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Reducing Vessel Turnaround Time to Improve Port Efficiency

A case study at Inter Terminals Gothenburg

Master's thesis in Supply Chain Management

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Abstract

This thesis investigates how vessel turnaround time can be reduced to improved operational efficiency at Inter Terminals Gothenburg, a liquid bulk terminal operating within a shared port infrastructure. The aim was to identify where waste, non-value-added time, and operational bottlenecks occur in the vessel turnaround process, and to propose improvements that can be implemented within the existing infrastructure and operating setup. A single case study was conducted using a mixed-method approach structured to the DMAIC framework, combining internal and external interviews, observations, operational documents, and quantitative time data. The findings show that the main structural bottlenecks are connected to quay and pipeline availability, where several actors depend on the same shared infrastructure. The findings also show that vessels may remain at berth during periods when pumping is not active, but that this time often consists of necessary surrounding activities such as documentation, inspection, sampling, customs and tax clearance, and coordination between the involved actors. A recurring issue was that vessels could remain at berth without pumping taking place. This was not always caused by the physical transfer itself, but by activities around it, such as late information, unclear documentation, coordination between actors, or uncertainty about when the next step could begin. The thesis therefore proposes that quay meetings and documents should be prepared digitally before the vessel arrives, so that vessels occupy berths for a shorter period. It also proposes that delays and incidents should be recorded in more detail, making it easier to understand why waiting time occurs. These measures are intended to reduce avoidable waiting and improve the use of existing berth capacity. The thesis contributes to the understanding of how port terminals can improve operational efficiency when the main physical infrastructure is shared and difficult to expand.

Keywords: Vessel turnaround time, Port efficiency, Bottlenecks, Non-value-added time, Liquid bulk terminal, DMAIC.

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Glossary

Bottleneck - A process step or resource with limited capacity that restricts overall flow and creates delays in a system.

Non-Value-Added Time - Time spent on activities that do not add value from the customer's perspective, including both avoidable waste and necessary but non-value-adding activities.

Vessel Turnaround Time - The total time a vessel spends in port from arrival to departure, including all operational, administrative, and waiting activities.

Operational Efficiency - The degree to which resources are used effectively to minimise waste and maximise output and throughput.

Table of Contents

1. Introduction.....	1
1.1 Background.....	1
1.2 Inbound & Outbound Material Flow at Inter Terminals Gothenburg.....	3
1.2.1 Inbound.....	4
1.2.2 Outbound.....	5
1.2.3 Vessel turnaround as a critical constraint.....	6
1.3 Purpose & Research Questions	7
1.4 Scope.....	7
2. Theory.....	9
2.1 Flows and Lead Time	9
2.2 Supply Chain Complexity and Responsiveness.....	9
2.3 Little's Law	9
2.4 Lean Six Sigma	10
2.5 Bottleneck Theory	10
3. Method.....	12
3.1 Research Design.....	12
3.2 Research process.....	12
3.3 DMAIC	13
3.4 Interview study	14
3.5 Literature study	14
3.6 Quantitative Data Collection.....	15
3.7 Observations	15
3.8 External Data Collection.....	16
3.9 Reliability and Validity of the Study	17
4. Measure	19
4.1 Process Map	19
4.2 Empirical Findings - Internal.....	20
4.2.1 Planning Conditions and Short Notice	21
4.2.2 Waiting Time and Delays in Vessel Handling	21
4.2.3 Bottlenecks in Shared and Internal Infrastructure.....	21
4.2.4 Information Flow, Coordination, and Replanning	22
4.2.5 Administrative and Organisational Constraints.....	23
4.2.6 Observations	23
4.3 Empirical Findings - External.....	24
4.3.1 Planning Conditions and Port Coordination.....	24
4.3.2 Shared Infrastructure and External Resource Constraints.....	25
4.3.3 Inspection, Sampling, and Time at Berth	25
4.3.4 Information Flow and Inter-Organisational Communication.....	26
4.3.5 Delays, Dependencies, and External Sources of Waiting Time.....	26
4.5 Quantitative data.....	27
5. Analyse	29

5.1 Qualitative Analysis	29
5.1.1 Planning uncertainty and short-notice changes	29
5.1.2 Shared quay and pipeline infrastructure as the main structural bottleneck	30
5.1.3 Administrative, coordination, and communication-related waiting	31
5.1.4 Synthesis: qualitative answer to RQ1	32
5.2 Quantitative Analysis	33
5.2.1 Application of Little’s Law	33
5.2.2 Analysis of Turnaround Time Distribution Across Berth Operations.....	34
5.2.3 Synthesis: quantitative answer to RQ1	34
6. Improve.....	36
6.1 Introduction of Digital Quay Meetings and Integrated Communication	36
6.2 Improved Data Collection and Incident Reporting.....	37
7. Discussion and Conclusion	38
8. AI Declaration.....	41
References	42

1. Introduction

1.1 Background

In today's industrial setting, complexity is steadily increasing, driven by broader product portfolios, more dispersed supply networks, and tighter coupling between upstream, internal, and downstream activities (Bozarth et al., 2009). As markets become more volatile, time has become a competitive weapon: firms are expected to synchronise supply with demand fluctuations and respond quickly to shifts in both volume and variety (Christopher, 2000). This places greater pressure on operations to deliver high service levels and simultaneously improve efficiency and cost performance. However, the challenge is not only a higher number of tasks (detail complexity), but also the less predictable effects that arise when many interdependent elements interact over time (dynamic complexity) (Bozarth et al., 2009). In ports, small disturbances can spread across shared equipment and routing decisions, creating instability that is difficult to correct locally. Under those conditions, continuous improvement becomes critical, not as isolated optimisation of individual activities, but as a structured effort to reduce sources of variability and to stabilise the system's overall behaviour. Variability in demand, supply, and internal schedules tends to hurt operational performance and make planning less effective (Bozarth et al., 2009; Christopher, 2000).

A central determinant of performance in these environments is material flow efficiency, i.e. the extent to which materials move through the process swiftly and evenly, with minimal delays and interruptions. The Theory of Swift, Even Flow explains why this matters; productivity improves as flow becomes faster and more consistent, while random variability, from both outside and inside the system, reduces output and increases waiting, queues, and idle time (Schmenner & Swink, 1998). Throughput time helps identify where flows are slowed or blocked, and the Theory of Swift, Even Flow argues that higher variability, from demand or within process steps, reduces productivity and impedes flow. Bottlenecks are therefore critical, since productivity improves by eliminating or better managing them, and disruptions such as quality problems can create temporary bottlenecks that interrupt material flow (Schmenner & Swink, 1998). Importantly, complexity-related performance losses are often more strongly linked to dynamic sources, such as unstable schedules, unreliable lead times, and demand variability, than to "numerousness" alone (e.g., many products, parts, or partners) (Bozarth et al., 2009). Improving material flow efficiency, therefore requires reducing sources of variability, both in demand on the process and within process steps, and managing obstacles to flow so that materials move more swiftly and evenly. This stabilisation supports higher productivity, while responsiveness remains critical in volatile markets where supply chains must react quickly to changes in demand (Christopher, 2000; Schmenner & Swink, 1998).

The focal company in this case study, Inter Terminals, is a multinational storage and logistics company for liquid bulk energy products and materials (Inter Terminals, n.d.). The company operates in the process industry and provides storage, blending, and loading services for several different fuel products. The Gothenburg terminal handles fluctuating inflows, a relatively broad product range, and varying demand, which creates challenges for maintaining high flow efficiency and effective capacity utilisation. In order to maintain competitiveness and meet customer demands, Inter Terminals is obliged to offer their services, and respond to orders, on short notice. This means that staffing, berth reservation, and the common pipeline system need to be in order for Inter Terminals to be able to process orders. Due to congestion and resource contention, it is critical to avoid delays as quays serve as a choke point.

Inter Terminals manages fuel flows along three principal routes: via pipelines, by truck, and by vessel, with the latter accounting for the greatest volume. Vessels transiting the terminal are

subject to queues and, when at berth, extensive administrative protocols. Vessel loading/unloading is not permitted before these protocols are finished, which tie up the berth and reduce operational efficiency. As orders, demand, and shipping routes change constantly, the consequences of congestion and inefficient use of resources are greater. Storage and capacity to increase volumes are, however, ample. If Inter Terminals had more frequent access to berths, the company would likely be able to increase shipments and efficiency. Streamlining of the vessel loading process is hence beneficial for both Inter Terminals as well as the Port of Gothenburg.

Congestion observed in blending and loading operations indicates potential imbalances in the material flow, particularly in connection with the handling of inbound and outbound vessels. Furthermore, scheduling and execution of administrative work requires time at berth which serves as a bottleneck in the system. Inter Terminals intends to assess the possibility of increasing operational efficiency through the elimination of bottlenecks. Consequently, a structured analysis of how materials and operations progress through the system is required to identify bottlenecks and assess their impact on processing time and terminal productivity. Such an analysis can support targeted decisions to reduce the impact of non-value-added activities and promote more efficient use of existing resources.

1.2 Inbound & Outbound Material Flow at Inter Terminals Gothenburg

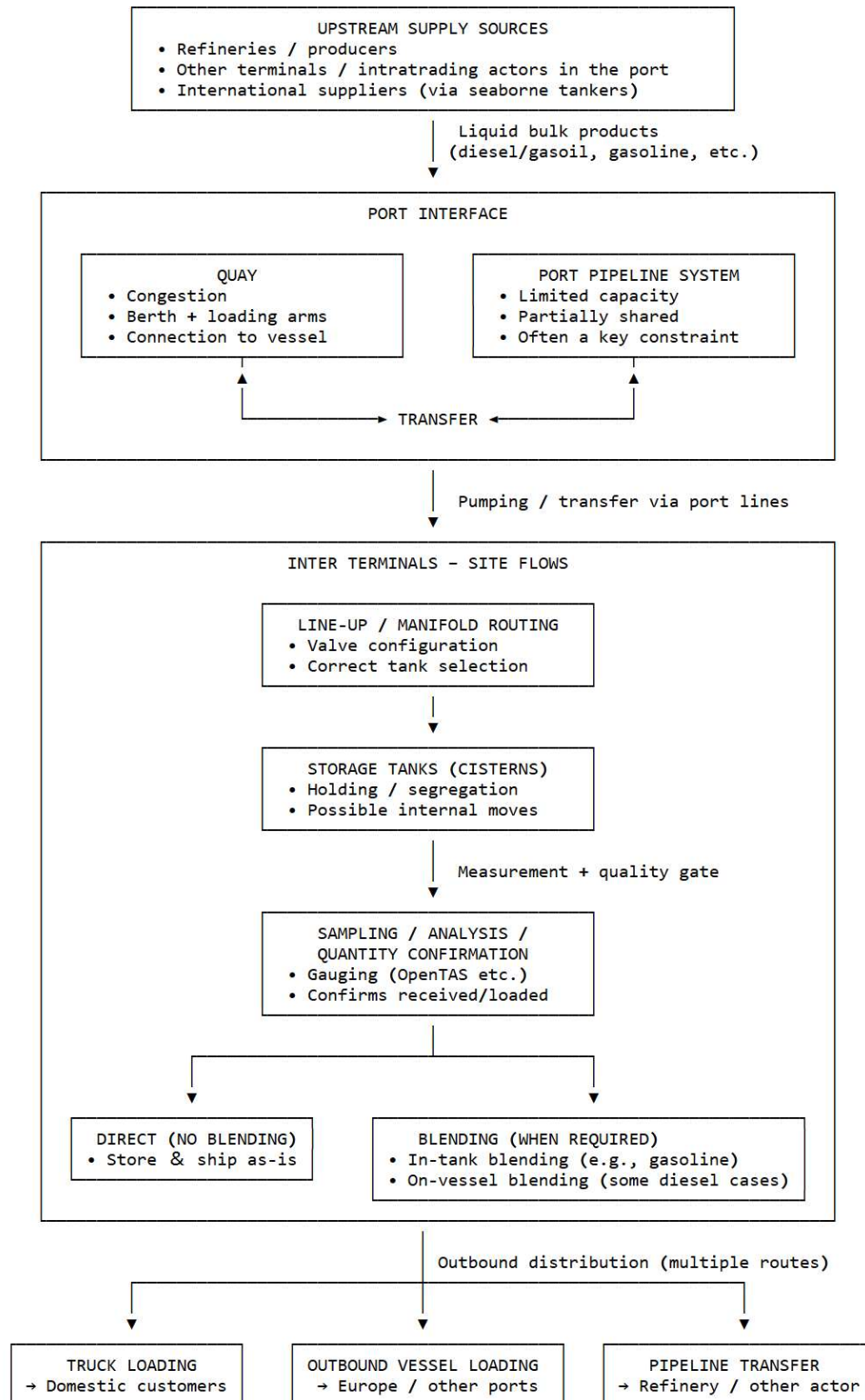


Fig. 1.1: Flowchart over the internal flows at Inter Terminals Gothenburg

1.2.1 Inbound

Inter Terminals in Gothenburg operates as a terminal for liquid bulk products, where the core task is to receive product, store it in a tank (cistern) system, and then enable onward distribution. In practice, the inbound flow is a chain of both physical and administrative steps that must be in place for receiving operations to start and be carried out in a controlled manner.

Arrival and planning for receipt

When an incoming delivery is made by a vessel, the process begins before the ship arrives at the quay. The planning team coordinates the vessel's arrival, assigns a berth, and agrees on a time window in dialogue with the port and other actors operating in the area. Because Inter Terminals relies on quay availability and shared port infrastructure, the inbound flow is shaped not only by the terminal's own capacity but also by how these shared resources are allocated across multiple users. In practice, this can result in significant waiting time, where a vessel may remain offshore until a berth becomes available.

Berthing, safety activities, and start-up

Once a vessel is alongside the quay, a few preparatory actions have to be done before pumping can start. This includes security-related controls and briefings, as well as reviewing the cargo/receiving plan. An important step is a joint start-up meeting where the involved parties confirm how operations will be executed, which products will be handled, which flow paths will be used, and which risks and constraints apply during the operation. The purpose is to create a common understanding of the working method, roles, and communication channels, as incorrect connections or misunderstandings can lead to both quality and safety risks. Pumping cannot always start immediately once the vessel is alongside; operation may be delayed while mandatory paperwork or administrative clearances are completed.

Connection to the system and establishing the flow path

After safety and documentation steps are completed, the vessel is connected through unloading arms at the quay. The product is then pumped from the vessel into the port's pipeline system. A central characteristic of the Gothenburg flow is that Inter Terminals uses a port pipeline system that is shared with other actors. This means that pipeline capacity, as well as the availability of certain product lines, can limit how many operations can be performed in parallel. For some products, a specific pipeline can effectively have "single capacity," meaning only one handling operation at a time is possible, making planning and prioritisation critical.

Transition into Inter Terminals' internal system (line-up)

When the product reaches Inter Terminals part of the system, the flow needs to be *lined up*, meaning that valves and routing are configured so that the product is directed to the correct cistern. This step is critical because it affects quality (right product to the right tank, avoiding contamination), safety, and efficiency. Line-up is often time-sensitive because quay time is expensive and vessel time windows can be tight.

Storage in cisterns and internal handling

After the line-up, the product is pumped into the selected cistern. Cistern storage acts as a buffer and makes it possible to decouple inbound and outbound in time. In other words, a product that is received is not necessarily shipped onwards immediately; it is often stored and waits for the next delivery window or customer order. In some cases, internal transfers between cisterns may occur, for example, to optimise capacity, create segregation between products, or enable upcoming dispatch operations.

Measurement, quantity confirmation, and sampling

During receipt, the received volume is measured and logged to ensure traceability and to complete the required documentation. Once pumping is finished, the tank is gauged, and the final quantity is confirmed. At the same time, samples are taken and sent for analysis to verify that the product meets specifications before it is released for onward distribution.

Potential blending (depending on product and customer requirements)

For certain products, blending is included in the handling process. Depending on the setup and customer requirements, blending is carried out either in the tank or during loading. This means the inbound flow is not always limited to "receiving and storage" but may also include activities that adjust product composition according to specification.

In summary, the inbound flow consists of a chain in which the vessel arrival and quay process, the port pipeline system, Inter Terminals line-up, and cistern storage are closely connected with measurement, sampling, and sometimes blending. The flow is shaped by coordination between multiple actors as well as infrastructural limitations in quays and pipelines, making planning and timing decisive for smooth material flow.

1.2.2 Outbound

Outbound distribution from Inter Terminals consists of several parallel distribution routes and is in practice the opposite of the inbound, with the addition of customer demands and a focus on correct dispatch execution. Similar to inbound, there are a number of physical and administrative activities that require alignment for proper outbound delivery.

Order, planning and coordination

Delivery is initiated through the reception of an order requiring the transport of product to customers or external parties. Planning involves the assurance of availability of the sought-after fuel product, capacity in the pipeline system, and that a time window can be secured for pumping. If the product is to be transported via vessel, a quay needs to be booked along with planning of the port's resources since part of the pipeline system is owned by the Port of Gothenburg, which Inter Terminals depends on. This often means dependence on external actors and limitations in capacity. For transportation via trucks planning is limited to access to loading stations, staffing, and availability of the cistern containing the requested field type without conflict with other terminal activities.

Preparation: line-up and routing

As with inbound, dispatch requires the establishment of a flow path through line-up. Valves and routing are configured to lead the product from the right cistern to the right destination. This element is crucial since an incorrect line-up can cause contamination, deviation of quality, or security hazards. Effectively, this process entails transport of the product from the cistern, via pipeline, to the loading arm at the quay and onto the ship.

Loading onto trucks

Central to outbound operations is also the loading of trucks for mainly domestic customers. The product is pumped to loading stations where volume is measured and registered. For dispatch to function with the desired quality of the product, the measurements and documentation all

need to be in order. Despite accounting for lower volumes, truck flows outnumber vessel flows, with each loading operation requiring the same rigorous process.

Loading onto vessels (international distribution)

Outbound operations by vessel is a resource-intensive and time-sensitive process, heavily reliant on coordination. Vessels require quays and engagement with loading arms, and the operation is preceded by extensive security briefings and confirmation of the cargo plan. The vessel can occupy a quay for hours before pumping due to the aforementioned administrative activities. Pumping to vessels is heavily dependent on the capacity of the pipelines and availability of quays, which as a consequence can lead to queues or idle time if several operations compete for the same infrastructure.

Transfer to other actors

A third route from the facility is pipeline transfer to other actors, such as refineries or other terminals. The product is sent via pipeline from Inter Terminals to the recipient's facility. This flow can be useful for balancing inventory, meeting demand or enabling further refinement of the resources.

Measuring, verification and administrative activities

After dispatch, volume and quality need to be measured and verified and can be considered the final step of delivery. Particularly for cross-border and tax-levied goods, this documentation is a necessity for the enablement of departure. Physical pumping is hence closely linked to flows of information and verification, where any deviations can result in delays or rework.

In conclusion, outbound distribution is not limited to mere transport; rather, it is an interaction between the terminal's internal tank and pipeline capacity, the port's shared infrastructure, and the need for coordination between several different parties such as the customer, the port, and customs. Dispatch often needs adjustment to fit fixed time windows, available resources, and sequencing in the pipeline system. Efficiency and throughput in outbound operations are affected by how well planning, communication, and division of resources are carried out.

1.2.3 Vessel turnaround as a critical constraint

Although Inter Terminals' overall goal is to enable efficient receipt, storage, and distribution of liquid bulk fuels, the terminal's performance is strongly influenced by the efficiency of vessel-related operations. Inbound and outbound vessel flows consist of a sequence of physical and administrative activities: berth allocation, safety briefings, documentation, line-up, pipeline routing, pumping, and verification. Each step needs to be completed before the next can begin. Because several of these activities rely on shared port infrastructure (e.g., quay capacity and pipeline availability), the terminal's throughput depends not only on internal resources but also on external constraints and coordination between multiple actors.

This reliance on shared infrastructure and coordination means that variation in one part of the system creates waiting time elsewhere. A vessel may be alongside and technically ready, but pumping can still be postponed if documentation is not finalised, if the required pipeline route is already occupied, or if another operation has priority for the same quay-related resources. However, this does not mean that the vessel is necessarily waiting passively. Several actors may still be carrying out required tasks, such as documentation, safety checks, inspection, customs and tax-related approvals, or operational confirmations before loading or unloading can start or before the vessel is allowed to depart. In those cases, the operation is essentially paused: the vessel occupies capacity, but no product is transferred. Even minor delays can add

up and extend berth occupancy. The consequences are felt beyond the quay. When a vessel operation runs late, planned blending and loading windows are pushed forward. In practice, this reduces how much the terminal can handle during a day and increases the need for short-notice replanning.

Mapping of the flow highlights two critical bottlenecks: the quay itself and the capacity/availability of the pipeline routes. Expanding quay capacity or increasing pipeline capacity typically requires significant capital investment and is often outside Inter Terminals' direct control because these assets are shared within the port system. Reducing vessel turnaround time is one of the few ways to improve throughput. Delays are rarely caused by one step. They usually occur in the handovers between planning, shared port resources, and the terminal's internal routing decisions. To work systematically, the vessel process needs to be broken down into its main stages, and the time spent in each stage needs to be made visible. This helps separate necessary work from avoidable waiting and shows how quay access, pipeline availability, and line-up decisions combine to create delays later in the process. With this in consideration, the relevance for decreasing the lead time is apparent and constitutes a concrete basis for targeted efforts to shorten turnaround time and improve terminal productivity.

1.3 Purpose & Research Questions

The purpose of this report is to analyse vessel turnaround at Inter Terminals Gothenburg and to identify waste, non-value-added time, bottlenecks, and to provide structured basis to enhance operational efficiency without the requirement of major infrastructure investments.

To achieve this purpose, the following research question were formulated:

RQ1: Which parts of the vessel turnaround process create waste, non-value-added time or operational bottlenecks at Inter Terminals Gothenburg?

RQ2: How can vessel turnaround time be reduced and operational efficiency be improved within Inter Terminals' existing infrastructure and operating setup?

1.4 Scope

This study focuses on vessel handling operations at the Gothenburg terminal of Inter Terminals. Even though the thesis is based on a single case, similar operational challenges may occur at other terminals with comparable conditions. The findings may therefore also be of interest outside the specific terminal studied.

The study focuses on operations at the Gothenburg terminal of Inter Terminals, specifically the handling and coordination of activities, such as pumping and supervision, connected to vessel turnaround.

Empirical data is collected mainly through interviews with employees involved in planning, coordination, and daily operational work. The analysis focuses on the operational roles and operating conditions that are most prominent in the turnaround process.

The analysis focuses on bottlenecks that arise within the terminal's current operating setup and examines how shared infrastructure, external coordination, and operational conditions influence vessel handling time and the flow of operations at Inter Terminals. The study also

considers improvement opportunities connected to these operational bottlenecks that exist within the existing terminal context and the influence of Inter Terminals.

2. Theory

Vessel turnaround time at the terminal is shaped by how work flows through constrained resources such as quay access and pipelines, and by variability and handovers between planning and operations. This chapter therefore treats the terminal as a flow system and introduces theories that explain how waiting and queues emerge, how bottlenecks determine performance, and how lead time can be improved.

2.1 Flows and Lead Time

A central component to the analysis of the performance of a system in a dynamic environment is the understanding of flows and lead time. Hopp and Spearman (2011) provide a fundamental framework for the understanding of flows and lead time for research. Their work covers concepts such as flow time, variability, bottlenecks, and Little's Law, which align storage, throughput and lead time to be used for quantitative evaluation of performance and identification of bottlenecks. Through the mapping of flows and analysis of the flow efficiency, organisations can identify waste and variation, central to improvement efforts.

Flow efficiency focuses on how smooth units navigate through processes as opposed to resource efficiency, which measures how well diverse resources are employed (Modig & Åhlström, 2012). In complex environments such as a port terminal, attention to flow efficiency could result in lower waiting times and bottlenecks, increasing overall productivity.

2.2 Supply Chain Complexity and Responsiveness.

Bozarth et al. (2009) separate between detail complexity and dynamic complexity in supply chains. Detail complexity is about the number of elements in a system, for example, products, resources, processes, or actors. Dynamic complexity, on the other hand, is about the uncertainty that appears when these elements integrate over time. This means that a change in one part of the system may lead to consequences in other parts of the system. This makes planning and control more challenging.

Christopher (2000) highlights that volatile and uncertain market conditions increase the need for responsive and agile supply chains. The responsiveness is not only about speed but also the ability to handle changes in demand, volume, and variation. To be able to achieve this, information sharing, process integration, and coordination between actors are emphasised.

2.3 Little's Law

Little's law is a fundamental principle in both queuing theory and operations management describing the relationship between pivotal elements of a system. It is expressed as:

$$L = W$$

where L represents the average number of units in a system, average arrival or throughput rate, and W the average time a unit spends in the system (Little, 1961). The formula signifies the dependence of work performed in the system on the velocity of the throughput of units and the amount of time they remain within the system.

The formula's strength lies in its versatility as the ratio applies to all systems in long-term equilibrium with clear average values, regardless of statistical distribution of arrival times (Hopp & Spearman, 2011). The law is therefore a useful tool in the determination of analysis of, e.g. systems of production or logistical flows. Hopp and Spearman demonstrate this with identification of congestion, formation of queues, and similar inefficiencies in their book.

In practice, Little's Law is used for approximation of one of the variables, provided the other two are known. If for example, throughput and average time in a system are known, one can calculate the average number of units in a system. Targeted efforts to reduce either L or W will hence result in a reduction of L and vice versa (Shortle et al., 2018).

2.4 Lean Six Sigma

Lean Six Sigma is an integrated process improvement method that combines Lean principles, focused on reducing waste, with Six Sigma, which aims to reduce variation and improve quality through data-driven analysis (George, 2002). The combination of these two approaches enables organisations to increase efficiency and establish standardised processes that can be performed in a consistent and predictable manner.

The method is mainly employed by organisations seeking to develop and enhance existing processes (American Society for Quality, n.d.). Through the identification of activities that do not create value for the organisation, resources can be put to better use while simultaneously reducing errors and anomalies. Lean Six Sigma often relies on structured methods such as DMAIC where improvement efforts are clearly divided into steps ranging from problem description to implementation and follow-up.

Central to Lean Six Sigma is evidence-based decision-making. Collection and analysis of data enable deeper comprehension of processes and thereby decision-making grounded in reality. Concurrently, an emphasis is placed on continuous improvement, where improvement initiatives aren't viewed as isolated measures for temporary results but rather as part of long-term strategic efforts for development and learning (Womack & Jones, 1996).

2.5 Bottleneck Theory

Bottleneck theory is based on the idea that the performance of a process is contingent upon the component of a system with the lowest capacity. The total output of a process that consists of several interconnected activities cannot exceed more than the limiting resource allows. This resource is commonly known as the bottleneck. A bottleneck can be a machine, workstation, human resource, transportation link, flow of information, or other parts of a process that limit throughput (Betterton & Silver, 2012). Improvement of non-bottleneck resources can increase local efficiency but does not aid the system as a whole (Betterton & Silver, 2012). Schmenner and Swink (1998) describe this through their *Law of Bottlenecks* which promotes an increase in productivity by addressing the bottlenecks that limit the system.

Bottlenecks are closely linked to flows and variation. Schmenner and Swink (1998) argue in their *Theory of Swift, Even Flow* that productivity is improved when materials move quickly and evenly through a process, while disruption and uneven flows inhibit performance. A bottleneck creates such disruptions because work consolidates in front of it while the subsequent parts of the system experience waiting time. Variation makes this harder to manage, because fluctuations in demand, process time, availability of equipment or direction can create queues and delays even when average capacity appears sufficient. Spearman (2014) explains that variation must be absorbed through buffers, primarily through inventory or supplementary time or capacity. The use of buffers is, however, a trade-off. Inventory binds resources and

capital, time increases lead time, and surplus capacity increases costs. A bottleneck is hence not only a technical capacity issue; it also revolves around how capacity interacts with variation and how well a process is coordinated.

Furthermore, it is important to distinguish between physical and operative limitations. Schmenner and Swink's (1998) *Performance Frontier* framework separates what a system can achieve through its equipment, technical and physical structure and what the system can actually realise through current routines, planning methods and management. Bottlenecks can therefore be the result of both structural limitations, such as insufficient equipment or infrastructure, as well as operative constraints such as vague routines, flawed scheduling, and inadequate communication. The difference is vital to recognise as different bottlenecks require different measures of improvement.

Another important aspect to understand about bottlenecks is that they are not always 'fixed' but rather are prone to relocate under changing circumstances (Betterton & Silver, 2012). The improvement of a resource upstream can move the bottleneck downstream. Similarly, changes in demand, assortment, staffing, or availability of equipment impact where the critical constraint manifests itself. Bottlenecks are therefore to be monitored continuously rather than to be viewed as static or permanent. Management of bottlenecks therefore requires a system-wide perspective.

3. Method

The Method chapter describes the research design, data collection methods, and analytical approach applied in the study. To investigate the vessel turnaround process at Inter Terminals Gothenburg, the study employed a case study methodology combining qualitative and quantitative methods. Interviews, observations, operational data, and literature were used to create a comprehensive understanding of the process, its bottlenecks, and the factors influencing operational efficiency and turnaround time.

3.1 Research Design

The study employs a dual qualitative and quantitative case study structure to enable in-depth analysis of complex processes in its real-life context. Case studies are particularly suitable for research questions focused on the ‘how’ and ‘why’ certain phenomena arise, as well as in situations where the researcher has limited influence on the processes at hand (Yin, 2017). Considering the study’s focus on material flow, handling time and bottlenecks, a case study approach is fitting for the purpose of gaining a detailed understanding of the correlation of processes, resources, and organisational prerequisites. Furthermore, the study adopts an abductive research approach, where empirical and theoretical findings are incorporated and evaluated against one another.

The study is executed as a single-case study with the motivation that it constitutes a relevant and insightful case in and of itself for analysis of process improvement within a complex environment. According to Yin (2018), single-case studies are useful when the case at hand is representative or offers insight into a comprehensive assessment of specific phenomena. This is backed by Eisenhardt’s (1989) notion of the case study’s use for analytical generalisation rather than statistical generalisation; where insights from the case can further theory development.

To the extent possible, data collection is to be based on several sources to endorse triangulation and strengthen the credibility of the study. According to Voss et al. (2002), this is notably important in supply chain research, where processes often are characterised by complexity and cross-functionality. The study combines process data, documentation, and observations to capture quantitative and qualitative aspects of material flows and handling times.

Analysis is performed through structuring of empirical data, which is interpreted with the aid of established theories in the subject of process improvement, simultaneously allowing for comparison between the two. As emphasised by Yin (2018), the significance of a clear analytical framework is crucial to ensure internal validity in case studies. Through this procedure, the study aims to generate conclusions that, notwithstanding its contextual boundaries, can prove relevant for similar institutions within supply chain management.

3.2 Research process

The research process was divided into two main steps. The first step was to collect empirical data through internal interviews with employees at Inter Terminals and observations at the site. The interviews were used to create an understanding of how vessel management is planned and implemented in practice, while the observations gave a better picture of the physical environment, resources, and workflows at the terminal. Through combining these two data sources, the study could identify areas in the process where challenges, waiting times, and

coordination issues appeared. This step was thereby used to locate a relevant improvement area to study further.

In the second step, the analysis deepened the identified improvement area. Relevant internal data in the form of Excel files was analysed to highlight the specific problem in detail. The internal data was used to analyse patterns, variations, and time-related aspects connected to the selected area of study. To complement the internal material, an external interview with an independent inspection company was carried out. The company is responsible for quality and quantity controls of inbound products from vessels to Inter Terminals. The external interview contributed with an additional perspective on the activities connected to the studied problem.

In parallel with these steps, a literature study was carried out to give theoretical support to the analysis and to connect the empirical results to relevant concepts such as bottlenecks and operational efficiency. Through this work process, the study could first identify a relevant improvement area and then analyse it in greater depth with support from both internal and external data sources.

3.3 DMAIC

The methodology uses the DMAIC-cycle consisting of five phases (Define, Measure, Analyse, Improve, Control), which entails a systematic approach to identify issues, measure current performance using relevant KPIs, analyse root causes to the issues, and implement improvements as well as control mechanisms that ensure that the implemented changes and their effects are maintained (George, 2002). The DMAIC process hence combines process mapping with statistical analysis and improvement efforts in a systematic framework to enhance process performance and reduce variation.

The aim of the *Define* phase is to establish the nature of the issue, its scope, and interpretation (George, 2002). Descriptions of the process to be studied, which actors are involved and which goals are to be achieved. Principal to this stage is the formulation of a clear problem statement, which is related to the organisation's overall objectives to facilitate clear direction for the improvement initiatives (George, 2002). This phase serves a foundation for the improvement work and ensures that the correct issue is addressed. In this report, chapter 1.2 serves as the *Define* section by establishing the process context, clarifying the scope of the problem, and providing the basis for the subsequent DMAIC phases.

During the *Measure* phase an overview of the current state is created through systematic fact-based collection of data and defining relevant measurements of performance (George, 2002). Appropriate methods and key metrics are identified and implemented to quantify output. The stage is crucial because it provides a baseline upon which further analysis is dependent on and aids in identifying flaws and variation in the studied process (George, 2002; Montgomery, 2020). It is therefore imperative that this phase is structured properly and any negligence undermines the reliability of the analysis and subsequent conclusions (Montgomery, 2020).

In the *Analyse* phase, the collected data is examined to identify root causes to the observed issue (George, 2002). The focus lies on separating symptoms from the underlying causes of the defined problem, often through statistical methods. By creating an understanding of the reasons why variation or inefficiency occurs, targeted efforts for improvement can be directed to the most critical parts of the process (George, 2002; Antony, 2014).

The *Improve* phase consists of the development and implementation of solutions that address the identified root causes. The improvements can include changes in the structure of the process, working methods, or allocation of resources with the aspiration to e.g. reduce variation,

eliminate non-value-added activities or reduce lead time (George, 2002). The purpose is to achieve measurable changes in quality, efficiency etc.

The final phase, *Control*, intends to preserve the improvements through the establishment of control mechanisms, surveillance systems, and standardised work processes (George, 2002). The introduction of control mechanisms should therefore prevent regression towards the initial stage and ensure that the implemented enhancements remain long-term (George, 2002; Montgomery, 2020).

Due to the limited time frame, the *Control* phase is not included in this project. Since the improvements will not have been implemented upon completion of the report and hence falls outside of the scope for the master thesis.

3.4 Interview study

To gain a better understanding of Inter Terminals' flows and operations, a qualitative approach is selected for the interview study to explore the subject in depth. Qualitative interviews are eminently suitable to achieve an understanding of different individuals' experiences and perspectives within their professional context (Kvale & Brinkmann, 2014). In line with this view, interviews are regarded as intellectual interactions where knowledge is exchanged rather than a mere data collection technique.

Following the notion of the qualitative research interview as a "professional conversation", a semi-structured interview structure is applied (Kvale & Brinkmann, 2014). This approach allows for flexibility to pursue themes and insights that emerge during the conversation without compromising on consistency across interviews. According to Brinkmann and Kvale (2018), semi-structured interviews are particularly appropriate in applied research, as they balance comparability with depth and openness.

Each interview is tailored to the respondents' professional roles and areas of expertise and consists of open-ended questions structured around key themes concerning the study. This thematic structure enables a conversational flow and space for following up on statements made during the course of the interview (Kvale & Brinkmann, 2014). In order to encourage elaboration and confirm accurate understanding, clarifying questions are asked throughout the dialogue.

Participants are selected from different departments involved in different roles, including planning, coordination, and operational activities related to material flows at the terminal. This is done to ensure that perspectives from both operational and planning divisions are included, and participants are selected based on their expertise and relevance to the study. Prior to each interview, participants are informed of the purpose of the study, matters of confidentiality and anonymity, and consent to the interview and its recording is obtained (Kvale & Brinkmann, 2014).

3.5 Literature study

To establish a theoretical foundation for analysing material flows and operational bottlenecks and to support the interpretation of the empirical findings, a literature study is conducted. The literature review contributes to the clarification of concepts and provides perspectives for identifying and assessing bottlenecks in operational processes, in line with the role of literature reviews described by Bryman & Bell (2015).

The literature search is carried out using Scopus, Web of Science, and Google Scholar. The literature search is conducted using keywords related to material flow efficiency, bottlenecks, operational processing time, and planning and coordination issues. Both older and more recent studies are included to gain an understanding of how these topics have been addressed in earlier research.

The literature used in this study consists mainly of peer-reviewed journal articles and a few well-established books in operations and supply chain management. The search mainly covered research on material flows, waiting times, and capacity constraints, as these topics are central to the thesis.

The reviewed literature is used to develop the theoretical framework presented in the theory chapter and to support the analysis of the empirical material. Previous research is used as support when identifying and describing bottlenecks in the studied operations. It also helps guide the analysis of how different types of bottlenecks influence processing time, overall throughput, and the use of available capacity. When discussing possible improvements, the literature is mainly used to relate the observed challenges to how similar issues have been handled or discussed in earlier studies, thereby linking empirical findings to existing research and strengthening the analytical credibility of the study (Bryman & Bell, 2015).

In addition to literature on material flows and bottlenecks, research related to Lean Six Sigma is reviewed to support the improvement-oriented aspects of the study. This literature is mainly used to support the identification of activities that do not add value, to analyse how the processes perform in practice, and to structure the improvement proposals developed in the study.

3.6 Quantitative Data Collection

In addition to the interview study, internal documents were used for the collection of quantitative data. While the interviews contributed to explanations around routines, coordination issues, and perceived bottlenecks, the internal documents gave registered operational data regarding the vessel turnaround process and delays. More detailed data regarding port calls was also gathered from the Port of Gothenburg's archives. This complemented the interview study with documented time-based information from the vessel turnaround process.

The internal material consisted of files that documented inbound/outbound vessels along with incident reports. The files included variables such as vessel name, order ID, quantity, ETA, connection time, pump start time, pump stop time, and product category. Beyond the information found in internal documents, port files included more extensive information regarding berth utilisation and quay lay times.

These documents were used mainly to explore time intervals in the inbound vessel flow, for example, time from arrival to pump start, pump time, and disconnection. This was relevant to identifying late arrivals, variation in handling time, and potential bottlenecks in the operational process. Before the analysis, the material was reviewed to remove duplicates and account for missing values. The internal documents, in addition to the interviews, strengthened the study's empirical basis.

3.7 Observations

Observations were used as a complement to interviews and internal documents to create a better understanding of the terminal's physical environment and operational context. While the

interviews contributed with descriptions of working methods, coordination, and perceived challenges, the observations gave a direct insight into how the operation is built up and how different resources are placed and used practically.

As a part of the study, a site visit was carried out where the supervisor at the company showed the facility. During the visits, cisterns, the control room, blending operations, and quays with connected vessels were examined. The visit contributed to a better understanding of the layout of the terminal, resource allocation, and the physical conditions surrounding vessel management.

By visiting the terminal, a more concrete understanding of the operation was gained. This aided in understanding of the interview material and gave a clearer picture of factors that may influence waiting times and coordination during vessel handling.

3.8 External Data Collection

In addition to the interviews with Inter Terminals, external interviews were used to gain complementary perspectives on the vessel turnaround process. While the internal interviews contributed insights around internal routines, coordination, and perceived operational challenges, the external interviews allowed for the inclusion of the perspective of actors involved in the vessel handling process outside of the terminal. This contributed to a broader understanding of how the process is influenced by activities and dependencies beyond Inter Terminal's direct control.

One interview was carried out with an independent inspection company, which is responsible for quality and quantity control of inbound and outbound products. Since the company has a central role in connection with vessel calls and loading activities, the interview contributed to a better understanding of how these control activities are carried out and how they relate to and impact the vessel turnaround process.

In addition, two interviews with representatives from the Port of Gothenburg were carried out, with the purpose of including the port's perspective on vessel calls, coordination, and operational constraints in the port environment. These interviews contributed insights into how the shared port infrastructure, planning conditions, and port-related dependencies affect operational efficiency in the vessel-handling process. They also provided a broader understanding of the different stages of a vessel call and potential bottlenecks connected to port operations and coordination between actors.

Additional external actor perspective was also collected through an interview with a current Inter Terminals employee, but the interview was carried out based on their previous experience as a port agent. The interview was thereby not treated as a standard internal operational interview, but as a role-based external perspective on vessel calls, coordination, and communication between terminals, vessels, agents, and port-related actors. This distinction was important because the respondents' answers focused on the interface between organisations rather than on Inter Terminals' internal routines. The interview contributed to a broader understanding of how external actors experience delays, information exchange, and coordination problems in the vessel turnaround process.

The external interviews were semi-structured, and the questions were adapted to the respondents' roles and areas of responsibility. This made it possible to address both common themes and actor-specific questions relevant to the study.

3.9 Reliability and Validity of the Study

To ensure the reliability and validity of the study, several approaches and strategies were employed in line with academic guidelines. Triangulation is a research strategy in which various perspectives, data sources, methods, and theories are combined for the purpose of strengthening the credibility of a study (Yin, 2017). There are several types of triangulation, of which method triangulation refers to research where different means of data collection are employed and integrated e.g. interviews, observations, and analysis of documents (Denzin, 1978). By examining the same phenomena through different methods, the risk of systematic errors, such as bias, can be decreased and allow for a more nuanced and robust comprehension of the research phenomenon (Bryman, 2018; Yin, 2018). Triangulation is often associated with qualitative research but it is also useful in research that combines qualitative and quantitative elements (Flick, 2023). While the principle of data complementing each other is central, Flick (2023) highlights that triangulation is not merely a means of confirming results but for identifying contradictions and empirical complexities.

With regard to validity, the methods were selected because they matched the type of research questions asked in the study. Since the thesis examines where time is spent in the vessel turnaround process, the quantitative data were relevant for identifying patterns in arrival times, pump start, pump stop, and departure. These timestamps made it possible to relate the analysis directly to turnaround time and non-value-adding waiting time. However, the timestamps could not, on their own, explain why delays occurred. For that reason, the quantitative analysis was combined with interviews and observations, which provided insight into planning, coordination, infrastructure availability, and information exchange. This follows Bryman's (2018) argument that mixed methods can be useful when quantitative and qualitative data contribute different but complementary insights into the same research problem. However, since turnaround time is also influenced by planning, coordination, infrastructure availability, and information exchange, interviews with internal employees were used to explain the causes behind the observed time patterns. External interviews with the Port of Gothenburg and the inspection company added perspectives from actors directly involved in berth allocation, port coordination, sampling, and inspection. In line with Yin (2018), the use of multiple sources of evidence in a case study strengthens construct validity through triangulation. Therefore, combining quantitative data, interviews, and observations improved the study's ability to capture how long delays lasted and why they occurred. However, since turnaround time is also influenced by planning, coordination, infrastructure availability, and information exchange, interviews with internal employees were used to explain the causes behind the observed time patterns. External interviews with the Port of Gothenburg and the inspection company added perspectives from actors directly involved in berth allocation, port coordination, sampling, and inspection. In line with Yin (2018), the use of multiple sources of evidence in a case study strengthens construct validity through triangulation. Therefore, combining quantitative data, interviews, and observations improved the study's ability to capture how long delays lasted and why they occurred.

The collected data used for the analysis of vessels' turnaround time consisted of manually registered information concerning e.g. arrival time, time of initiation and conclusion of pumping, and departure time. Since this is done manually, the registration of time is prone to a certain degree of clerical error expressed in the form of incorrect dates or miscalculated durations of pumping. Upon review of the data set, a number of such deviations were identified. To the extent possible, these errors were corrected using Excel formulas or manually with the available information. Errors that could not be corrected were removed from the dataset. These adjustments could impact the reliability of the study, as data points removed amount to information not taken into account in the study and changes are susceptible to bias. Considering this, the impact of the quality of the data and the effect of errors is estimated to be limited since the number of amendments are small in relation to the total data set, and were performed

consistently. To avoid potential expression of seasonality, over a year's worth of data was collected and used in the analysis. The number of data points exceeds 700, which is a high number adequate for statistical reliability and precision, ensuring that estimates and results are less influenced by random variation (Jordan, 2025).

4. Measure

The *Measure* phase aimed to gather detailed understanding of the turnaround process at Inter terminals and identify factors that impact operational performance. To achieve this both qualitative and quantitative data was collected. Together, the empirical findings created a fundamental basis for the subsequent analysis.

4.1 Process Map

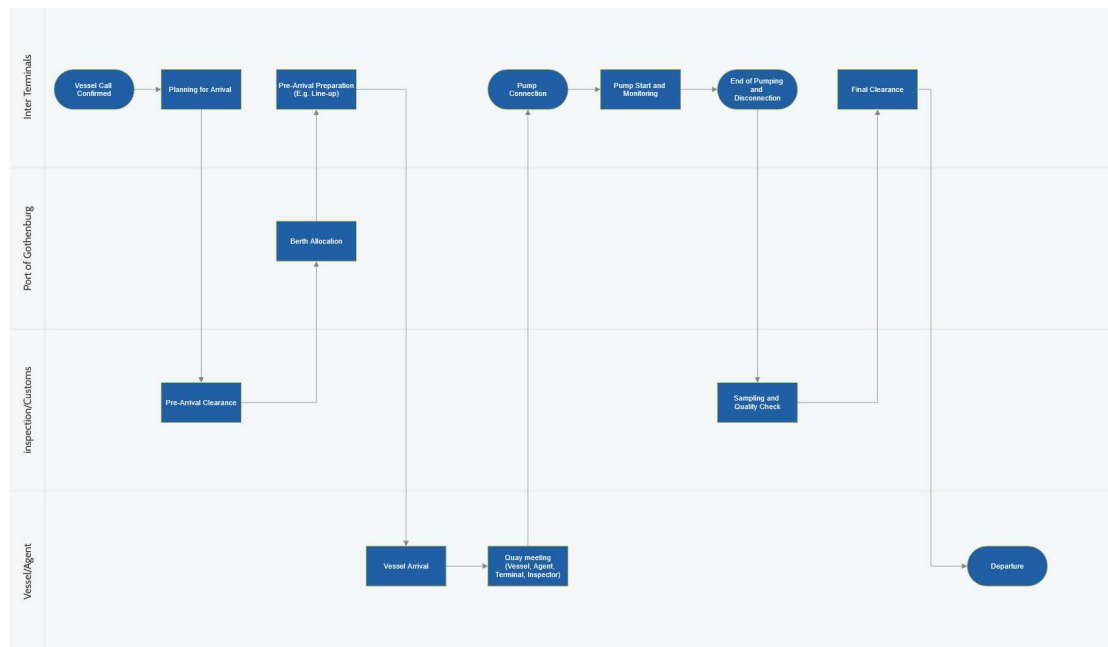


Fig. 4.1: Process map of the vessel turnaround process at Inter Terminals. The model is based on vessels loading cargo alongside berth; however, the reverse operation, cargo discharge, also occurs depending on the specific order.

For the purpose of demonstrating a comprehensive picture of the flow of goods through the berths, from docking to departure, and to visualise key steps, decision points and continuity, a process map was compiled (see figure 4.1). In addition to process steps, functions and the actors responsible for them are visible as well. This enables an overview of potential bottlenecks, waiting times, and handovers throughout the vessel handling process. To ensure its accuracy, the information used to create the process map was aggregated from the interview study, observations, and available maps. When all process steps were documented, input and output were identified for each step through coordination with employees at Inter Terminals as well as with already collected data.

Vessel Call Confirmed: As illustrated by the process map, the process begins with a vessel call or order being acquired by Inter Terminals. planning and quay allocation. In this step the planning function coordinates the vessel's expected arrival, available quay capacity, and the operational prerequisites required for the call.

Planning for Arrival: In anticipation of vessel arrival, the terminal, the agent and the port coordinate arrival time, berth availability as well as tugboats and pilot vessels. Cargo information, customs documentation, and operational details are shared between the involved parties to ensure that the vessel can be received and handled efficiently upon arrival.

Pre-Arrival Clearance: Before unloading or loading can begin, customs and tax-related documentation is submitted to the relevant authorities. The terminal, agent, and customs systems coordinate the required declarations and approvals to ensure that the cargo is authorised to enter or move within the EU.

Berth Allocation: Prior to vessel arrival, the port and terminal arrange for a berth based on the size, cargo, and operational schedule. Adjustment may occur dependent on delays or schedule changes that affect other planned operations.

Pre-Arrival Preparation: Before either arrival or pumping, tanks/cisterns are prepared and pipeline line-up occurs before the movement of cargo. Documentation, cargo specifications, and safety requirements are reviewed to ensure that all systems and personnel are ready before the vessel reaches the berth.

Vessel Arrival: Upon arrival, the ships are guided to berth with the support of tugboats and pilots if required and mooring lines secure the vessel in place. Once secured, terminal and vessel personnel prepare for the start of cargo operations.

Quay Meeting: After berthing, representatives from the vessel, terminal, agent, and inspectors meet and review operations. Safety procedures, cargo plans, communication routines, and transfer details are confirmed before cargo handling is authorised to begin.

Pump Connection: After the quay meeting, terminal operators connect loading arms to the vessel. Safety controls and pressure tests are conducted to verify that the connection is secure and ready for cargo transfer.

Pump Start and Monitoring: After approval, pumping is commenced. During the entire process operators and crew monitor tank levels, flow rates, pressure and safety conditions to ensure operation is conducted safely and according to plan.

End of Pumping and Disconnection: Once the planned quantity of cargo is transferred, pumping is concluded. Loading arms are disconnected and the different parties confirm correct transfer.

Sampling and Quality Check: Tests and sampling can occur before, during or after transfer of cargo to verify quality and quantity in accordance with order specifications. Inspectors and terminal operators compare results before approval.

Final Clearance: After cargo operations have ended, remaining documentation, customs declaration and operational reports are finalised. Authorities, terminal staff and the agent confirm that all requirements have been met before permission for departure is given.

Departure: Once clearance is granted the vessel prepares for departure. Mooring lines are released, departure services are coordinated, and the vessel departs the terminal.

4.2 Empirical Findings - Internal

The internal interviews demonstrate that the vessel handling at Inter Terminals is characterised by several dependencies between internal functions, external actors, and shared resources. Despite the recurrent nature of the process and its familiarity, employees working in planning, logistics, operations, and administrative functions describe how planning conditions, waiting time, coordination problems, and limited infrastructure affect the efficiency of the flow. The

interviews thereby provide a more practical picture of which factors contribute to extended turnaround time.

4.2.1 Planning Conditions and Short Notice

A recurring theme in the interviews is that planning often takes place with limited advance notice. The manager of Logistics Services and other employees working in planning and logistics describe how nominations and information about upcoming handling operations often arrive one or two days in advance and in some cases, even later. It is explained that this makes it difficult to plan beyond the short-term.

It is also clear that the short planning horizon is linked to how customers and other actors plan their flows. The manager and staff of the Logistics Services department state that the terminal often receives information late, even though other actors may, in some cases, have been aware of the handling operation earlier. The planning thereby becomes largely reactive, with the operations adapting to incoming updates rather than working according to a stable long-term plan.

The interviews further show that the planning conditions are complicated by the fact that several handling operations compete for the same resources. Already at the planning stage, consideration must be given to berths, pipelines, and vessels' estimated arrival times. The department of Logistics Services, therefore, reports that potential bottlenecks may arise even before the actual handling operation begins.

4.2.2 Waiting Time and Delays in Vessel Handling

The interviews convey that waiting time often arises before pumping itself begins. The shift leader, together with employees working in the Logistics Services department, describes that a substantial share of the total lead time is spent on preparations, control activities, paperwork, communication between actors, and waiting for other functions to complete their tasks.

From the shift leader's perspective, it is common that an operation that, on paper, is expected to take a certain number of hours in practice takes considerably longer. This is because the preparatory and closing activities are not always reflected in the original time estimate. These activities include preparing pump routes, verifying volumes, finalising documentation, and ensuring that all involved actors are ready before the operation can proceed. The time required for these activities can vary considerably depending on how quickly each actor completes their part of the process.

Another finding is that waiting time often arises when the terminal is dependent on third parties. The shift leader describes that if an inspector is not finished, if the port's systems are not ready, or if the vessel itself is not prepared, the entire process is delayed. From the operational perspective, even small deviations in one part of the process may create significant consequences for the rest of the handling operation.

Several interviews point to vessel delays as a recurring source of waiting time. The manager of Logistics Services and other logistics-related functions describes that when vessels do not arrive as planned, this affects not only the individual handling operation but also the subsequent resource planning. It is further explained that this creates a need for replanning and leads to less efficient use of both berth time and staff resources.

4.2.3 Bottlenecks in Shared and Internal Infrastructure

A recurring theme in the interviews is that quays and pipelines are described as limiting resources in the operation. Employees working in planning and logistics point to gas oil handling as particularly constrained, since it depends on a single pipeline that is shared with other actors in the port. One employee states that this makes gas oil handling more vulnerable than fuel oil handling, where more pipelines are available. The same employee describes queues and waiting times as occurring mainly in relation to quays, pipelines, gas oil, and berths 510 and 511.

The interviews further underscore that these limitations are not only found in the shared port system. The shift leader and staff of the Logistics Service department describe the terminal's internal infrastructure as another source of constraint. They mention situations where operations that appear possible on paper, in practice, may conflict in pumping routes, pump houses, or internal pipeline arrangements. According to the interviews, bottlenecks thereby arise both at the interface with the port and within the terminal's own system.

Both the manager of Logistics Services and an employee in the same department emphasise that storage capacity is not the main limiting factor in the operation. I.e. tanks are generally not perceived as a constraint. Instead, the interviewees describe the practical capacity as being mainly determined by the ability to move more product to and from the berth, and by the possibility of handling several flows simultaneously.

The interviews also indicate that some parts of the infrastructure are perceived as less flexible than others. The manager and staff of the Logistics Services department repeatedly point to gas oil as the most vulnerable product type, whereas fuel oil and gasoline are described as more flexible due to a higher number of available pipelines. At the same time, the Manager of Logistics Services also highlights other physical limitations, such as pipeline dimensions and berth depth, which may affect both capacity and handling speed depending on the product type.

4.2.4 Information Flow, Coordination, and Replanning

The interviews show that the information flow surrounding the vessel handling operations is extensive and involves many internal and external actors. According to the interviews with planning, logistics, and operations, vessel handling depends on information exchange between several actors. These include customers, logistics functions, operations staff, inspectors, the port, and vessels. The communication is described as taking place mainly through emails, phone calls, and chats, which creates an information flow that is difficult to oversee fully.

From the shift leader's perspective, the same information can sometimes reach the terminal from several sources but in different versions. This creates uncertainty regarding which information is valid and leads to additional verification before action is taken. The shift leader also describes situations where the operations staff notices that a change is about to occur but still needs confirmation from the logistics department before proceeding.

Employees working in planning and logistics describe replanning as a recurring part of the daily work. They mention delayed vessels, changed customer instructions, revised blending requirements, and situations where other terminals have not shared their plans in time as examples of changes that may require adjustments. From the shift leader's perspective, information can also reach the terminal from several sources but in different versions, which creates a need for additional verification before action is taken. The shift leader further describes late adjustments as increasing stress in the operation and as something that may increase the risk of mistakes. Overall, the interviews describe coordination as dependent not only on whether information is available, but also on when it is received and whether the involved actors have the same understanding of the current plan.

4.2.5 Administrative and Organisational Constraints

The employee responsible for customs and tax matters describes how administrative requirements also affect the flow at the terminal. For certain types of handling operations, declaration, documentation, and quantity records need to be in place before the process can be completed. The employee explains that if this information is missing or delayed, it can hinder subsequent steps, and in some cases, also delay other vessels waiting for the same resources. In some cases, vessels may also need to remain at berth for several hours after the physical handling has been completed, while customs and tax-related documents are finalised and approved. The vessel cannot depart before all required documents have been completed and accepted.

From the customs and tax perspective, this is evident for customs goods and products from third countries. In these cases, rules concerning segregation and residual product volumes in tanks mean that all available capacity cannot always be fully utilised. The customs representative explains that even small remaining volumes in a tank can prevent a new handling operation, despite the fact that physical space is available in the system. The customs and tax representative therefore describes these restrictions as administrative or regulatory limitations rather than physical limitations in the infrastructure.

Staffing is also highlighted by both operational and planning-related functions as an important factor, but not as the most fundamental bottleneck in operations. Instead, staffing mainly appears as a constraint during periods of high workload, sickness, vacation periods, or when many handling operations need to be carried out in parallel. The shift leader, as well as employees working in logistics and planning, describe that it is not sufficient that the infrastructure in theory allows for several operations in parallel; there must also be enough staff to supervise and carry them out safely.

Taken together, the interviews with the customs and tax function, operations staff, and planning and logistics functions show that administrative and organisational conditions act as complementary constraints in the system. They are described as not always being the primary cause of waiting time, but they affect how well the available capacity can actually be utilised in practice.

4.2.6 Observations

The site visit gave a direct understanding of the terminal's physical environment and of how vessel-related operations are embedded in a larger technical and operational system. The observations showed that the terminal is structured around a network of cisterns, pipelines, quays, and control functions, where several resources must be coordinated at the same time for vessel handling to take place. The operation appeared as an interconnected system in which quay access, routing possibilities, tank allocation, and internal handling are dependent on one another.

A clear observation during the visit was the physical relationship between the quays, the pipeline system, and the tank area. The quays could not be understood as isolated loading or unloading points, but rather as entry and exit points to a broader infrastructure of shared and internal pipelines. This made it clear that vessel handling depends on the availability of the correct pipeline and the correct receiving or dispatch tank. The observations thereby provided a more concrete picture of how quay operations are connected to internal routing and the use of cisterns.

The control room was also an important part of what was observed during the visit. It became clear that many operational activities are followed from there and that it functions as a point for managing what occurs across the terminal. This gave a clearer picture of vessel handling as being broader than the pumping itself. Vessel handling also includes keeping track of the operation, communicating between actors, and handling coordination as different activities unfold.

Another observation was that blending and internal product handling form an important part of the terminal environment. The visit showed that flows involve more than receipt and storage, since products may also be transferred internally before further distribution. Tank allocation and internal routing are important practical conditions in the operation, and vessel-related activities are closely connected to what takes place inside the terminal after the product has left the quay.

Finally, the observations contributed to a clearer understanding of the practical conditions surrounding vessel handling. The physical environment demonstrated that several activities and resources are mutually dependent, and that vessel operations take place in a context where quays, pipelines, cisterns, and control functions must work together. By observing connected vessels, quay areas, and the terminal's internal facility, it became clearer how the terminal's physical layout and resource structure shape the conditions for coordination during the vessel turnaround process.

4.3 Empirical Findings - External

The external interviews provide a complementary perspective on the vessel turnaround process by describing activities and dependencies outside Inter Terminals' direct control. While the internal interviews highlight how the process is perceived within the terminal, the external interviews show how berth allocation, shared infrastructure, port coordination, inspection activities, and communication between organisations influence vessel handling. Representatives from the Port of Gothenburg and the independent inspection company thereby describe vessel turnaround as a process that depends not just on the terminal's internal work but also on the timing, coordination, and availability of external resources.

4.3.1 Planning Conditions and Port Coordination

A recurring theme in the external interviews is that the vessel handling starts before the vessel arrives at berth and involves continuous coordination between the port, terminal actors, and vessel-related parties. The Port Control Manager describes that planning in the Energy Port, the segment of the port dedicated to fuel products, typically begins around 72 hours before arrival. The first indication of an incoming vessel may be received earlier or later, depending on origin and route. At an early stage, information is collected regarding the relevant terminal, the product to be handled, and the quay where the vessel is expected to berth. Planning then continues through an ongoing dialogue between the port and the terminal until the vessel approaches Gothenburg.

The Operational Planner describes the port as a coordinating actor in the arrival process. They have responsibility for berth allocation, safe access to the quay, and coordination of arrival-related actors. According to this function, the port needs to align its planning with the terminals and the shared port infrastructure, as well as with the vessel and agent. The representatives of the Port of Gothenburg thereby indicate that planning conditions are shaped by several parallel dependencies already before the vessel reaches berth.

The Operational Planner also describes two different queueing principles in the port environment. One is a just-in-time approach, where vessels reduce speed and adapt arrival to berth availability while still retaining their place in the queue through a virtual notice of readiness. The other is first come, first served, where vessels must physically reach the port area before receiving the queue position. According to this description, vessel planning is not just about assigning a berth but also about managing how arriving vessels are sequenced in relation to shared capacity.

4.3.2 Shared Infrastructure and External Resource Constraints

The interviews with the Port of Gothenburg show that vessel turnaround depends on more than berth availability alone. Both the Operational Planner and the Port Control Manager describe that a vessel can only proceed when several conditions are fulfilled at the same time: the berth must be available, the relevant pipeline system must be free, and the terminal must be ready to handle the vessel. Since the number of pipelines is fewer than the number of berths, the pipeline system functions as a shared and limiting resource.

The external interviews also highlight other resource constraints connected to the port system. The Manager of Port Control describes how the arrival process depends on actors such as pilots, tugboats, and mooring staff. The Port Control Manager notes that limitations in tugboat or pilot availability affect operations in some cases, even if such shortages are not the most frequent source of delay in the energy port. The interviews thereby suggest that external marine resources act as additional constraints that can influence the overall time of a vessel call, especially when several arrivals are planned close together.

At the same time, the interviews with the Port of Gothenburg show that not all constraints are constant. The Port Control Manager describes how the shared infrastructure creates varying constraints depending on how many vessels are expected, what products are handled, and which parts of the pipeline system need to be used. The interviews, therefore, describe how external bottlenecks may shift over time depending on the mix of arrivals and the availability of the shared resources.

4.3.3 Inspection, Sampling, and Time at Berth

The interview with the independent inspection company adds a more detailed perspective on how inspection and control activities affect time at berth. The inspection company representative describes that both loading and unloading involve similar control activities, although the sequence differs depending on whether product is being loaded onto or discharged from the vessel. Several tasks can be prepared before the vessel reaches berth, such as sampling and measuring shore tanks, which means that part of the inspection process can be completed in advance. However, vessel-related tank inspection, onboard measurements, and some sampling activities can only begin once the vessel is at berth.

According to the representative from the inspection company, the initial onboard inspection for a loading operation can usually be completed within about one hour under normal conditions. However, the total time related to inspection after loading can be significantly longer, especially for heavier products such as fuel oil, where post-loading sampling and measurement may take up to three or four hours before the vessel can depart. The interview, thereby, shows that inspection and control activities are not only formal checks but can account for a substantial part of the vessel's berth occupancy time.

The interview also describes how these activities are affected by the operational conditions. If tanks are being blended just before the vessel arrives, or if certain parameters must be analysed

before the unloading can begin, the vessel needs to wait before product transfer can start. The inspection activities are thereby described as closely tied to the readiness of the product, tank conditions, and the coordination between vessel and terminal.

4.3.4 Information Flow and Inter-Organisational Communication

A clear theme in the external interviews is that vessel handling depends heavily on communication between organisations. The Port Control Manager describes the port as a central coordination point that communicates with terminals, agents, marine service actors, and vessels through traditional channels such as phone and email, as well as a digital information platform called Digital Port Call intended to provide a shared operational picture. The platform is described as useful, but the interviews also indicate that its benefits depend on how consistently different actors use it and contribute data to it.

The Port Control Manager similarly describes planning as dependent on continuous dialogue between the port and the terminal, especially regarding quay planning and shared pipeline use. The need to keep multiple actors aligned is thereby not limited to a single handover. It continues throughout the vessel's approach and expected arrival.

From the inspection company's perspective, communication problems are also linked to terminology, language, and the form of the quay meeting. The representative explains that digital quay meetings were introduced during the pandemic, when physical meetings were difficult to conduct, and that Inter Terminals continued using this approach for a period afterwards. However, the inspection company representative argues that physical communication between vessels, the terminal, and the inspector reduces the risk of misunderstandings. Electronic exchange of checklists and documents, on the other hand, may create interpretation errors and delays. The representative describes it as problematic when participants do not share the same professional terminology or when the inspector is excluded from parts of the communication loop.

The interview with the former port agent adds an agent-based perspective to the role of communication in vessel handling. From this perspective, digital communication is viewed as beneficial because it allows information and documents to be shared quickly between the vessel, agent, terminal, and other port actors. The respondent emphasised that many preparatory activities, including documentation and information exchange before the vessel arrives at berth can be handled digitally in advance. This can reduce the amount of coordination that needs to take place once the vessel is alongside and thereby support a faster start-up process. The perspective highlights the potential of digital communication to reduce waiting time, provided that the relevant actors receive timely and clear information.

4.3.5 Delays, Dependencies, and External Sources of Waiting Time

The interviews held with Inter Terminals' external partners show that waiting time can appear from several sources outside of Inter Terminals' direct control. According to the Port Control Manager, one of the most difficult parts of the planning process is determining when the vessel currently at berth will actually be ready to leave. It is explained that this timing affects how tightly the next vessel can be planned, and uncertainty in that estimate creates knock-on effects for berth allocation and arrival coordination. The port control manager, therefore, describes how delays connected to a vessel can easily spread to the following operations.

The Port Control Manager also points out that a vessel cannot proceed simply because the berth is physically available. The pipeline system and the terminal must also be ready, and after the

handling has been completed, there may still be hours of additional activities before the vessel can depart. According to this description, berth occupancy includes more than just the pumping time alone.

From the inspection company’s perspective, unnecessary waiting time may also arise when communication gaps or booking gaps occur between the vessel, the terminal, and the actors who need to be physically present at the quay. The inspection company representative describes examples where time can be lost if quay-related staff are not ready when the inspector has completed the onboard start-up activities or when communication between vessel and terminal is not handled efficiently. The external interviews thereby support the view that waiting time is often created in handovers and dependencies between organisations, rather than in a single isolated activity

The interviews held with the Port of Gothenburg further describe how late information from terminals may create avoidable delays in the port system. The Port Control Manager explains that when terminal-related problems are not communicated in time, the port cannot adjust pilot orders, berth sequencing, or other planning decisions early enough. According to the Port Control Manager, this may lead to vessels having to wait unnecessarily or result in flow-on effects for other arriving ships.

4.5 Quantitative data

Name	OrderID	Tank	mt (vac)	ETA	ArrivalTerminal	ConnectionDateTime	ArrivalToPumpStart	PumpStartDateTime	PumpEndDateTime	Duration	DisconnectionDateTime	DepartureTerminal	Jetty	C
375	2,005			5/1/2025 1:00:00 PM	5/1/2025 12:50:00 PM	5/1/2025 1:45:00 PM 01:25		5/1/2025 2:15:00 PM	5/1/2025 8:05:00 PM 05:50		5/1/2025 8:30:00 PM	5/1/2025 9:00:00 PM 551	Sw	
373	886			5/1/2025 1:00:00 PM	5/1/2025 12:50:00 PM	5/1/2025 1:45:00 PM 06:45		5/1/2025 7:30:00 PM	5/1/2025 8:00:00 PM 02:30		5/1/2025 8:30:00 PM	5/1/2025 9:00:00 PM 551	Sw	
331	838			5/2/2025 12:00:00 AM	5/2/2025 1:00:00 AM	5/2/2025 1:02:00 AM 00:05		5/2/2025 1:05:00 AM	5/2/2025 3:35:00 AM 02:30		5/2/2025 3:40:00 AM	5/2/2025 3:45:00 AM 510	BL	
381	1,999			5/2/2025 4:00:00 AM	5/2/2025 5:00:00 AM	5/2/2025 5:10:00 AM 00:40		5/2/2025 5:40:00 AM	5/2/2025 10:35:00 AM 04:55		5/2/2025 10:50:00 AM	5/2/2025 11:30:00 AM 510	BL	
303	700			5/3/2025 7:30:00 AM	5/3/2025 7:00:00 AM	5/3/2025 7:15:00 AM 01:40		5/3/2025 8:40:00 AM	5/3/2025 12:00:00 PM 03:20		5/3/2025 12:20:00 PM	5/3/2025 1:00:00 PM 516	BL	
166	154			5/3/2025 11:00:00 AM	5/3/2025 2:30:00 PM	5/3/2025 2:30:00 PM 02:40		5/3/2025 4:40:00 PM	5/3/2025 7:00:00 PM 02:20		5/3/2025 10:30:00 PM	5/3/2025 1:00:00 PM 510	Sw	
167	179			5/3/2025 11:00:00 AM	5/3/2025 2:30:00 PM	5/3/2025 2:30:00 PM 05:00		5/3/2025 7:00:00 PM	5/3/2025 8:30:00 PM 01:00		5/3/2025 10:30:00 PM	5/3/2025 1:30:00 PM 510	Sw	
161	312			5/3/2025 11:00:00 AM	5/3/2025 2:00:00 PM	5/3/2025 2:30:00 PM 06:00		5/3/2025 8:00:00 PM	5/3/2025 9:40:00 PM 01:40		5/3/2025 10:30:00 PM	5/3/2025 11:00:00 PM 510	Sw	
381	1,484			5/3/2025 9:00:00 AM	5/3/2025 2:00:00 PM	5/3/2025 2:30:00 PM 06:30		5/3/2025 2:50:00 PM	5/3/2025 8:30:00 PM 05:40		5/3/2025 8:45:00 PM	5/3/2025 9:00:00 PM 517	BL	
305	799			5/6/2025 3:00:00 AM	5/6/2025 3:00:00 AM	5/6/2025 4:00:00 AM 01:20		5/6/2025 4:20:00 AM	5/6/2025 7:05:00 AM 02:45		5/6/2025 7:30:00 AM	5/6/2025 8:00:00 AM 516	BL	
331	1,001			5/6/2025 9:00:00 AM	5/6/2025 9:45:00 AM	5/6/2025 11:05:00 AM 01:35		5/6/2025 11:20:00 AM	5/6/2025 2:40:00 PM 03:20		5/6/2025 2:45:00 PM	5/6/2025 3:00:00 PM 516	BL	
381	1,992			5/6/2025 11:00:00 AM	5/6/2025 1:00:00 PM	5/6/2025 1:10:00 PM 00:40		5/6/2025 1:40:00 PM	5/6/2025 6:30:00 PM 04:50		5/6/2025 6:45:00 PM	5/6/2025 7:00:00 PM 510	BL	
380	1,991			5/6/2025 5:00:00 PM	5/6/2025 4:00:00 PM	5/6/2025 4:30:00 PM 01:10		5/6/2025 5:10:00 PM	5/7/2025 12:15:00 AM 07:05		5/7/2025 12:40:00 AM	5/7/2025 1:30:00 AM 551	BL	
331	1,001			5/6/2025 5:00:00 PM	5/6/2025 7:30:00 PM	5/6/2025 8:00:00 PM 02:20		5/6/2025 8:10:00 PM	5/6/2025 11:00:00 PM 02:50		5/6/2025 11:15:00 PM	5/7/2025 12:00:00 AM 510	BL	
308	1,343			5/7/2025 4:30:00 AM	5/7/2025 3:50:00 AM	5/7/2025 4:00:00 AM 00:40		5/7/2025 4:30:00 AM	5/7/2025 10:00:00 AM 05:30		5/7/2025 11:10:00 AM	5/7/2025 11:30:00 AM 516	BL	
303	1,248			5/7/2025 2:00:00 AM	5/7/2025 3:50:00 AM	5/7/2025 3:50:00 AM 00:20		5/7/2025 4:10:00 AM	5/7/2025 9:40:00 AM 05:30		5/7/2025 9:50:00 AM	5/7/2025 1:00:00 AM 516	BL	
125	1,199			5/8/2025 11:00:00 AM	5/8/2025 9:00:00 AM	5/8/2025 9:10:00 AM 00:35		5/8/2025 9:35:00 AM	5/8/2025 12:55:00 PM 03:20		5/8/2025 1:30:00 PM	5/8/2025 2:00:00 PM 511	Ni	
305	491			5/8/2025 2:00:00 PM	5/8/2025 2:00:00 PM	5/8/2025 2:25:00 PM 01:00		5/8/2025 3:00:00 PM	5/8/2025 8:45:00 PM 02:45		5/8/2025 9:00:00 PM	5/8/2025 9:30:00 PM 551	BL	
380	1,555			5/8/2025 2:00:00 PM	5/8/2025 2:00:00 PM	5/8/2025 2:40:00 PM 01:40		5/8/2025 3:40:00 PM	5/8/2025 8:10:00 PM 04:30		5/8/2025 8:20:00 PM	5/8/2025 9:00:00 PM 551	BL	
358	34,560			5/8/2025 10:01:00 PM	5/9/2025 12:00:00 AM	5/9/2025 12:30:00 AM 01:05		5/9/2025 1:05:00 AM	5/10/2025 1:00:00 AM 23:55		5/10/2025 5:30:00 AM	5/10/2025 6:00:00 AM 510	Ni	
357	2,007			5/8/2025 10:01:00 PM	5/9/2025 12:00:00 AM	5/9/2025 12:30:00 AM 25:20		5/10/2025 1:20:00 AM	5/10/2025 5:10:00 AM 03:50		5/10/2025 5:30:00 AM	5/10/2025 6:00:00 AM 510	Ni	
308	1,509			5/9/2025 5:00:00 PM	5/9/2025 5:00:00 PM	5/9/2025 5:30:00 PM 01:05		5/9/2025 6:05:00 PM	5/10/2025 12:20:00 AM 06:15		5/10/2025 12:30:00 PM	5/10/2025 1:00:00 AM 516	BL	
303	1,459			5/9/2025 5:00:00 PM	5/9/2025 5:30:00 PM	5/9/2025 5:45:00 PM 00:30		5/9/2025 6:00:00 PM	5/10/2025 12:30:00 AM 06:05		5/10/2025 12:15:00 AM	5/10/2025 12:45:00 AM 516	BL	
303	1,277			5/12/2025 10:00:00 AM	5/12/2025 11:00:00 AM	5/12/2025 11:15:00 AM 01:25		5/12/2025 11:20:00 AM	5/12/2025 6:05:00 PM 06:45		5/12/2025 6:06:00 PM	5/12/2025 6:07:00 PM 516	BL	
308	1,263			5/12/2025 10:00:00 AM	5/12/2025 11:00:00 AM	5/12/2025 11:15:00 AM 01:25		5/12/2025 12:25:00 PM	5/12/2025 6:00:00 PM 05:35		5/12/2025 6:01:00 PM	5/12/2025 6:03:00 PM 516	BL	
342	1,336			5/12/2025 2:00:00 PM	5/12/2025 3:00:00 PM	5/12/2025 3:30:00 PM 01:12		5/12/2025 4:12:00 PM	5/12/2025 7:45:00 PM 03:33		5/12/2025 7:46:00 PM	5/12/2025 7:47:00 PM 511	BL	
342	1,338			5/13/2025 2:00:00 AM	5/13/2025 4:00:00 AM	5/13/2025 4:30:00 AM 01:00		5/13/2025 7:00:00 AM	5/13/2025 11:06:00 AM 04:06		5/13/2025 12:00:00 PM	5/13/2025 1:00:00 PM 511	Ni	
118	1,190			5/13/2025 9:00:00 AM	5/14/2025 2:00:00 AM	5/14/2025 3:00:00 AM 02:00		5/14/2025 4:00:00 AM	5/14/2025 7:05:00 AM 03:05		5/14/2025 9:15:00 AM	5/14/2025 9:00:00 AM 510	BL	
305	690			5/14/2025 10:00:00 AM	5/14/2025 10:00:00 AM	5/14/2025 10:30:00 AM 00:50		5/14/2025 10:50:00 AM	5/14/2025 1:00:00 PM 02:30		5/14/2025 2:00:00 PM	5/14/2025 2:30:00 PM 516	BL	
126	3,071			5/14/2025 1:30:00 PM	5/14/2025 1:00:00 PM	5/14/2025 2:45:00 PM 03:10		5/14/2025 4:10:00 PM	5/14/2025 9:40:00 PM 05:30		5/14/2025 9:50:00 PM	5/14/2025 9:55:00 PM 519	Fr	
303	1,041			5/14/2025 11:00:00 PM	5/15/2025 12:00:00 AM	5/15/2025 12:30:00 AM 00:40		5/15/2025 12:40:00 AM	5/15/2025 9:05:00 AM 04:25		5/15/2025 9:10:00 AM	5/15/2025 9:30:00 AM 516	BL	
308	585			5/15/2025 11:00:00 PM	5/15/2025 1:00:00 AM	5/15/2025 1:05:00 AM 00:10		5/15/2025 1:10:00 AM	5/15/2025 3:50:00 AM 02:40		5/15/2025 4:00:00 AM	5/15/2025 4:30:00 AM 516	BL	
381	795			5/15/2025 10:00:00 AM	5/15/2025 10:00:00 AM	5/15/2025 10:30:00 AM 00:45		5/15/2025 10:45:00 AM	5/15/2025 2:15:00 PM 03:30		5/15/2025 2:30:00 PM	5/15/2025 3:00:00 PM 517	BL	
161	4,181			5/15/2025 3:30:00 PM	5/15/2025 4:00:00 PM	5/15/2025 4:30:00 PM 05:30		5/15/2025 9:30:00 PM	5/16/2025 6:10:00 AM 08:40		5/16/2025 6:30:00 AM	5/16/2025 9:00:00 AM 510	Fr	
121	155			5/16/2025 6:00:00 AM	5/16/2025 3:00:00 AM	5/16/2025 4:00:00 AM 11:50		5/16/2025 2:30:00 PM	5/16/2025 4:10:00 PM 01:20		5/16/2025 9:00:00 PM	5/16/2025 10:30:00 PM 511	Ni	
119	517			5/16/2025 6:00:00 AM	5/16/2025 3:00:00 AM	5/16/2025 4:00:00 AM 15:15		5/16/2025 4:15:00 PM	5/16/2025 6:20:00 PM 02:05		5/16/2025 9:59:00 PM	5/16/2025 10:30:00 PM 511	Ni	
125	446			5/16/2025 6:00:00 AM	5/16/2025 3:00:00 AM	5/16/2025 4:00:00 AM 15:35		5/16/2025 6:35:00 PM	5/16/2025 8:15:00 PM 02:40		5/16/2025 9:59:00 PM	5/16/2025 10:30:00 PM 511	Ni	
127	96			5/16/2025 6:00:00 AM	5/16/2025 3:00:00 AM	5/16/2025 4:00:00 AM 18:25		5/16/2025 9:25:00 PM	5/16/2025 9:50:00 PM 00:25		5/16/2025 9:59:00 PM	5/16/2025 10:30:00 PM 511	Ni	
305	996			5/16/2025 12:00:00 PM	5/16/2025 12:00:00 PM	5/16/2025 12:15:00 PM 00:45		5/16/2025 12:45:00 PM	5/16/2025 3:55:00 PM 03:10		5/16/2025 4:30:00 PM	5/16/2025 5:00:00 PM 516	BL	

Fig. 4.2: Sample of the dataset from Inter Terminals.
Vessel names and Order IDs have been redacted for confidentiality purposes.

The screenshot shows an Excel spreadsheet with a complex layout. At the top, there are tabs for 'Arkiv', 'Start', 'Infoga', 'Dela', 'Sidlayout', 'Formler', 'Data', 'Granska', 'Visa', 'Automatisera', 'Hjälp', 'Rita', and 'Tabelldesign'. Below these is a search bar with 'Z7064' and a date filter '2025-09-28 11:28'. The main data area is a large table with columns for 'Vessel ID', 'Vessel Name', 'Origin', 'Arrival Time', 'Departure Time', and 'Status'. The data is organized in a grid with various filters and formulas visible at the top. The table contains multiple rows of data, each representing a vessel's arrival and departure from the port. The columns are color-coded and have various filters applied. The data is organized in a grid with various filters and formulas visible at the top.

Fig. 4.3: Sample of the dataset from the Port of Gothenburg.

In the *Measure* phase data was collected mainly from Inter Terminals as well as the Port of Gothenburg in the form of excel files. The files belonging to Inter terminals contained information about the vessels transiting their terminals, including vessel name, order ID, estimated and actual arrival and departure times, the berths used, in addition to other details. Also included, were timestamps of different steps in the handling process. Time periods for how long it took vessels from arrival to connect to a cargo loading pump, how long until commencement of pumping as well as the duration between conclusion of pumping, disconnection and departure could therefore be calculated. This data was later used in the *Analyse* phase to evaluate operational performance and identify potential delays and inefficiencies in the terminal handling process. Incident reports were also reviewed for questionable data points.

To ensure the quality of the data received from Inter Terminals, the files were reviewed for potential inaccuracies and discrepancies. Orders with missing data points were removed in order to prevent them from affecting the accuracy of the analysis. The same was done with obvious errors, such as negative values, in consultation with the focal company. Despite the removal of data points there was still a large dataset of which analysis could be performed on. The data was almost exclusively recorded in five-minute intervals, meaning timestamps were rounded to the nearest five-minute increment. Another recurring theme in the data are near identical timestamps for two sequential activities, i.e. that the duration between would be very short which likely isn't factual.

Similar to the files obtained from Inter Terminals, the datasets from the Port of Gothenburg contained information about vessels transiting the port, vessel names, port calls, estimated and actual arrival and departure times, the berths used, in addition to other details. The main difference were the insights into the port as whole with information that Inter Terminals does not collect on their own. This information is vital for the analysis of berth utilisation as it includes data regarding all actors who frequent the same berths as Inter Terminals, thereby enabling a more comprehensive assessment of berth occupancy and traffic patterns.

5. Analyse

Based on the data collected during the *Measure* phase, the *Analyse* phase aimed to address Research Question 1 (RQ1): *Which parts of the vessel turnaround process create waste, non-value-added time, or operational bottlenecks at Inter Terminals Gothenburg?*

5.1 Qualitative Analysis

5.1.1 Planning uncertainty and short-notice changes

The qualitative material shows that planning uncertainty is a clear source of process inefficiency in vessel handling. Both the internal and external interviews indicate that operations are often planned with short lead times, while information regarding vessels, volumes, and sequences may change close to execution. This means that planning does not function as a stable basis for execution, but rather as something that continuously needs to be adjusted. As a result, resources, pumping routes, and berth times must be reprioritised at short notice, which increases the need for replanning and coordination between multiple actors.

The vessel handling process is thus characterised by high variability even before the handling operation has started. This can be related to Schmenner and Swink's (1998) idea that performance is improved when flow is more stable and less disrupted. In the present case, short planning horizons and late changes make stability difficult to achieve. As a consequence, it becomes more difficult to align berth allocation, pipeline access, and internal routing, which in turn creates more waiting, more replanning, and more disruptions in the process. Instead waiting, reprioritisation, and additional coordination are introduced, which extend lead times without the product actually moving through the system.

Through the lense of Bozarth et al.'s (2009) distinction between detail complexity and dynamic complexity this issue becomes more transparent. Concerning Inter Terminals, it is primarily dynamic complexity that appears problematic. In other words, the issue is not mainly that many activities take place simultaneously, but that changes in one part of the system have consequences elsewhere. When a vessel is delayed, when information from other actors changes, or when the availability of shared resources shifts, several subsequent steps in the process are affected. As a result, vessel handling becomes highly sensitive to late changes, and the dependencies between actors are reinforced.

Christopher (2000) similarly emphasises that volatile markets and uncertain conditions place high demands on responsiveness and the ability to manage variations. In the case of Inter Terminals, this is evident because the terminal operates in an environment where short-term changes must be handled within the limits of the already constrained berth and pipeline resources. Planning uncertainty therefore not only creates an administrative burden, but also contributes to making the process more reactive than proactive. Time is spent adjusting plans, rearranging sequences, and waiting for clarifications, rather than on value-adding vessel handling.

Taken together, the qualitative analysis shows that planning uncertainty and short-notice changes constitute an early but significant challenge to process efficiency in vessel turnaround. The problem lies not only in the fact that information arrives late, but also in the way limited planning horizons make the entire process more sensitive to variability. This reduces the conditions for swift and even flow and thereby contributes to longer turnaround times.

5.1.2 Shared quay and pipeline infrastructure as the main structural bottleneck

The interview material indicates that quay and pipeline infrastructure constitute the most central structural constraint in vessel handling. Unlike other problems, which are more closely related to planning, information flow, or administrative activities, this issue concerns a physical limitation in the system's capacity. Even when Inter Terminals is internally ready to carry out an operation, handling cannot begin if the correct berth is not available or if the relevant pipeline is already being used by another actor. As a result, waiting time arises because several actors depend on the same limited resources.

Berths and pipelines thereby function as bottlenecks. Betterton & Silver (2012) argue that system improvement requires identifying the resource that has the greatest influence on system performance, since improvements in other parts of the process will not increase total capacity as long as the main constraint remains unchanged. In this case, the qualitative material suggests that access to a berth and the correct pipeline is exactly what limits how many vessels can actually be handled and how quickly turnaround can be completed. This means that other improvements, for example, in internal routines or administrative handling, may still be valuable, but their effect remains limited as long as the shared infrastructure continues to control the flow through the system.

This is consistent with Schmenner & Swinks (1998) argument that operational performance improves when material flows move swiftly and evenly, and declines when variability and interruption increase. They also emphasise throughput time as a central measure for identifying where flows are slowed down or blocked. In the case of Inter Terminals, this becomes relevant because vessels may have arrived and, in principle, are ready for handling, yet are still unable to begin pumping because berth or pipeline capacity is not available. This means that time is effectively lost in the process, even though resources are tied up, and the vessel continues to occupy capacity. The shared infrastructure, therefore functions as the point at which uneven and interrupted flow becomes most visible.

This is also reasonable from a queuing perspective. In systems with limited resources, waiting occurs when several units compete for the same capacity, and in terminal settings queuing theory is used to analyse vessel waiting times and resource utilisation at berths. Steenken et al. (2004) describe how an overall objective in terminal operations often is to minimise the time a vessel spends at berth, since this has direct implications for terminal productivity and competitiveness. When several vessels and product flows must share the same berth and pipeline system, the risk of queues, sequencing problems, and prolonged berth time increases. The qualitative material reinforces the view that this type of competition for shared resources is recurring, meaning that the berth should be understood as more than a place where the operation is carried out; it is a system-constraining resource that affects the entire vessel turnaround process.

It is also important to separate between structural and operational limitations. Schmenner & Swink (1998) describe how performance is influenced partly by physical assets in the system, and partly by how the operations are managed within the limits of the assets. This means that berths and pipelines represent a structural limitation, while planning, sequencing, and coordination affect how well these limitations are handled in practice. This distinction is important analytically because it shows that the problem is not just about inefficiency in daily work, but also of Inter Terminals operating within a system where the most critical resource is shared with other actors and therefore cannot be fully controlled internally.

Taken together, the analysis shows that shared quay and pipeline infrastructure constitute the main structural bottleneck in vessel handling. The limitation lies in the fact that they must be

shared, coordinated, and prioritised among several actors in the port system. As a result, the throughput of vessel handling is largely determined by access to these common resources. This means that much of the waiting time that arises in the process should not be understood as isolated disturbances, but rather as expressions of a more fundamental capacity constraint in the entire system.

5.1.3 Administrative, coordination, and communication-related waiting

The interview material shows that a significant share of the vessel turnaround is affected by waiting time that arises in administrative and coordination-related activities before, during, and after the transfer. This includes documentation, start-up activities, quay meetings, inspection dependencies, and situations where information is missing or must be confirmed by several actors before the next step can begin. As a result, non-value-added time emerges in parts of the process where the vessel remains in the system without product being pumped or moved forward. However, several of these activities are necessary for safety, legal compliance, quality assurance, and operational control, even though they do not directly involve the physical transfer of product.

This can be understood through the lens of Lean Six Sigma, where the focus lies in identifying activities that do not directly create value in the process (George, 2002). The point here is that safety checks, documentation, and coordination extend lead time while not directly contributing to moving the product through the system. They can therefore be understood as necessary but non-value-adding activities from a flow-efficiency perspective. This is consistent with Modig & Åhlström's (2012) argument about flow efficiency, where the key issue is not whether resources are busy, but whether the flow unit is actually progressing. In this case, personnel, inspectors, and other actors may all be active, while the vessel process is in practice standing still. This type of activity can therefore conceal inefficiency if the focus is placed mainly on resource utilisation rather than on how swiftly and evenly vessel handling progresses.

The external interviews indicate further that digital solutions can reduce some of the coordination-related waiting time by moving information exchange earlier in the process. This can be analysed through Lean Six Sigma, where lead time reduction is achieved by reducing unnecessary waiting between value-adding process steps (George, 2002). The former port agent's perspective suggests that digital communication can be useful when documents, vessel information, and operational instructions are shared before the vessel reaches berth. In those cases, part of the start-up work can be prepared in advance, which reduces the amount of information that must be clarified once the vessel is occupying quay capacity. From this perspective, digital communication can be interpreted as a way of reducing non-value-added time in the berth phase, provided that the information is complete, updated, and accessible to the relevant actors.

This is consistent with Schmenner and Swink's (1998) Theory of Swift, Even Flow, which argues that operational performance improves when flows become faster and more even, and declines when variability, interruptions, and waiting increase. If digital systems make information available earlier and reduce repeated clarification during the start-up phase, they may support a more continuous vessel handling process. However, the benefit depends on consistent use and data contribution from the actors involved. The Port Control Manager's description of Digital Port Call supports this point, as the platform is intended to provide a shared operational picture and reduce the risk that information is lost through traditional communication channels such as phone and email.

When vessel handling becomes dependent on repeated approvals, exchanges of information, and coordination between several parties, the process no longer develops as a continuous flow but instead as a sequence of pauses, confirmations, and restarts. The analysis therefore shows

that administrative, communication, and coordination-related activities constitute a clear source of both non-value-added time and operational bottlenecks in vessel turnaround at Inter Terminals Gothenburg, particularly in the parts of the process where the transfer is delayed even though the vessel has already arrived or remains at berth. The improvement focus should therefore be on reducing unnecessary gaps, repeated clarification, and late information. A way to engage these challenges is to encourage more extensive use of the Digital Port Call system to enable the different actors to have up-to-date information and mitigate coordination-related waste.

5.1.4 Synthesis: qualitative answer to RQ1

Collectively, the qualitative analysis shows that the parts of the vessel turnaround process that primarily create non-value-added time and operational bottlenecks at Inter Terminals Gothenburg are found in three connected areas: planning uncertainty before execution, shared quay and pipeline infrastructure during execution, and administrative, communication, and coordination-related activities before, during, and after the transfer itself. These themes demonstrate that turnaround time is shaped by the way flow is slowed down, interrupted, or delayed by both structural constraints and recurring patterns that systematically hinder swift and even flow.

From an analytical perspective, the results indicate that the shared quay and pipeline infrastructure constitute the main structural bottleneck, while planning uncertainty and coordination-related waiting act as recurring causes that reinforce this limitation in practice. This is consistent with Betterton and Silver's (2012) argument that system performance is primarily constrained by the resource with the greatest influence on throughput, as well as with Schmenner and Swink's (1998) view that operational performance declines when flow becomes uneven and interrupted. Although some delays arise from physically limited capacity, the analysis also demonstrates that a considerable share of turnaround time is affected by waiting, replanning, information gaps, and activities that do not directly move the vessel or product forward in the process. This is particularly important in relation to quay meetings and start-up documentation.

The analysis indicates that some information exchange can potentially be handled digitally before the vessel reaches berth, namely the quay meeting. When the vessel is already alongside but waiting for paperwork, checklists, or operational information that could have been prepared before arrival, the waiting time is closer to pure waste. Quay capacity is occupied without any corresponding progress in the physical flow, making the delay problematic from a flow efficiency perspective. In this respect, George (2002) is relevant, since these activities can be understood as important improvement targets in processes where lead time is extended without corresponding progress being created. Modig and Åhlström (2012) also support the interpretation that high activity in itself is not equal to efficient flow; resources may be occupied while vessel handling remains at a standstill.

The qualitative answer to RQ1 is therefore that the most significant source of non-value-added time and operational bottlenecks in vessel turnaround are found in the transition and dependencies between different stages of the process, rather than in pumping as an isolated activity. The time before pumping starts, waiting related to access to berths and pipeline, and administrative and coordination-related delays emerge as central problem areas. The analysis therefore shows that vessel turnaround is constrained both by a physical capacity restriction in the system and by variation and coordination losses that make the flow less swift and less even. This provides the basis for the next part of the analysis and for improvement proposals focused on reducing avoidable waiting, moving preparatory activities earlier in the process, and improving the visibility of information before berth capacity is occupied.

5.2 Quantitative Analysis

5.2.1 Application of Little's Law

Based on data collected during 2025, Inter Terminals primarily utilised four berths for transiting vessels, 510, 511, 516 and 551. All berths but 516 are used by other actors who also utilise berths other than the aforementioned in addition to Inter Terminals. 516 caters to smaller vessels, 551 mainly to medium sized vessels and 510 and 511 to larger vessels, which fits most oil tankers. These berths have different queues and constitute three different systems.

Overall capacity is sufficient, while local congestion persists at berths 510 and 511 which, considering the variability that can be expected at ports, limits an increase in transiting vessels without efficiency initiatives or investments in capacity.

$$\lambda_{510,511} = \text{Number of arrivals (ships)} \div \text{Time period (days)} = 418 \div 365 \approx 1.18 \text{ ships/day}$$

$$W_{510,511} = \text{Average transit time (days)} \approx 1.11 \text{ days}$$

$$L_{510,511} = \text{Average number of vessels in the system} = \lambda \times W = 1.18 \times 1.11 \approx 1.31 \text{ ships}$$

$$\lambda_{551} = \text{Number of arrivals (ships)} \div \text{Time period (days)} = 267 \div 365 \approx 0.73 \text{ ships/day}$$

$$W_{551} = \text{Average transit time (days)} \approx 0.70 \text{ days}$$

$$L_{551} = \text{Average number of vessels in the system} = \lambda \times W = 0.73 \times 0.70 \approx 0.51 \text{ ships}$$

$$\lambda_{516} = \text{Number of arrivals (ships)} \div \text{Time period (days)} = 239 \div 365 \approx 0.65 \text{ ships/day}$$

$$W_{516} = \text{Average transit time (days)} \approx 0.29 \text{ days}$$

$$L_{516} = \text{Average number of vessels in the system} = \lambda \times W = 0.65 \times 0.29 \approx 0.19 \text{ ships}$$

The results show clear differences in utilisation of berth capacity. For berths 510 and 511, an $L_{510,511}$ value 1.31, or roughly 0.66 per berth, indicates more than one ship present at those berths on average and continuous operation without signs of serious congestion, since the system has a combined maximum capacity of 2. This implies the system is idle, on average, a third of the time without taking the unpredictability of vessel handling into account. These figures do not take into account the time allocated for vessels that e.g. arrive later than planned. Furthermore the time intervals at which the berths are idle may be too short to fill with other orders or there simply isn't demand at those periods. The L value should therefore be interpreted with caution and with consideration for the environment it concerns.

For berth 551 that value is 0.51, meaning the berth may often be free and with limited overlap and lower capacity utilisation. Berth 516 exhibits the lowest L_{516} value of 0.19, indicating it being underused to a great extent. These insights point toward the possibility of increasing port calls. As previously mentioned however, it should be noted that variation is common for ports, manifested as delays and changes on short notice and other factors such as e.g. access to the shared pipeline system. The demand for these berths are also not identical and the berths cater to different sized vessels that limit the effectiveness of efficiency measures.

5.2.2 Analysis of Turnaround Time Distribution Across Berth Operations

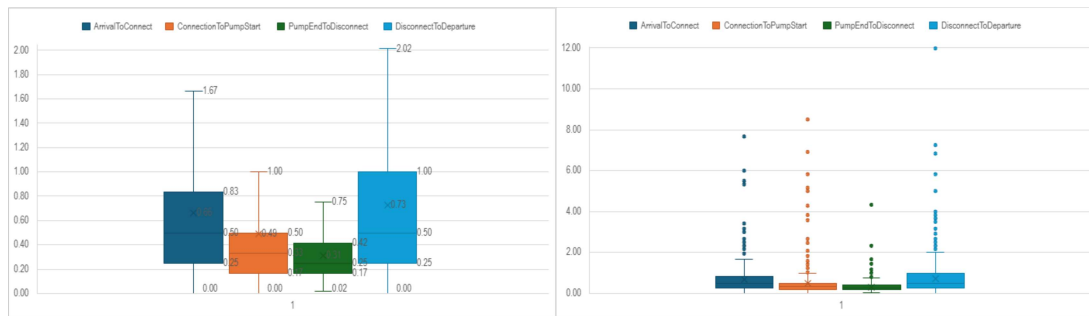


Fig. 5.1: Box plot of the duration of different steps in the vessel turnaround process (hours). Based on vessels with unique Order IDs on any given occasion transiting Inter Terminals' terminal between January 2015 - February 2026.

Left: Zoomed in with internal values and without outliers. Right: Original boxplot including outliers.

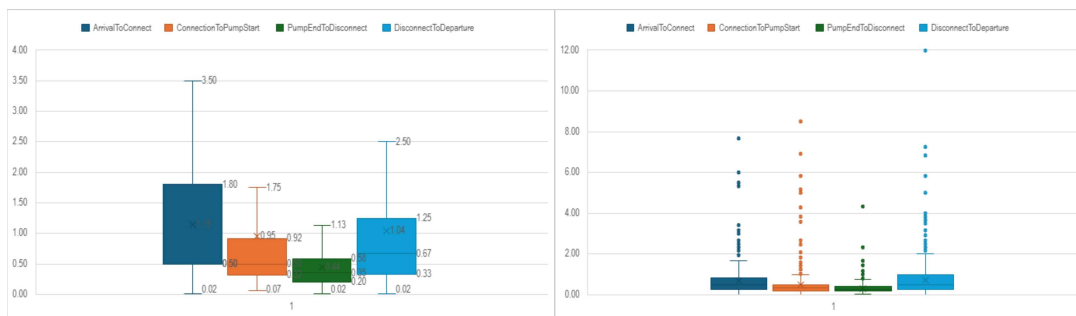


Fig. 5.2: Box plot of the duration of different steps in the vessel turnaround process (hours). Based on vessels with multiple Order IDs on any given occasion transiting Inter Terminals' terminal between January 2015 - February 2026.

Left: Zoomed in with internal values and without outliers. Right: Original boxplot including outliers.

Figures 5.1 and 5.2 are boxplots over the main four steps of vessel turnaround at berth. Figure 5.1 includes vessels with unique Order IDs and figure 5.2 includes vessels with more than one order ID measured from the connection of the first tank to the disconnection of the final tank. This distinction was made partly due to the fact that vessels with multiple Order IDs often require additional steps such as additional connection and disconnections than vessels with unique Order IDs. This is reflected by longer process time for vessels with more than one Order ID. The majority of vessels however, about 88%, have unique orders.

Common for both, is that the PumpEndToDisconnect stage is the most stable, with minimal variability and smallest interquartile range, while DisconnectToDeparture and ArrivalToConnect exhibit the greatest spread; suggesting these steps are the least predictable portion of turnaround at berth. Additionally, ArrivalToConnect and ConnectionToPumpStart have low mean and median durations but with high intermittent outliers, indicating that while most operations are completed quickly, occasional disruptions lead to disproportionately long durations. Hence, delays which are not part of the regular operations, occur. Overall the greatest variation is found in arrival and departure, pointing towards fluctuations in communication, coordination and external factors.

Around 119 outliers were found across the 14 month period the data covers, a relatively high number, all of whom were upper outliers. Of these, 14 were random delays found in incident

reports and 39 were orders shared with other terminals which could explain their perceived delay in the data. No further information on the causes behind the remaining 66 was found, as well as any particular patterns in the data that could e.g. suggest overrepresentation of a particular step in the process. Ergo, a significant proportion of outliers could not be explained with available data, indicating limited visibility into disruption drivers and highlighting a need for improved incident tracking.

5.2.3 Synthesis: quantitative answer to RQ1

Quantitative analysis shows that waste, non-value-added time and operational bottlenecks are concentrated to specific parts of the turnaround process rather than being evenly distributed. The results indicate the more significant inefficiencies linked to limitation in berth utilisation, variation in activities related to arrival and departure as well as irregular delays that interrupt relatively stable flows.

Application of Little's Law shows substantial differences between the main four berths used. Berth 510 and 511 show the highest average number of vessels in the system, indicative of consistent traffic and local congestion. Berths 551 and 516 however, exhibit lower utilisation and more available capacity. The main quantitative bottleneck in the system is hence concentrated around berths catering larger vessels, where higher traffic intensity increases sensitivity for delays, sequencing issues, and variability. Furthermore analysis demonstrates that total terminal capacity is not fully used, but that the main operational challenge is uneven demand, dependencies in shared infrastructure, and variation.

Analysis of turnaround activities further strengthens this interpretation. ArrivalToConnect, ConnectionToPumpStart and DisconnectToDeparture exhibit large spread and many outliers. These activities can therefore be presumed to cause a large portion of the non-value-added time and operative uncertainty. Common for these activities are that they occur during transitions between activities and handovers. Inefficiency can hence be traced to coordination, communication and external dependencies.

The great number of upper outliers also support the conclusion that variation and disruptions constitute a source of inefficiency. Although some delays could be traced in incident reports as delays, orders shared with other terminals falsely perceived as delays, a significant portion remain unaccounted for due to insufficient data. The causes are thus not always fully visible within existing systems and important causes of delays may remain unmanaged.

In summary, the quantitative analysis answers RQ1 by showing the main causes for waste and operative bottlenecks exist in highly utilised berth systems, in waiting and coordination-related stages and in variation caused by disruption and unidentified causes of delay. Results align with qualitative conclusions by demonstrating that the inefficiencies in turnaround stem from capacity constraints, coordination losses and process variability that hampers an even flow.

6. Improve

Based on the findings from the *Analyse* phase, the *Improve* phase aimed to address the issues facing Inter Terminals by answering Research Question 2 (RQ2): *How can vessel turnaround time be reduced and operational efficiency be improved within Inter Terminals' existing infrastructure and operating setup?*

6.1 Introduction of Digital Quay Meetings and Integrated Communication

One improvement proposal is to introduce an integrated digital communication system for quay meetings and startup coordination. The purpose of this proposal is not simply to replace physical quay meetings with digital meetings, but to create a shared communication structure where quay meeting-related information can be prepared, distributed, clarified, and confirmed before the vessel reaches berth. The qualitative analysis showed that waiting at berth for paperwork, checklists, or operational clarifications can create non-value-adding time, especially when these activities could have been prepared before the vessel arrived. Since quay capacity is one of the most constrained resources in the system, time spent waiting at berth without product being pumped should be treated as particularly critical waste.

The proposal is therefore to establish a shared digital quay meeting process and communication process where the terminal, vessel representative, agent, inspector, and relevant port actors can share and confirm key information before the vessel reaches berth. Information regarding cargo documentation, safety checklists, loading or unloading instructions, operational constraints, contact details, and required confirmations is suggested to be included. The system should also function as one common communication space where actors can follow document status, raise questions, clarify uncertainties, and confirm responsibilities before the vessel is alongside. By completing these steps earlier, the physical time at quay can be used more directly for activities that must take place when the vessel is alongside, such as safe access, final checks, connection, inspection tasks that require presence onboard, and start-up of the operation.

This proposal is supported by the former agent's perspective, which indicates that digital communication can be useful when documents and operational information are shared before the vessel arrives. From this perspective, an integrated digital communication process can reduce the amount of coordination that needs to take place once the vessel has already occupied quay capacity. This is important from a Lean Six Sigma perspective, since the purpose is to reduce unnecessary waiting time between value-adding process steps rather than making people or equipment work faster. In this case, the improvement does not require a major expansion of physical infrastructure but instead aims to improve how existing berth capacity is used.

However, the proposal must also address the concerns raised by the inspection company. The inspection company representative criticised digital quay meetings because they can create misunderstandings, especially when documents are exchanged through fragmented email communication and when the inspector is excluded from the communication loop. Thereby, digitalisation alone is not sufficient. The integrated communication system should be standardised, structured, and inclusive. All relevant actors should have access to the same information, and the system should clearly show which documents have been uploaded, reviewed, approved, or are still missing. It should also make clear which actor is responsible for each required confirmation so that digital communication does not become another fragmented handover. This would reduce the risk that digital communication creates new interpretation errors or replaces one coordination problem with another.

A practical way to implement this would be to integrate the communication system with Digital Port Call, or develop it as a connected module within the existing platform used by all relevant actors in the port system. The system should enable large file sharing, real-time communication between actors, and transparent tracking of document and confirmation status. It should also provide clear channels for written updates and direct contact when additional clarification is required. For the platform to work, all actors must use it consistently. The interviews indicate that one weakness of digital coordination platforms is that the benefit depends on whether actors actually update and contribute information. Therefore, the improvement requires not only a technical system, but also agreed-upon routines for how and when information must be shared.

Although such a solution would require investment, the investment would be considerably smaller than expanding quay or pipeline capacity. The improvement therefore fits the study's focus on reducing turnaround time within the existing infrastructure and operating setup. If key information can be confirmed before arrival, fewer activities need to be completed while the vessel is physically occupying the berth. This would reduce avoidable waiting time, improve coordination between actors, and make the start-up phase more predictable. In the long term, even small reductions in berth waiting time may create capacity benefits, since shorter and more predictable vessel turnaround can allow more efficient sequencing of vessels.

6.2 Improved Data Collection and Incident Reporting

Quantitative analysis revealed a number of significant anomalies unaccounted for in the dataset of the turnaround process. Although the cause of a number of delays could be identified in incident reports or by other circumstances, a great deal of the deviations could not be explained with the information at hand. This lack of traceability indicates that important sources of inefficiency are not consistently captured in the current reporting structure, which limits the ability to fully understand and address process disruptions.

In order to manage this constraint, a more structured routine for data collection and reporting of incidents is suggested. A possible limit of what constitutes as a delay could be values beyond the upper whisker of the boxplot of each respective activity. Furthermore, more detailed registration of time would aid traceability and reliability of the dataset. Flaws in the data currently include negative time durations, identical timestamps for different activities, and missing timestamps.

While not a direct approach to enhance efficiency, improved incident tracking and data collection routines increase transparency and create a stable foundation for decision-making. This enables more targeted and data-backed efficiency opportunities. From a Lean perspective, increased process visibility is essential for identification of non-value-adding activities and reduction of variation (George, 2002). Improved data quality would hence not only strengthen future analysis, but also improve the conditions for systematic identification of bottlenecks, non-value-added time, and waste.

7. Discussion and Conclusion

The findings of this study show that vessel turnaround at Inter Terminals Gothenburg should not be understood as a transfer of fuel product alone but as a flow that depends on several interconnected steps before, during, and after the physical transfer. The purpose of the study was to identify where waste, non-value-added time, and operational bottlenecks occur in the vessel turnaround process, and to propose improvements that can reduce turnaround time within the existing infrastructure and operating setup. Through the Lean Six Sigma approach, the process could be examined step by step, from the definition of the current situation to the development of improvement proposals. A central insight is that the vessel may be physically present at berth while the process is still not progressing, due to waiting for documentation, inspection, communication, planning decisions, or access to shared infrastructure. However, the study also shows that this time is not always idle or unnecessary. In many cases, the involved actors are performing required tasks that must be completed before the operation can start or before the vessel is allowed to depart.

The results indicate that quay and pipeline access and capacity are the most important structural bottlenecks in the studied process. These resources are shared with other actors in the port system, meaning that Inter Terminals does not fully control when the required berth or pipeline is available. This creates a situation where the terminal may be ready internally, but the vessel still cannot proceed. However, the analysis also shows that the bottleneck is not only physical. Planning uncertainty, short-notice changes, unclear information, and repeated confirmations can make the existing capacity less efficient. In other words, the problem is not only that quay and pipeline capacity are limited, but also that valuable berth time is sometimes occupied by activities that could potentially have been prepared earlier.

This is relevant for the activities surrounding quay meetings and start-up coordination. The study shows that several preparatory activities, such as documentation, checklists, cargo information, safety details, and operational clarifications, influence how quickly the vessel can move from arrival to transfer. If such information is not ready when the vessel reaches berth, the vessel occupies one of the most constrained resources in the system without product being pumped. From a flow efficiency perspective, this type of waiting is particularly problematic because it extends turnaround time without creating corresponding progress in the physical flow. The improvement proposal concerning digital quay meetings and integrated communication is therefore not mainly about replacing physical meetings with digital ones but about moving avoidable coordination work away from the berth phase.

At the same time, the study also shows that digitalisation is not a complete solution by itself. The interviews indicate that digital communication may support faster preparation if documents and operational information is shared before the vessel arrives. However, the inspection company's perspective also shows that digital communication can create misunderstandings if it is fragmented, if terminology is unclear, or if important actors such as the inspector are excluded from the communication loop. This means that the value of a digital solution depends on how it is designed and used. A digital system that only adds another communication channel may create the same problems as scattered emails and phone calls. The improvement proposal must thereby be standardised, including, and connected to clear routines regarding responsibilities, document status, approvals, and communication.

The role of Digital Port Call is important in this context. Since vessel turnaround involves several organisations, a system used only internally by Inter Terminals would have a limited effect. The value of an integrated communication system depends on whether the terminal, port, vessel, agent, inspector, and other relevant actors use the same information base. This also means that implementation requires common routines and a shared commitment from the

involved actors to update information consistently. If this is not achieved, the platform risks becoming incomplete and unreliable, which would reduce its practical value. The challenge is therefore both technical and organisational.

The second improvement proposal, improved data collection and incident reporting, is also important for future process improvement. The quantitative analysis showed that several outliers and delays could not be explained with the available data. Some delays could be connected to incident reports or shared orders with other terminals, but a substantial share remained unclear. This limits the possibility of identifying root causes and makes it difficult to establish if delays are caused by internal preparations, external actors, vessel readiness, inspection, or documentation. Improved incident reporting would improve the transparency and make future improvement work more accurate. Without reliable information on the reason for delays, there is a risk that improvement measures are directed towards symptoms rather than underlying causes.

The data used in the study should also be considered critically. The quantitative data made it possible to analyse several time intervals in the vessel turnaround process, such as ArrivalToConnect, ConnectionToPumpStart, PumpEndToDisconnect, and DisconnectToDeparture. However, the dataset was not fully clean. Some rows had missing time stamps, negative durations, or timestamps that were registered at almost the same time, even though the activities should have taken longer. Since most timestamps were rounded to five-minute intervals, the data cannot show the exact duration of every activity. In addition, several long delays could not be explained through the available incident reports. For this reason, the quantitative analysis was mainly useful for identifying broader patterns and unusual deviations, rather than explaining every individual delay. The interviews and observations were therefore used to contextualise the quantitative patterns and provide explanations for why certain time variations and delays may have occurred.

The choice of DMAIC was suitable because the study focused on an existing process where the aim was to identify inefficiencies and develop improvement proposals. In this study, the early phases were mainly used to map the vessel turnaround process and separate pumping time from the surrounding waiting and coordination activities. The analysis phase then helped show that the main issues were not found in one isolated process step, but in the combination of shared infrastructure, planning uncertainty, and handovers between actors. Based on this, the improvement proposals focused on actions that could reduce avoidable waiting within the current operating setup, rather than on solutions that would require major infrastructure expansion. Since the proposals were developed but not implemented, their effect on turnaround time could not be measured within the scope of the study. A future pilot study would therefore be needed to evaluate whether digital quay meetings and improved incident reporting actually reduce waiting time in practice.

The findings are also limited by the study's single-case design. Inter Terminals Gothenburg operates in a specific port environment with particular products, infrastructure, actors, and planning conditions. The results should therefore not be directly generalised to all terminals. However, the underlying challenge is likely relevant in other port environments where vessels depend on shared quays, pipelines, external actors, and administrative coordination. The broader insight from the study is that vessel turnaround should be understood as an inter-organisational flow problem. Even when the terminal is operationally ready, the process can be delayed if other actors, documents, systems, or infrastructure are not synchronised.

In conclusion, the study suggests that improving vessel turnaround time does not necessarily need to begin with large physical infrastructure investments. Although quay and pipeline capacity remain central bottlenecks, part of the waiting time can be reduced by improving how the existing capacity is used. Moving preparatory activities earlier, creating a more

integrated communication structure, and improving visibility regarding causes of delay are therefore realistic first steps. These improvements may not remove the structural bottleneck, but they can reduce avoidable waiting around it. At the same time, the study recognises that vessel handling requires substantial work before, during, and after loading or unloading, and that some berth time without active pumping is necessary due to safety, inspection, documentation, customs, and tax requirements. In this way, Inter Terminals can improve operational efficiency by ensuring that limited quay capacity is used for activities that move the vessel process forward, rather than for waiting that could have been avoided.

8. AI Declaration

Artificial intelligence tools were used solely to assist with grammar, wording, and general informational guidance in the preparation of this document. All analysis, interpretation, and substantive content were created and verified by the authors.

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