train in a terminal



Mapping of the process of loading a vessel in a terminal

Appendix 3: Interview Guide

We are currently doing our master thesis within seaport logistics and we are especially going to study container flows in the port of Gothenburg (APMT), through conducting a value stream mapping, tool used in Lean. We are collabourating with SSPA Sweden AB in connection with the STM project (do you know about this project?)

Background:
What is your background?
How long have you been working here?
What are your tasks?

General about the container terminal:
How many containers do you handle in a year?
How many (what percentage) is TEUs, FEUs and 45 feet containers?
How many containers do you typically handle per day?
How does it vary (over the day, over the week, monthly, seasonally)
How long is a container on average in the port? Does it differ between export and import? If yes, why?
How much is automated, how much is manually in the port operations such as loading/unloading or moving cargo?
Do you have a certain storage/parking for empty containers?
Do you have any documents concerning the container terminal that we can get, especially organisation charts or flowcharts?
Do you offer any additional service in the container port such as container storage, customs, repairs and maintenance etc.?

The flows:
Can you tell us about the container flows?
Are the flows divided somehow? (i.e. depending on import/export, seaside/landside, refrigerated cargo, dangerous cargo)
Are there any different flows? Truck/train/feeder vessels? How much in percent?
Customs: Where in the flow does this take place? How much of the cargo/containers are controlled?
Do you offer weighing services? If yes, when? For all? If no, how many/which are weighed?
There are some transports associated with the container handling. Do you work towards optimising your transports? Do you measure how efficient these transports are? How do you measure this?

ICT:
What functions in Catos do you use? Why/why not?
What does Catos optimize on?
Why have you chosen to have Catos and not Navis?
How do you communicate? Internally between divisions? In between the shifts?

KPIs:
Which KPIs are the most important one?

How do you measure efficiency?

Internal actors/staff:
How does the organisation of the containers terminals looks like i.e. who are involved?
How many employed do you have?
How many stevedores work in the port? Share? Full time vs part time?
What education do they have? (Before, education during the work)
How does the resource allocation look like?
How many shifts do you have? How long are the shifts?
Do you have standardized procedures concerning ways of working?
How much do you collaborate with the other terminals this port?
How much do collaborate with the port authority?

External actors:
Who are you main customers and where are they located?
Do most shipping lines arrive on regular schedules or not?
How are the relationships with the shipping lines?
How much is controlled by contracts?

Equipment:
What equipment is used in the terminal?
How many do you have of each equipment type?
Where is the equipment located?

Measurements:
Time to unload/load a container to/from the vessel?
Time to transport a container to/from stacking area to/from a vessel?
Time to transport a container to/from a truck/railway?
Average time in stacking area?
Time in other storage/Buffers?
Fluctuations of volumes?
How many boats/train do you handle daily? Yearly?

Performance/future:
Which are the main limiting factors in the flows according to your opinion?
What are your suggestions about automation in the terminal?
What opportunities and challenges do you see for the terminal in the future?

Appendix 4: Equipment Used in Container Terminals

Straddle carrier (Meisel, 2009) *Quay crane (Meisel, 2009)*

RTGC (Murty et al., 2005)

RMGC (Voβ, 2008)

Reach stacker (Voβ, 2008) *Yard truck (Meisel, 2009)*