Just-in-Time Arrival in Port Calls: Potential and Implementation

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Department of Science and Technology
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ABSTRACT

There is an urgent need to reduce emissions from maritime transportation to meet environmental targets set by international organizations and governments. To reduce emissions from maritime transportation, technical, market-based, and operational measures can be used. In this thesis, the focus is on operational measures, and in particular Just-in-Time arrival in the port call process. Just-in-Time arrival in the context of port calls refers to maintaining an optimal vessel sailing speed to arrive to the port when the availability of berth and other services are ensured. In earlier studies, the estimated fuel and emission savings potential of Just-in-Time arrival, is promising. Despite the promising potential of Just-in-Time, its implementation remains limited, with few real-world examples. The purpose of this thesis is to explore how to implement Just-in-Time arrival by studying coordination in the port call process.

Two research questions were formulated to address the purpose. The first aims to capture the potential benefits of implementing Just-in-Time arrival in port calls and the second aims to address what is required to implement Just-in-Time arrival in port calls. This thesis is based on two studies in the Swedish context. First, a quantitative study, in which Automatic Identification System data in combination with port call statistics and vessel-specific data were used to estimate the fuel and emission savings potential of Just-in-Time arrival. Second, a qualitative single case-study exploring the coordination mechanisms necessary for implementing Just-in-Time arrival in port calls was conducted.

The studies show that fuel and emission savings potential of Just-in-Time in previous studies is overestimated due to the assumptions used. Though, the implementation of Just-in-Time has potential to improve port call actors’ resource planning and utilization and increase the competitiveness of ports. This is because Just-in-Time arrival has the potential to aid actors in reaching mandatory emission reduction targets. To implement Just-in-Time arrival, it is necessary to coordinate the plans of actors. The required mechanisms to coordinate planning are pre-booking berth allocation policy and port community systems. The pre-booking policy implies booking time-slots for berths, facilitated by using the port community system. The port community system and the pre-booking policy enable the effective coordination of the planning processes of individual actors enabling Just-in-Time arrival in port calls.

Keywords: maritime transportation; port call process; Just-in-Time arrival; coordination and information sharing; port community system.
SVENSK SAMMANFATTNING


Keywords: maritime transportation; port call process; Just-in-Time arrival; coordination and information sharing; port community system.
LIST OF PAPERS

This thesis is titled *Just-in-Time Arrival in Port Calls: Potential and Implementation* and is a thesis by publication. The first part of this thesis constitutes the “Kappa”. In the Kappa, the purpose and the research questions of the thesis are presented and motivated. The kappa also serves as a summary of the findings from the publications. In the second part, the three enclosed papers are presented. The title of each paper, together with the contribution of the author of this thesis to each paper is described below.

   Mubder contributed to writing the introduction and literature review of the paper.

   Mubder was the main author, responsible for data collection and analysis, and most of the writing. Fredriksson contributed to the data collection and analysis, and the theoretical framing of the paper.

   Mubder was the sole author, responsible for research design, data collection and analysis, and authorship.
# KEY TERMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Terms and Abbreviations</th>
<th>Description</th>
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<tbody>
<tr>
<td>Actual Time of Arrival (ATA)</td>
<td>The actual time of arrival of the vessel to the port.</td>
</tr>
<tr>
<td>Automatic Identification System (AIS)</td>
<td>Provides information about vessel’s position, identification, and other information to other vessels and coastal authorities. The AIS data can be monitored in real-time, and historical AIS can be used for different analyses of vessels’ movements.</td>
</tr>
<tr>
<td>Baltic and International Maritime Council (BIMCO)</td>
<td>Maritime organization specialized in trade and regulations. It is one of the largest international organizations that represent vessel-owners, charterers, and ship brokers.</td>
</tr>
<tr>
<td>Carbon Intensity Indicator (CII)</td>
<td>Mandatory measure to determine the annual reduction factor needed to ensure continuous improvement of vessel’s operational carbon intensity.</td>
</tr>
<tr>
<td>Demurrage</td>
<td>Charge that can be claimed by vessel owners if the agreed laytime in the charter party is exceeded.</td>
</tr>
<tr>
<td>Despatch</td>
<td>Charge that can be claimed by charterers if the agreed laytime in the charter party is shorter than agreed.</td>
</tr>
<tr>
<td>Estimated Time of Arrival (ETA)</td>
<td>The estimated time of arrival of the vessel to the port.</td>
</tr>
<tr>
<td>Estimated Time of Completion (ETC)</td>
<td>The estimated time of completion of cargo-operation while the vessel is berthed.</td>
</tr>
<tr>
<td>Estimated Time of Departure (ETD)</td>
<td>The estimated time of departure of the vessel from the port.</td>
</tr>
<tr>
<td>European Emission Trading System (EU ETS)</td>
<td>The world’s first major carbon market. It is part of the European policy to combat climate change and reduce emission.</td>
</tr>
<tr>
<td>First-Come-First-Served (FCFS)</td>
<td>Berth allocation policy in which the access to berth is determined by the sequence of arriving vessels to the port.</td>
</tr>
<tr>
<td>International Maritime Organization (IMO)</td>
<td>Specialized agency of United Nations to maintain comprehensive regulatory framework for maritime transportation. The IMO focuses on safety, environmental, and legal matters.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<td>-------------------------------------------</td>
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</tr>
<tr>
<td>Just-in-Time (JIT) arrival</td>
<td>The philosophy of vessels arriving JIT to the port, based on the availability of the berth and other required services.</td>
</tr>
<tr>
<td>Laytime</td>
<td>The time allowed for charterers for loading and/or discharging. The laytime starts when the NOR is tendered</td>
</tr>
<tr>
<td>Laycan</td>
<td>Agreed range of days between vessel owners and charterers when the vessel must be at port.</td>
</tr>
<tr>
<td>Maritime Single Window (MSW)</td>
<td>Portal for reporting information regarding vessels calling Swedish ports.</td>
</tr>
<tr>
<td>Marine Environment Protection Committee (MEPC)</td>
<td>Specialized committee under IMO's remit to address environmental issues.</td>
</tr>
<tr>
<td>Noon Reports (NR)</td>
<td>Data sheet prepared by the vessel's chief engineer daily. The sheet contains vessel's speed, main engine rpm, sea condition, wind and wave conditions etc.</td>
</tr>
<tr>
<td>Notice of Readiness (NOR)</td>
<td>A statement that indicates the vessel has arrived at the port and is physically and legally ready to begin cargo-operations. The purpose of the NOR is to inform the charterers that the vessel is at their disposal, and start clocking the laytime.</td>
</tr>
<tr>
<td>Port Community System (PCS)</td>
<td>Information system designed to share information among public and private actors in ports.</td>
</tr>
<tr>
<td>Pre-booking berth allocation policy (PBP)</td>
<td>Berth allocation policy in which shipping companies, charterers, and port authorities agree to reserve the berth for a specific vessel during a specified time interval.</td>
</tr>
<tr>
<td>Recommended Time of Arrival (RTA)</td>
<td>The time which port authorities/terminals instruct the vessel crew to arrive to the port at. RTA allows the vessel crew to adjust the speed of the vessel based on the availability of the services at the port of destination.</td>
</tr>
<tr>
<td>Swedish Maritime Authority (SMA)</td>
<td>Swedish government agency providing services to the transport sector to keep sea lanes open and safe. The SMA provides services such as pilotage and ice-breaking.</td>
</tr>
<tr>
<td>Time charterparty (TCP)</td>
<td>Contract between vessel owner and charterer to hire the vessel under specified time period. TCP typically allows for the charterer to decide the voyages and speed of the vessel under charter.</td>
</tr>
<tr>
<td>Utmost dispatch</td>
<td>Charterers in time charter party instructing the vessel to proceed to the berth without delays.</td>
</tr>
<tr>
<td>Virtual Arrival (VA)</td>
<td>Contractual agreement between shipping companies and charterers to reduce the speed of the vessel to avoid known delays in the port of destination.</td>
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### Key terms and abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tr>
<td>Voyage charterparty (VCP)</td>
<td>Contractual agreement between vessel owner and charterer for the carriage of cargo from one port to another on a per-ton or lump-sum basis.</td>
</tr>
</tbody>
</table>
I am very privileged to be trained by three phenomenal supervisors. I could possibly write a book about my appreciation for them, but I will only mention the most important thing. For every supervision meeting we had, they managed to let me leave the meeting motivated, with positive attitude, looking to improve both my thesis and my character in general. That is luxury supervision. Thank you, Anna Fredriksson, Joakim Kalantari, and Niklas Arvidsson, for your time, effort, commitment, and more importantly your critical feedback. You made this journey joyful!

I would like to thank Per Wide for his excellent opposition in the pre-licentiate seminar. He trained and challenged me to defend and improve my thesis. Thanks to the cool, calm, and calculated Axel Merkel for our collaboration.

I would like to thank Linda Astner, Torbjörn Henriksson, Niklas Hermansson, Tryggve Berlin, Claes Möller, Lasse & Hasse, Peter Andersson, John Söderström, Anders Berg, Richard Nordlander, and many others at the Port of Gävle, who taught a lot of things about maritime transportation and port calls. I was lucky to work and learn from all of you.

I dedicate this thesis to my parents, who dedicated their lives to me and my brother.

Abbe, Linköping, August 2023.
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1. INTRODUCTION

The background, purpose, scope, and outline of the thesis are presented here.

1.1 Background

Maritime transportation accounts for 3% of the global greenhouse gas (GHG) emissions (IMO, 2020). In 2018, the International Maritime Organization (IMO) adopted an initial strategy to reduce emissions from maritime transportation (IMO, 2020). One target of the IMO’s strategy is to reduce the emissions of international shipping per transport work by 40% by 2030, compared to the levels of 2008. Similar initiatives are adopted on a European level, e.g., the Fit for 55 package and the inclusion of shipping in the European Union Emission Trading System (EUETS) (Regeringskansliet, 2023).

To reduce emissions from maritime transportation, a variety of different measures can be used. These measures can be categorized as technical, market-based, and operational measures (Bouman et al., 2017; Psaraftis et al., 2021; Jimenez et al., 2022; Shi, 2016). For technical measures, the aim is to incorporate new technologies helping to reduce emissions from vessels (Xing et al., 2020). Rudders, high efficiency propellers, and alternative fuels are examples of the technical measures (Alamoush et al., 2022; Xing et al., 2020; Zhang et al., 2019). For market-based measures, the aim is to change the behavior of maritime actors to reduce emissions by the adoption of operational and technical measures (Psaraftis et al., 2021). Examples of the market-based measures are bunker levy, port state levy, and Emission Trading Systems (ETS) (Psaraftis et al., 2022; Chen et al., 2023). For operational measures, the aim is to reduce emissions during operations of vessels or fleets by operational efforts and changes (Bouman et al., 2017; Corbett et al., 2009; Xing et al., 2020). Speed and voyage management, capacity utilization management, trim optimization, and logistics and supply chain planning are examples of the operational measures (Bouman et al., 2017; Stevens et al., 2015; Rehmatulla and Smith, 2015; Xing et al., 2020; Winnes et al., 2015).

In this thesis, the focus is on operational measures, particularly within the category of speed and voyage management. In earlier research, a variety of alternative speed measures are presented, evaluated, and discussed. One example is slow steaming, i.e., reducing the sailing speed of the vessel to reduce fuel consumption and emissions (Psaraftis, 2019; Psaraftis and Kontovas, 2013). Another example is speed optimization, i.e., the selection...
of an appropriate speed profile for the vessel to optimize a specific objective (Psaraftis, 2019). Speed limit is yet another example, that is imposed on vessels passing specific sea-areas (Cariou and Cheaitou, 2012). Lastly, reducing the sailing speed of vessels during the voyage to avoid known delays at the port of destination is also an alternative (Winnes et al., 2015). This last measure is referred to as Just-in-Time (JIT) arrival (Jia et al., 2017; Johnson and Styhre, 2015; IMO, 2020).

The IMO defines JIT arrival as maintaining an optimal ship sailing speed to arrive at the pilot boarding place when the availability of berth, fairway, and all other port call services are ensured (IMO, 2020, p.3). Adjusting the sailing speed of vessels during the voyage based on the availability of berth and other port call services to avoid delays is relevant because of the lengthy duration of delays experienced in port calls. For instance, IMO (2020) reported that vessels (tankers and dry-bulkers) annually spend on average 9% of their time delayed at anchorage. Andersson and Ivenhammar (2017) identified vessels that anchored in the Baltic Ports. Their estimates for those anchored vessels show that 54% of the anchored vessels spend between 1-23 h at anchorage, and 46% spend 24 h or more. These delays are caused by capacity constraints in the port call process, e.g., occupied berth upon arrival of vessels, or due to shortage in pilots and captains to provide towage during port calls (Nikghadam et al., 2023; Poulsen and Sampson, 2020).

Avoiding delays by slower sailing speed benefits the fuel efficiency during the voyage and port stay, leading to fuel and emission savings. The estimated potential for fuel and emission savings by the implementation of JIT arrival ranges between 2-20% (Jia et al., 2017; portXchange, 2022; Johnsson and Styhre, 2015; Fuentes and Adland, 2023). This potential is relevant to port authorities, vessel owners, and charterers. Port authorities benefit from decreased delays at the ports as this enables decreased emissions from vessels in the port area. Moreover, the safety within the port area can potentially increase thanks to reduced congestion of vessels. For vessel owners and charterers, the benefits relate to avoiding delays and saving fuel costs and emission (Jia et al., 2017). Besides the potential of fuel and emissions savings, JIT arrival does not impact the capacity of maritime transportation negatively as opposed to other speed reductions measures like slow steaming. With JIT arrival, delays are avoided by extending the voyage time, without impacting the total transportation time from port to port (Poulsen and Sampson, 2019). This entails that the transport capacity is not affected negatively either (compared to the case for slow steaming for instance), and that transportation services (in particular total transportation time) from the perspective of charterers remain indistinguishable. Also, unlike some technical measures, JIT arrival does not require any engineering breakthroughs (Alamoush et al., 2022). Instead, efficient information sharing, planning, and coordination among port call actors are necessary for its implementation (Gibbs et al., 2014; Jia
et al., 2017). Compared to other measures (e.g., turbocharger cut-out), JIT arrival has low implementation costs related to software solutions, which is another advantage associated with this measure (Eide et al., 2011; Schorer et al., 2022; Gundersen et al., 2016).

Given the fuel costs and emissions savings potential of JIT arrival in maritime transportation, its implementation is relevant for public authorities and commercial actors alike. In practice, however, the implementation of JIT arrival in port calls remains limited. Survey results based on European shipping companies revealed that only a small share of companies have implemented JIT arrival in their operations (Rehmatulla and Smith, 2015; Sung et al., 2022). The limited implementation of JIT arrival can be explained by several barriers in maritime transportation. These barriers are related to the uncertainty of the actual fuel and emissions savings that can be realized by JIT arrival, the present berth allocation policy First-Come-First-Served (FCFS) used in ports, the charterparties used in shipping, and the insufficient coordination, planning and quality of information sharing among actors in maritime transportation. These barriers are further described below.

In earlier studies, the estimates of JIT arrival indicate a promising potential for the fuel and emissions savings. However, in two recent studies, researchers have emphasized that the potential of JIT arrival is uncertain, and that earlier studies may have overestimated its potential (Adland et al., 2020; Berthelsen and Nielsen, 2021). This uncertainty in the validity of the fuel and emissions savings might cause actors to pause regarding the implementation of JIT arrival, which would constitute a barrier for its implementation (Poulson and Sampson, 2019).

The FCFS combined with the charterparties used in shipping is another barrier limiting the implementation of JIT arrival (Rehmatulla and Smith, 2015; Fuentes and Adland, 2023). The allocation of vessels to berths in the port call process is predominantly coordinated by the FCFS arrival policy (Cho et al., 2022). This means that the access to the berth, and the different services required to proceed to the berth (e.g., pilotage) is determined by the sequence of the arriving vessels to the port (Alvarez et al., 2011). Although, perceived as fair and robust, the FCFS coordination mechanism is considered as environmentally unsustainable (Senss et al., 2023; Rosæg, 2010, Schwartz et al., 2020).

Due to FCFS, shipping companies are incentivized to “rush-to-wait” to tender the Notice of Readiness (NOR) (Schwartz et al., 2020). The NOR is a document issued by captains of vessels to showcase the readiness of vessels to start loading and/or discharging. Tendered NOR and the rush-to-wait would reduce the risk of contract cancellation and potentially increase the profit from demurrage in market conditions where freight rates are unprofitable (Poulson and Sampson, 2019; Fuentes and Adland,
From the perspective of charterers (buyers of shipping services), they may instruct the speed of the vessel to proceed to the port without delays, i.e., use the utmost dispatch clause, when the vessel is operating on a time charter party (Adland and Fuentes, 2023). This is because charterers prioritize the certainty of delivery of cargo more than fuel and emissions savings associated with JIT arrival (Poulsen and Sampson, 2019). These charterparty properties limit the implementation of JIT arrival. Even if the vessel owners and the charterers agree to reduce the sailing speed to arrive JIT, the risk of the berth being occupied by another vessel during their arrival hinders such agreements. This risk is relevant to consider by vessel owners and charterers as long as ports coordinate vessels’ arrival on the basis of FCFS.

Another barrier limiting the implementation of JIT arrival is the insufficient quality of information shared among actors in the port call process (Johnson and Styhre, 2015; Aroca et al., 2020). The port call process is characterized by the involvement of many actors providing interdependent services to the arriving vessels. The interdependent nature of these services requires coordination (Fransen and Davydenko, 2021). Successful implementation of JIT arrival relies on efficient coordination of the actors and their services. Though, in practice, evidence about the insufficient quality of shared information exists, limiting the possibility for efficient coordination among actors (Johnson and Styhre, 2015). For example, vessels’ Estimated Time of Arrival (ETA) shared by agents are rarely updated and are unreliable (Aroca et al., 2020; Veenstra and Harmelink, 2022). The reliance on manual modalities to share information in port calls also affects the information quality (Gumuskaya et al., 2020, Wide, 2021). The limited quality in information sharing among port call actors negatively affects the possibility to manage the speed of vessels during the voyage and implement JIT arrival (Schøyn and Bråthen, 2015). Insufficient quality of information sharing also affects the resource planning and utilization associated with the port call services at shore (Elbert and Walter, 2014; Nikghadam et al., 2023). Unreliable ETA from vessels, and insufficient coordination among the arriving vessels to the port affect the planning of terminals and cause “clashes” in the port call process (Neagoe et al., 2021). Improved information sharing can be facilitated by information sharing platforms like Port Community Systems (PCS) to enable better coordination among port call actors (Gibbs et al., 2014; Jia et al., 2017; Elbert et al., 2017). Though, presently only few implementations of PCS exist for the port call process, and particularly JIT arrival.

To enable the implementation of JIT arrival, and reach the expected potential, alternative coordination mechanisms for coordinating the arrival of vessels with the required services in the port call process are necessary. Pre-booking policy (PBP) allowing the berth to be booked in advance would facilitate JIT arrival implementation (Gibbs et al., 2014; Kontovas and Psaraftis, 2011). However, to pre-book berths and possibly implement JIT
arrival, the level of planning and information sharing needed to coordinate actors is higher compared to the case where FCFS is used. Therefore, the focus in this thesis is on exploring how coordination mechanisms can be used to enable the implementation of JIT arrival. In earlier studies, the need for better coordination among port call actors to implement JIT arrival is underlined (IMO, 2020). However, little is known about the required coordination mechanisms, the interaction between these mechanisms, and what, when and how plans and information should be shared among port call actors to coordinate vessel arrivals and port call services on JIT basis. Furthermore, while the potential of JIT arrival in earlier studies is perceived as promising, recent studies emphasized that the fuel efficiency potential of implementing JIT is uncertain, and may be overestimated (Adland et al., 2020). The uncertainty of potential fuel and emissions savings limits the implementation of JIT arrival (Poulsen and Sampson, 2019). Thus, further research about the fuel and emissions savings potential of JIT is necessary to understand its actual potential, which is an additional focus in this thesis.

1.2 Purpose

The purpose of this thesis is to explore how to implement Just-in-Time arrival by studying coordination during the port call process.

1.3 Scope

The starting point in this thesis is in maritime logistics and transportation, with a focus on the port call process. The start-boundary of the port call process is the late stage during the voyage execution, when the vessel approaches the port of destination. In this context, the “late stage” is not a pre-defined moment in time but can be approximated to 24–72 h before the arrival of the vessel to the port. The end-boundary of the port call process is when the cargo-operations and other services are completed, and the vessel departs from the port area to sail to the next port. Within the port call process, there are several subprocesses, e.g., activities and services that are included in the scope. The included activities are the voyage execution process, pilotage, towage, mooring, inspection and cargo operations, agent assistance and activities conducted by the port authority and Vessel Traffic Service (VTS).

Within the boundaries of the port call process, the following actors are included in this scope of the thesis: tanker shipping companies, oil and gas companies (charterers), port authority and VTS, terminal operators of different oil and gas companies, surveyors and load/discharge masters, agents, pilots, tugboat operators, and mooring operators. The focus is on

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1 In practice, this depends on how far the port of origin is from the port of destination.
the transportation of bulk cargo, for which tankers and dry bulkers are suitable vessel types. The transportation of bulk cargo represented 56% of the total cargo transported during 2021 (UNCTAD, 2022).

The focus in the studied system is on the following coordination mechanisms: the PBP, the information sharing (facilitated by PCS) among port call actors, and the planning of services and activities. These are considered as important coordination mechanisms to enable efficient coordination to realize the potential of JIT arrival in port calls. More specifically, the focus is on the interaction between these mechanisms and how they contribute to the implementation of JIT arrival in port calls. For example, the availability of relevant information is necessary for individual actors’ planning processes. In turn, the PBP intends to coordinate the different individual plans of actors into one plan to potentially facilitates the implementation of JIT arrival.

The port call process is illustrated in Figure 1, including the services and activities, the actors, and the different coordination mechanisms required to implement JIT arrival.

Figure 1. The studied system in the thesis.

1.4 Outline

In chapter 2, the frame of reference and the research questions (RQs) are presented. In chapter 3, the methodology, including research approach and process, data collection methods and research quality, is discussed. The summary and the contribution of each appended paper to the thesis is presented in chapter 4. The findings of the thesis are presented in chapter 5. The discussion, conclusion and contribution are presented in chapter 6.
2. FRAME OF REFERENCE

In this chapter, the frame of reference and its structure are presented. In the first section, maritime transportation and logistics, and the port call process are introduced. Moreover, the concept of JIT arrival in port calls, its potential and the barriers that limit its implementation are also presented. In the second section, the concepts of coordination, information sharing, and information quality are first presented, followed by a review of the maritime transportation literature where these concepts are used and discussed. In the third and last section, the reviewed literature is synthesized to formulate the research questions (RQs) of the thesis.

2.1 Maritime transportation and logistics

Maritime transportation refers to transportation services supplied to passengers and cargo owners over water masses using different types of vessels (Rodrigue, 2020). Different types of vessels are suitable for different types of cargo. The different vessel types such container carriers, tankers, and dry bulkers can be used to carry containers, coal, oil and other types of commodities (UNCTAD, 2022; Rodrigue, 2020; Christiansen et al., 2007).

There are two common types of transportation services offered in the maritime transportation market: liner services and tramp services. Liner services refer to regular and scheduled maritime transportation services, often calling several ports, and are like the “bus services” of maritime transportation (Rodrigue and Notteboom, 2020; Poulson and Sampson, 2019; IMO, 2020). Tramp services refer to renting a vessel (or space in a vessel) for specific transportation between specified ports of origin and destination (Rodrigue and Notteboom, 2020). Tramp services are like the “taxi services” of maritime transportation (Poulson and Sampson, 2019; IMO, 2020).

Maritime logistics refers to the management of physical maritime transportation flows, information flows, and the interfaces between relevant actors involved in the transportation such as vessel owners, charterers, terminals, and transport intermediaries like freight forwarders and agents (Panayides and Song, 2013). The aim of maritime logistics is to improve the efficiency and the service quality of transportation, and to reduce the environmental impact of transportation (Panayides and Song, 2013).
Within maritime logistics and transportation, there are three relevant processes to manage: *voyage planning*, *voyage execution*, and *port calls* (Poulsen et al., 2022; Poulsen and Sampson, 2020). For tankers and dry bulkers (operating in tramp shipping), voyage planning entails the decision-making and the agreements between shipping companies (vessel owners) and charterers about the transportation (Poulsen et al., 2022). The voyages are normally contracted through charterparties where agreements between shipping companies and charterers are handled. In these charterparties, a variety of different aspects such as preliminary route, ports of origin and destination, amount of cargo, vessel’s speed, laytime, demurrage and despatch, and other vessel specifications and performance are negotiated (Poulsen et al., 2022; Cai et al., 2021, Branch, 2007; Bonello, 2021). There are three common types of charterparties used in shipping: Voyage Charterparty (VCP), Time Charterparty (TCP), and bareboat charter (Stopford, 2009; IMO, 2020). The differences between the three are the structure of the cost allocation between the shipping companies and the charterers, and the pricing mechanism (received revenue) used by the shipping company to offer their services. For instance, in a VCP, the shipping company bares the costs of cargo-handling, voyage and operating expenses, capital costs, and receives payment per freight ton basis. Whereas in a TCP, the charterer is responsible for costs associated with cargo handling and voyage expenses, while paying the shipping companies per day (Bonello, 2021). In Table 1, the cost allocation between vessel owners and charterers under the TCP and the VCP is presented.

Table 1. Cost allocation between vessel owners and charterers under different charter parties (Stopford, 2009; Bonello, 2021).

<table>
<thead>
<tr>
<th>Cost element</th>
<th>Time Charterparty (TCP)</th>
<th>Voyage Charterparty (VCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo handling</td>
<td>Charterer</td>
<td>Vessel owner</td>
</tr>
<tr>
<td>Voyage expenses</td>
<td>Charterer</td>
<td>Vessel owner</td>
</tr>
<tr>
<td>Operating expenses</td>
<td>Vessel owner</td>
<td>Vessel owner</td>
</tr>
<tr>
<td>Capital cost</td>
<td>Vessel owner</td>
<td>Vessel owner</td>
</tr>
</tbody>
</table>

In addition, there are also different types of clauses that can be incorporated into the charterparties to modify the standard terms of agreement in the charterparties. For example, if the original agreement instructs the vessel crew to sail at “utmost dispatch” during the voyage, some clauses can be incorporated to reduce the speed given a known delay at the port of destination. Relevant shipping clauses to this thesis are Virtual Arrival (VA), JIT arrival, and Sea Traffic Management (STM), all of which are described in Appendix 1 in the thesis.
2.1.1 The port call process

The port call process is a key process in managing maritime transportation. It includes all the activities performed by different actors to serve the vessel during her arrival, stay, and departure from the port. The starting point of the process is the first submitted ETA by the vessel crew – or agents – to the port of destination (Veenstra and Harmelink, 2021). Before arriving to the port area, the agent is responsible to coordinate and book the required services to serve the vessel upon arrival. Upon arrival, the captain tenders the NOR, which starts the laytime. The laytime refers to the agreed period between charterers and shipping companies within which the cargo-operation is to be completed (Sun et al., 2021; Stopford, 2009). The NOR can be tendered only when the vessel is ready for cargo-operations (Sun et al., 2021). If the agreed laytime that is specified in the charterparty is not met, demurrage or despatch may be claimed. The demurrage is paid by the charterer to the shipping company when the actual laytime exceeds the one that is agreed on. Whereas the despatch is paid by the shipping company to the charterer if the actual laytime is shorter than the agreed laytime. Both the demurrage and the despatch occur normally under VCP.

When the vessel arrives to the port area, the port authority, and Vessel Traffic Service (VTS), ensure that the vessel meet the mandatory requirement of the port (e.g., draught). Based on the availability of the berth, the VTS also instructs the vessel to proceed to the berth or to wait at the anchorage area if the requested berth is occupied. Before proceeding to the berth, the nautical services including in-going pilotage and towage are provided to the vessel (Fransen and Davydenko, 2021). Pilotage refers to the navigational support provided to the vessel crew, whereas towage refers to the dragging of one vessel with the aid of other vessels to the berth. Once the vessel is berthed, mooring operators arrive to moor and stabilize the vessel at berth. Cargo-operation can then commence to load or discharge the cargo. During some circumstances, especially for tankers, the cargo must be inspected by surveyors to certify the quality of cargo before cargo-operation can commence (Cho et al., 2022). After cargo-operations, vessels can proceed to the next berth, or leave the port (Cankaya et al., 2019). When the vessel departs from the port, unmooring and out-going pilotage are provided.

It is also important to address that some of the activities that are provided to the vessels during the port call process are interdependent. For example, cargo-operation cannot commence before inspection is finished, and pilotage must first be provided to allow the vessel to proceed to the port/berth, as it is compulsory to enhance navigational safety in most ports (Wu et al., 2022).

In Figure 2, the illustration of the services (both nautical and berth services) provided to the vessels during the port call process is presented.
The coordination mechanism that is used to allocate the arriving vessels to the berths in port calls is FCFS (Cho et al., 2022; Li et al., 2022; Imai et al., 2001). The allocation of berths in FCFS is determined by the sequence of the arrival of vessels to the port (Cho et al., 2022; Alvarez et al., 2011). While FCFS is perceived as fair by actors (Røsæg, 2011), findings from the literature have pointed out several inefficiencies in the port call process associated with FCFS. Examples of these inefficiencies are delays (and the economic consequences on vessels’ efficiency caused by these delays), poor resource utilization, and increased emissions (Cankaya et al., 2019; Strandenes, 2004; Adland and Jia, 2018). It is discussed that FCFS drives speed competition among shipping companies and the “rush-to-wait” phenomenon that is inefficient vis-à-vis fuel consumption and emissions (Kontovas and Psaraftis, 2011; Adland and Jia, 2018). In FCFS, information sharing among port call actors is also limited and at some instances is discouraged (Cho et al., 2022; Nikghadam et al., 2023). Citing Cho et al. (2022, p. 104): “According to the current FCFS rule, the broker does not share information with other brokers, and seeks favorable scheduling for the tanker in charge only.”.

2.1.2 Just-in-time arrival in maritime transportation

JIT arrival in maritime transportation refers to maintaining an optimal ship sailing speed to arrive at the pilot boarding place when the availability of berth, fairway, and all other port call services are ensured (IMO, 2020, p.3). The aim with JIT arrival is to detect and avoid delays at the port of destination by adjusting the sailing speed of the vessel during the voyage (IMO, 2020; Jia et al., 2017). This is also referred to as speed reduction to enable port efficiency (Johnson and Styhre, 2015).

The potential benefits of JIT arrival and adjusting the sailing speed are to reduce delays at ports and obtain fuel and emissions savings by slower
sailing speed (Aroca et al., 2020; Jia et al., 2017; IMO, 2020). Also, the total port-to-port time remains unaffected, as JIT arrival extends the duration of the voyage only based on the duration of delays at the port of destination. This is relevant because it entails that the transport service remains indistinguishable from the charterer’s perspective. This also means that no further transport capacity is required as the slower sailing speed aims to avoid delays only.

Detailed estimates about the savings in fuel and emissions associated with the implementation of JIT arrival are found in the literature. Combining quantitative operational data from Voyage Reports and Statement of Facts with interviews, Johnsen and Styhre (2015) concluded that bulk shipping companies can reduce the average waiting time between one to four hours using JIT arrival. Moreover, their analysis shows that the savings of JIT for two bulk vessels in the Baltic Region ranges from 2% to 8% in fuel consumption reduction (Johnson and Styhre, 2015). Based on Automatic Identification System (AIS) data, the potential of JIT arrival for Very Large Crude Carriers (VLCC) in global trade is estimated to range between 7%-19% in emissions savings, and up to 138 tonnes of fuel saving per voyage (Jia et al., 2017). Sung et al. (2022) found that on average, 9% fuel savings per voyage, can be reached through the implementation of JIT arrival. Fuentes and Adland (2023) estimated the potential of JIT arrival for voyages sailing through the Panama Canal and found that 0.3-5% in emissions savings per year can be reached depending on the JIT arrival strategy that is used. In a white paper written by PortXchange (2020), the potential of JIT arrival was estimated to 16% in emission reduction on average.

Despite the promising potential of JIT arrival, its implementation remains limited in practice (EPA, 2020; Bloomberg, 2023). This limitation is explained by a variety of barriers found in the literature and presented next.

**The barriers of Just-in-Time arrival in maritime transportation**

A variety of barriers related to the implementation of JIT arrival were found in the literature. These barriers include:

- Uncertainty about the potential of fuel and emissions savings associated with the implementation of JIT (Poulsen and Sampson, 2019; Adland et al., 2020).
- The charterparties and contractual agreements used in shipping (Fuentes and Adland, 2023; Rehmatulla and Smith, 2015).
- The berth allocation policies used in ports, in particular FCFS (Kontovas and Psaraftis, 2011; Gibbs et al., 2014).
- Coordination and information sharing barriers (Aroca et al., 2020; Veenstra and Harmelink, 2022; Johnson and Styhre, 2015).
The uncertainty in the validation of fuel savings obtained from JIT arrival is one barrier limiting the implementation of this measure (Poulsen and Sampson, 2019). While in some publications the estimates of the potential of JIT arrival are promising (up to 20% in savings), in others there is uncertainty about how much fuel can be saved (Poulsen and Sampson, 2019; Berthelsen and Nielsen, 2021). Vessel owners and charterers still rely on Noon Reports to assess the performance of vessel (e.g., fuel efficiency potential due to speed reduction). As the frequency of updating these reports is not high, the quality of the data is low, making the estimation of the potential difficult (Bonello, 2021). This can potentially explain the reason for the uncertainty in the validation faced by maritime actors, mentioned by Poulsen and Sampson (2019). Moreover, recent publications have warned about that researchers in previous studies estimating the potential of JIT arrival may have overestimated the potential of JIT arrival (Adland et al., 2020).

Regarding contractual barriers, the split incentive arising from the principal-agent relationship in VCP limits the implementation of JIT arrival (Rahmetulla and Smith, 2015). Vessel owners bear the fuel costs in the VCP and have sometimes incentives to increase the fuel efficiency of the vessels during the voyage. However, the charterers in VCP have no other concern apart from arriving on time to the port of destination (Fuentes and Adland, 2023). Thus, in VCP, during some circumstances, where the utmost dispatch clause is used, the possibility to implement JIT arrival are more limited as the clause limits the flexibility of speed adjustment during the voyage. In other circumstance, where fuel efficiency is not rewarded, vessel owners are incentivized to “rush-to-wait” (Adland et al., 2017). This means that it is in the interest of vessel owners to sail fast to tender the NOR. This is because “rush-to-wait” has potential to allow vessel owners to earn demurrage revenue, which in poor market conditions can be higher than revenue from freight rates (Adland and Jia, 2018). The FCFS mechanism is pointed out as one of the drivers for the “rush-to-wait” phenomenon in the literature (Schwartz et al., 2020, Adland and Jia, 2018).

In TCP, the charterers can adjust the speed of the vessel during the voyage within an allowed range of speeds. This freedom in speed-adjustment is important to maximize the charterer’s profits (Beullens et al., 2023). However, the utmost dispatch clause is also sometimes used in TCP as charterers prefer the certainty of delivery of cargo over earnings from speed reduction (Poulsen and Sampson, 2019). It is important to address that the split incentives problem in TCP is less evident compared to VCP. This is because charterers benefit of the speed reduction as they bear the fuel costs directly.

Even if vessel owners and charterers agree to adjust the sailing speed to arrive JIT, regardless of the type of charterparty, there are risks associated
with FCFS that limit such considerations. As the allocation of berths is determined by the sequence of arrival in FCFS, charterers and vessel owners risk losing the berth to another vessel arriving before them. To mitigate this risk, earlier publications highlight the need to replace the commonly used FCFS with “time-slot policy”, or “pre-booking policy” allowing the berth to be booked in advanced before arrival (Kontovas and Psaraftis, 2011; Gibbs et al., 2014; Lind et al., 2021). This would protect charterers and vessel owners from the risk that the berth will be occupied by another vessel upon their arrival.

Coordinating the arrival based on pre-booked berths to facilitate the implementation of JIT arrival requires efficient planning that relays on real-time information sharing (Jia et al., 2017; Gibbs et al., 2014). Though, in practice, evidence about the insufficient quality of shared information that negatively affects the planning and coordination among actors exists. Actors in maritime transportation are still behind in utilizing digital tools such as PCS, as reported in the literature (Helig and Voß, 2017). There is also a reliance on manual information sharing modalities, that limits the quality of information (Veenstra and Harmelink, 2022; Aroca et al., 2020; Lind et al., 2021; Gibbs et al., 2014). For example, deviations in the shared ETA negatively impact the entire planning of port calls (Yu and Voß, 2023). Agents not sharing information with their vessels about disruptions also negatively impact the planning and execution of the voyages (Schöyn and Bråthen, 2015). The information deficiency in maritime transportation is considered as a barrier for JIT arrival. This is because the implementation of JIT requires increased quality in the operational information sharing among port call actors. These information deficiencies are further elaborated in Section 2.2.2.

**Earlier studies of alternative berth allocation policies to coordinate port calls**

Earlier studies have compared FCFS with alternative berthing allocation policies and analyzed their potential benefits and drawbacks. To improve port efficiency, Imai et al. (1997) concluded that optimal berth allocation policies must be found and operated instead of FCFS. Though, the authors also elaborated on the sensitivity of these policies as they fail to satisfy shipping companies' perception regarding the order of service (Imai et al., 1997). For example, an optimal policy may prioritize smaller vessels to serve before larger ones. This may lead to longer waiting times for the large vessels, but shorter waiting times in total. Several studies on berth allocation policies are presented and evaluated in the literature. These studies are presented below.

Eisen et al. (2021) use a simulation-optimization approach to examine the potential of berth allocation policy with four alternative priority rules for tankers in the port of Amsterdam. These priority rules are: 1) FCFS with
fixed arrival times, 2) No FCFS with fixed arrival times, 3) Pre-booking policy with 48 h restriction to book in advance, 4) Pre-booking policy with no restriction, i.e., berth booking can occur whenever. Compared to a FCFS baseline scenario, their results show that scenarios in which berths can be booked in advance with no restriction provide the most improvement in terms of berth utilization.

Yildirim et al. (2020) use simulation-optimization approach to evaluate FCFS with other hybrid berth allocation policies in which they consider different operational characteristics such as vessel sizes in the port of Izmir, Turkey. The outcome of their proposed policies reduces the average vessel waiting time and increase berth utilization compared to the FCFS policy.

Alveraz et al. (2011) use a simulation-optimization approach to compare FCFS with two alternative berthing policies: a Standardized Estimated Arrival Times (SETA) and Global Optimization of Speed, Berth, and Equipment Allocation (GOSBEA). Their results — of the sampled vessels based on market conditions of 2008 and 2009 — indicate that the GOSBEA leads to a reduction in total fuel consumption by 6% compared to the other two policies. Moreover, the average waiting time in ports is reduced by more than an hour, and half an hour, compared with FCFS and SETA, respectively.

Abou Kasm et al. (2022) distinguish between minimizing the total delay policy and minimizing the maximum delay policy. They argue that the latter is fairer, as the difference between waiting times are reduced compared to the first. They use a mixed integer programming approach to evaluate the minimizing maximum delay berthing policy while considering several constraints. Their proposed berthing policy is simulated for the port of Abu Dhabi, showing improvement compared to the existing FCFS policy used in the port. Maximum delay was reduced from 6 h to 4.5 h, total delay was reduced from 42 h to 18 h, and utilization rates for tugboats, pilots and pilot boats increased from 75.56%, 21.9%, 24.4% to 82.93%, 24.1%, 26.8%. They also found that the outcome of their proposed policy increases when the congestion ratio at the port increase.

Zhang et al. (2016) propose a mathematical model for channel-berth coordination in a Chinese port. They later compared their model with FCFS and a simple genetic algorithm approach. Their proposed model leads to reduction in total waiting time, total scheduled time, and maximum waiting time for visiting vessels.

Nikghadam et al. (2023) propose a coordination-based policy involving information sharing and vessel differentiation in the Port of Rotterdam. Vessel service providers (tug- and pilot organizations) share information about arriving vessels between each other, and pilots can prioritize vessels
with smaller towage requirement. The simulation of their proposed policy shows 30% reduction in waiting times can be achieved, while service providers improve their services. Their coordination-based policy and the prioritization of vessels with smaller towage requirement was motivated as the Port of Rotterdam suffers of limited towage capacity, i.e., the bottleneck in the port call process.

2.2 Coordination and Information sharing

Coordination is a managerial function used to manage interdependencies between activities and the joint effort towards a common goal (Malone and Crowston, 1994). This definition entails that coordination arise only when there are interdependencies (Soroor et al., 2009). Examples of different interdependencies are: Sequential interdependency, reciprocal interdependency, and pooled interdependency (Thompson, 1967; Bankvall et al., 2010).

According to Thompson (1967), sequential interdependencies occur when there is a unidirectional pattern of interdependency that can be specified. It describes the interdependence between activities/workers, where “the previous one must act properly before the next; and unless the previous one acts, the next one cannot solve its output problem”. Reciprocal interdependencies occur when the outputs of each activity become inputs for other activities. A typical reciprocal interdependency is when two related activities must change at the same time in order to work. Pooled interdependencies occur when each part renders a discrete contribution to the whole and each is supported by the whole. Pooled interdependency between two activities implies that they are related to a third activity or share common resource (Thompson, 1967).

Coordination mechanisms are specific tools designed to address specific coordination problems (Fugate et al., 2006). Different types of mechanisms are suitable for different problems. A variety of different classifications of coordination mechanisms are described in the literature. Examples of these classifications include inter-organizational mechanisms, intra-organizational mechanisms, impersonal mechanisms, and personal mechanisms. Specific examples of coordination mechanisms include information sharing and technology, joint decision-making, mutual adjustment, direct supervision, standardization of work, standardization of output, standardization of skills and knowledge, standardization of norms, and planning and information management (Mintzberg, 1989; Kanda and Deshmukh, 2008; Tuomikangas and Kaipia, 2014).

In this thesis, the focus is on planning and information sharing as coordination mechanisms to coordinate JIT arrival in port calls. The relationship between these two mechanisms is presented by Tuomikangas
Sharing information among individual actors may enable them to make decisions with a positive impact on the transportation chain (Tuomikangas and Kaipia, 2014; Lehoux et al., 2013). For instance, sharing container information can potentially improve the planning of terminal-operators, which in turn improves the transportation chain. Moreover, the focus is on the coordination of inter-organizational actors in the port call process. Kembro and Näslund (2014) defined information sharing as sharing inter-organizational data, information, and knowledge in supply chains (Kembro and Näslund, 2014). In this thesis, the focus is on inter-organizational information sharing, however, the focus is on the transportation chain level instead of supply chain level.

There are four aspects of information sharing: Information content, information frequency, information modality, and information direction (Mohr and Nevin, 1990). Information content refers to what information to share. Information frequency refers to the number of communications between actors. Information modality refers to the method that is used to share information. Information direction refers to how information is shared, i.e., bidirectional (in two directions) or unidirectionally (in one direction).

Another important factor that is related to information sharing, planning, and coordination is information quality. Information quality is defined as the ability to satisfy implied and stated needs of information receivers (Myrelid and Jonsson, 2019). Several dimensions can be used to measure information quality, e.g., relevance, accessibility, reliability, consistency, security, credibility (Gustavsson and Wänström, 2009; Stvilia et al., 2007; Viet et al., 2018).

The relation between information sharing, coordination, and uncertainty is highlighted in the Organizational Information Processing Theory (OIPT) (Galbraith, 1977). In OIPT, the fit between the processed and the required information when uncertainty increases is considered. Uncertainty is considered as “the difference between the amount of information required to perform the task and the amount of information already possessed by the organization” (Galbraith, 1973). The information processing approaches used in OIPT to manage increased uncertainty are: 1) to reduce the information processing needs, or 2) to increase the information processing capacity. If no choice is made between these approaches, performance is likely to be negatively influenced by creation of slack resources. In the increased information processing capacity approach, the investments in information systems and the creation of lateral relations to share information are important. Whereas in the approach of reduced information processing need, this leads to the creation of slack resources, self-contained task and environmental management. The OIPT is used to analyze information and coordination in supply chain and transportation chain contexts (Wide et al., 2021; Srinivasan and Swink, 2015). In Figure
3, an overview of the information processing approaches of OIPT is provided. These include both those that can be used to reduce the information processing needs and increase the capacity for information processing. Both approaches are marked under the red frame.

2.2.1 Coordination in maritime transportation

The maritime transportation literature with coordination perspective focuses primarily on three aspects of coordination. The first aspect relates to identifying coordination problems in different processes, e.g., vessel arrival, truck arrival, and port operations. The second aspect relates to explaining the causes and the consequences of these identified problems. The third aspect is related to relevant coordination mechanisms to manage the identified problems. Below, a review of the studies addressing these aspects of coordination is presented.

Several coordination problems were identified by van der Horst and De Langen (2008) in the context of inland container transport chains in the Port of Rotterdam. These problems include insufficient container operations planning caused by insufficient information of container data. In turn, the insufficient planning cause delays in different areas of the transportation chain, e.g., rail terminals. Delays due to congestion also occur in the Port of Rotterdam caused by peak load in road transports. Other studies, in the same port found bottlenecks in towage services, which in turn cause delays in the nautical service chains provided to arriving and departing vessels (Nikghadam et al., 2021; Nikghadam et al., 2023; Gymuskaya et al., 2020).

In Australian maritime transportation chains, the limited coordination among the arriving vessels calling the ports causes clashes in landside
Delays due to congestion can also occur due to limited information sharing among organizations operating in different transport chains, but using the same facilities (Neagoe et al., 2021). Wide et al. (2021) found that the coordination to manage disruptions in the Swedish intermodal freight transportation is limited.

The coordination mechanisms that are discussed in the maritime transportation literature are classified as strategic and/or operational (Wide, 2021; Gumuskaya et al., 2020). van der Horst and De langen (2008) proposed four mechanisms to manage the coordination problems they identified. These are 1) the introduction of incentives (e.g., tariff differentiation and penalties), 2) creation of an interfirm alliance (subcontracting, project specific contract), 3) Changing scope (e.g., vertical integration, and 4) creation of collective actions, e.g., ICT system for a sector of industry. These coordination mechanisms are viewed as strategic. Similar mechanisms such as contracts with risk-bearing commitment and subsidiaries were considered by Franc and van der Horst (2010) to integrate services between terminals and shipping lines.

From an operational coordination perspective, information is considered as an important mechanism to manage coordination problems in transportation (Wide, 2021; Sternberg et al., 2012). In this thesis, the use of information to facilitate improved planning and coordination among actors in the context of JIT arrival in the port call process is considered.

2.2.2 Information sharing and quality in maritime transportation

The importance of sharing information with high quality to plan, coordinate, and execute transport operations is well documented in the maritime transportation literature. Early and frequent sharing of ETA can increase the utilization of resources in ports (Elbert and Walter, 2014; Yu et al., 2018). Nikghadam et al. (2021) provided a framework in which they address the direction and the content of information sharing among actors in the port call process to mitigate delays. For example, they proposed that sharing ETA, together with Estimated Time of Departure (ETD), shared resources (e.g., pilots and required number of tugboats) can be utilized to potentially mitigate delays in port calls (Nikghadam et al., 2021). Yu et al. (2022) provides a framework for information sharing addressing the content, direction, and frequency of information to optimize the speed of vessels with regards to berth allocation. Simulation of sharing cargo-specific information and real-time traffic information that allow for dynamic stowage planning have shown potential to mitigate delays in port calls (Conca et al., 2018; Zudiwijk and Veenstra, 2015). In addition, the progress of cargo-operation, i.e., real-time information and the Estimated Time of Completion (ETC) has been highlighted as important content to enable efficient planning by a variety of actors involved in the port call operations (Neagoe et al., 2021).
process (Weigsmans et al., 2018). Information about disruptions (Wide 2021), like delays of incoming vessels during their voyage, or delays at the port, are important for different port call actors’ plans (Weigsmans et al., 2018; Reis, 2019; Gibbs et al., 2014). Vessel-specific order-information such as towage requirement is important to allow actors providing port call services to plan their resources efficiently and to mitigate delays (Nikghadam et al., 2023).

In several studies, the quality of information sharing in maritime transportation is examined. Some of these studies focus on the reliability of ETA. Based on time stamps from AIS data, Veenstra and Harmelink (2021) found significant inaccuracy of the ETA provided by arriving vessels in the Port of Antwerp. The authors concluded that the unreliability of ETA negatively influences the implementation of JIT arrival (Veenstra and Harmelink, 2022). Other studies address the timely dimension of information quality. For instance, Schøyn and Bråthen (2015) found how feeder operators at ports receive late information about arrival time of ocean-vessel in the Baltic region. The late information affects feeder operators planning of the resources to serve the vessels. The authors also presented evidence about how current information sharing practices are insufficient to support voyage planning for economical sailing speed related to JIT implementation (Schøyn and Bråthen, 2015).

Information about the availability of tugboats and pilots are not accessible to the direct users of these services, i.e., the shipping companies (Wang and Vogt, 2019). However, the agent representing the shipping company must access this information via phone from relevant actors. The use of manual modalities like telephone and e-mails for information sharing is common in maritime transports, affecting the accessibility of information negatively, and creating uncertainty (Reis, 2019; Gumuskaya et al., 2020). Information systems as a modality to share information is also common, however, the connectivity of different actors’ information systems is still not matured enough. Subsequently, the information either don't reach, or get delayed, impacting the planning processes of actors negatively (Gumuskaya et al., 2020). The insufficient information systems were evident in detecting and recovering from disruptions in intermodal freight transportation (Wide et al., 2021). Lastly, evidence related to incomplete cargo-information that is needed by actors for planning purposes is also available in the literature (van Der Horst and De Langen, 2008; OECD, 2018; Reis, 2019).

2.2.3 Port Community Systems
Information sharing and information quality are positively influenced by the development of information systems and information and communication technology (ICT) (Elbert et al., 2017; Nikghadam et al., 2023).
One example of these technologies is the Port Community System (PCS), which is studied in this thesis.

A PCS is defined as a dedicated maritime ICT application developed to enhance the coordination between port actors within a specific maritime transportation process (Carlan et al., 2016). Examples of application areas are logistics, customs, navigation, hazardous goods, or specific business process such as port calls (Helig and Voß, 2017; Tasamboulas et al., 2012; Carlan et al., 2016; Di Vaio and Varriale, 2020). The core aim of PCS is to facilitate paperless procedures and information sharing between public and private actors, involved in port processes (Simoni et al., 2022; Helig and Voß, 2017). OECD (2018) highlights the importance of providing these types of applications that include public and private actors to enhance the efficiency of port processes.

A variety of different benefits associated with the use of PCS are listed in the literature: accessibility of information to relevant actors, reduced transportation and administrative costs, higher operational efficiency of transportation operations, and improved customer service (Tasamboulas et al., 2012; Carlan et al., 2016). Some studies deploy a quantitative approach to estimate the value of PCS. Irannezhad et al. (2017) simulate a baseline scenario with no PCS, compared with an information-rich scenario facilitated by the PCS. The simulation revealed that coordinated decisions for shipment bundling facilitated by the PCS reduce the total costs for shipping lines in Australia. Aydogdy and Aksoy (2015) conducted a simulation study to quantify the value of PCS on the administrative processes in Turkish ports during arrival, berthing, and departure of vessels. Their simulation revealed that the average document procedure per vessel can be reduced by 2.75 h using the PCS. Complementary to the simulation studies, case-studies also show reduction in delays, improvement of inter-organizational relationships, and an overall improved port performance by the utilization of PCS in port calls (Di Vaio and Varriale, 2020). PCS-enabled information sharing streamlines the transition and compliance towards new constraining policies like the Verified Gross Mass to enhance port safety (Fedi et al., 2019).

Another stream of literature focuses on the facilitating conditions of the successful implementation and use of PCS. Internal and external integration of different actors’ information system is considered as an important prerequisite to achieve the value of PCS (Jiang et al., 2021). Commitment and interaction among involved actors are also considered as an important facilitator for successful implementation and use. However, one challenge is that as the scale of benefits of PCS to different actors varies, it may be difficult to make all actors commit, especially those who don’t gain much benefit from utilizing the PCS (Gustafsson, 2007; Srour et al., 2007). Socio-technical factors, like training actors to utilize the PCS, willingness to change, leadership, quality of information and analytical
methods to support decision making were also found important for implementation and utilization of PCS (Vairetti et al., 2019).

2.3 Research Questions

The implementation of JIT arrival is motivated by its potential to increase fuel efficiency in maritime transportation. Accurate estimates of the fuel efficiency potential of JIT arrival are necessary to better understand the contribution of JIT arrival to achieve the environmental targets initiated by policy makers and regulatory organizations (IMO, 2020; EPA, 2021). In the existing literature, the estimated potential of JIT arrival is promising, ranging between 2-20% in fuel and emissions savings (Jia et al., 2017; Johnson and Styhre, 2015). However, recent empirical evidence has revealed a risk about overestimations in the potential of JIT arrival regarding fuel efficiency due to optimistic assumptions in these estimates (Adland et al. 2020; Berthelsen and Nielsen, 2021).

The used assumptions to estimate the fuel efficiency potential of JIT arrival are related to the technical and the operational characteristics of voyages. In this thesis, the technical characteristics refer to the speed-power curves used to estimate the potential of JIT arrival, e.g., cubic, quadratic, or speed-dependent (Jia et al., 2017; Andersson and Ivehammar, 2017; Adland et al., 2020). In some of the earlier studies, the cubic law is used to estimate the potential of JIT arrival (Corbett et al., 2009; Jing et al., 2021; Jafarzadeh and Scholberg, 2018; Jia et al. 2017; IMO, 2020). The cubic law is known to hold true at speed intervals close to the design speed of vessels (Norstad et al., 2011). However, many factors such as the actual sailing speed of vessels and weather conditions affects the validity of using this law, i.e., whether it holds true in practical settings or not (Yan et al., 2021; Psaraftis and Kontovas, 2013). Therefore, studies in which the cubic law is used without consideration of the actual sailing speed of the sampled voyages risk systematically overestimating the effect of JIT arrival on fuel efficiency (Adland et al., 2020; Taskar and Andersen, 2020). The reason for this is that the cubic does not hold true if the sailing speed of sampled vessels deviates from the design speed, leading to significant error in the estimated effect of JIT arrival (Berthelsen and Nielsen, 2021).

The operational characteristics in this thesis refer to the time at which speed reduction can commence during the voyage. In some studies, the speed reduction is assumed to be viable during the whole voyage (Jia et al., 2017). In practice, this assumption is unrealistic, leading to the effect of JIT arrival to be overestimated (Fuentes and Adland, 2023). Realistic scenarios, about the time at which the speed reduction associated with JIT arrival can commence is important to obtain more accurate and realistic estimates of the potential.
Therefore, it is necessary to combine the technical and the operational characteristics of voyages when estimating the potential of JIT arrival. The simultaneous consideration of these characteristics can potentially overcome some of the optimistic assumptions in the literature that cause the potential to be overestimated. Overcoming these assumptions leads to more accurate estimates of the potential of JIT arrival. In turn, the improved accuracy of the potential is crucial for shipping companies, charterers, and policy makers who consider the implementation of JIT arrival to reduce emissions (IMO, 2020; Berthelsen and Nielsen, 2021).

Moreover, most of the current literature associated with the potential of JIT arrival focuses only on the fuel efficiency aspects of JIT arrival. Hence, there is a need to broaden the scope and address whether the implementation of JIT arrival can contribute to additional types of benefits apart from fuel efficiency. For example, exploring the potential of JIT arrival regarding the actors at the land-side is necessary for its implementation. Research question one (RQ-1) is therefore:

- **RQ-1: What is the potential of Just-in-Time arrival in the port call process?**

Besides exploring the question of “what” is expected from JIT arrival in terms of potential, the “how” behind coordinating the port call actors and their planning processes to enable them to realize the potential of JIT arrival is also explored. The implementation of JIT arrival requires the transition from FCFS to PBP (Kontovas and Psaraftis, 2011; Gibbs et al., 2014). Most of the existing literature about FCFS and alternative berth allocation policies is modelling-oriented. Several studies model a baseline scenario in which FCFS is used, which is later compared to alternative berth allocation policies proposed in these studies. The potential of these policy is related to reduction of delays in ports, improved resource utilization, and improved fuel efficiency during the voyages. However, studies about real-world implementation and tests of these policies remains scarce in the literature. The need of the PBP as a coordination mechanism to enable JIT arrival is underlined in the literature. This is because the PBP allows the arriving vessel to reserve the berth in advance and adjust the sailing speed accordingly. This also entails that the risk of the berth taken by another vessel is minimized. As a result, understanding the different activities and decisions in the implementation process undertaken by port authorities to implement the PBP is crucial for the implementation of JIT arrival. To the best of the author’s knowledge, FCFS remains the predominant policy, and the literature regarding the implementation of alternative berth allocation policies is scarce. Especially regarding those policies that are associated with JIT arrival such as the PBP.

Beside the implementation process of the PBP, the coordination among port call actors to implement JIT arrival requires further research. More
specifically, the interaction between the PBP as a coordination mechanism, with other coordination mechanisms such as PCS and planning is important to address how actors can be coordinated to realize the potentials of implementing JIT arrival. The interaction between the coordination mechanisms, in which specific rules for information sharing and planning must be explored to enable the implementation of JIT arrival. Thus, the aim in this research question is exploring how coordination mechanisms can be used to coordinate port call actors in the implementation of JIT arrival. Research question two (RQ-2) is therefore:

- **RQ-2: How can port authorities facilitate the implementation of Just-in-Time arrival in the port call process?**
3. RESEARCH METHODOLOGY

In this chapter, the methodological choices are presented and justified to allow the reader to assess the quality of the research. The research approach is first presented, followed by an overview of the research process for the studies and their related papers appended to the thesis. The data collection methods used in the two studies are also presented here. Finally, the quality of the research is discussed.

3.1 Research approach

Schwarz and Stensaker (2014) distinguish between Theory Driven Research (TDR) and Phenomena Driven Research (PDR). They emphasize that knowledge creation in the TDR approach contributes to specific theory. Whereas the PDR approach is driven by real-world organizational problems. In the PDR approach, the aim is to identify, capture, document and conceptualize a phenomenon of interest to create knowledge within a specific field (Schwarz and Stensaker, 2014).

The research in this thesis follows the PDR approach, and the phenomenon that is studied is the PBP, information sharing and the planning that is required to enable an efficient coordination to obtain the potential of implementing JIT arrival in port calls in the Swedish context.

The focus on this phenomenon is driven by its relevance to the maritime industry (IMO, 2020; EPA, 2021; SMA, 2019). The importance of relevance in logistics and transportation research is underlined by Lambert (2019) and Svanberg (2020). The relevance motivating the choice of the studied phenomenon is derived from a variety of national and international bodies highlighting the potential of JIT arrival in maritime transportation. The Marine Environment Protection Committee (MEPC. 78, 2022) considers JIT arrival as an important measure for emissions reduction. The IMO (2020) published a specific report highlighting the potential of JIT arrival, and addressing some barriers related to its implementation. The United States Environmental Protection Agency (EPA, 2021) published a report highlighting the promising potential of JIT arrival. Moreover, The Baltic and International Maritime Council (BIMCO) developed contractual clauses such as JIT-clause, Virtual Arrival, and Sea Traffic Management. These clauses assist practitioners in the implementation of JIT arrival, as practitioners can incorporate them in their charterparties.
The examples mentioned above acknowledge the interest from public authorities to implement JIT arrival in practice to reduce emissions. In turn, the interest from these authorities and the potential of JIT to reduce emissions motivates the reason to conduct research about JIT arrival. Despite the interest of public authorities, the implementation of JIT arrival in practice remains limited (EPA, 2021). According to a recent Bloomberg news article, one shipping company managed to implement JIT arrival in seven voyages out of hundreds completed (Bloomberg, 2023). The gap between the interest of public authorities, the promising potential of JIT arrival reported in the literature, and the limited implementation motivates the need for more research about JIT arrival in port calls. More specifically, research about the potential of JIT arrival, and the coordination mechanisms associated with the implementation of JIT arrival need to be explored. Exploring the potential and the coordination mechanisms associated with JIT arrival can potentially contribute to organizations involved in port calls to implement JIT arrival. Or at least to better understand the reasoning behind why the implementation rate of JIT arrival remains limited despite the promising potential.

There are different methodological approaches, which are common in logistics research, among the most common and used are the analytical approach, the actors’ approach, and the system approach (Gammelgaard, 2004).

The analytical approach is related to the positivist research tradition in which patterns and causal relations are investigated during the research. In this approach, the researchers stay outside the research object and refrain from interacting with it to avoid having an influence on the studied object. In the actors’ approach, the importance of contextual considerations on how logistics is perceived in organizations are addressed (Gammelgaard, 2004). In the system approach, the aim is to understand the world as a system with parts, links, goals, and feedback mechanisms. The systems approach assists researchers in providing objective and illustrative descriptions of their studied systems (Nilsson and Gammelgaard, 2012). Gammelgaard (2023) discussed the importance of elaborating on the boundaries and the actors included in the studied systems.

The methodological approach that the work in this thesis is based on is the system approach. The system approach is suitable as it allows for studying the interaction between different mechanisms and actors that are necessary to enable efficient coordination to realize the potential of JIT arrival. The studied system was presented earlier in Figure 1.

Research can also be based on inductive, deductive, or abductive approaches (Bryman et al., 2019). The inductive approach begins by observing a phenomenon to inform theory. The deductive approach begins with theoretical hypothesis to be confirmed or rejected by empirical data. The abductive approach refers to combining the inductive and deductive approaches in an iterative process to better explore the studied phenomenon (Kovacs and Spens,
This entails that the researcher goes back and forth between theory and empirical data to enhance the understanding of the phenomenon (Dubois and Gadde, 2002). This research is based on the abductive approach.

### 3.2 Research process

The research in this thesis started as a part of the research project “Coordination and Information Sharing to Improve the Energy Efficiency of Maritime Transports” (MODIG). The aim in MODIG is twofold: 1) Digitalized information sharing in maritime transportation and its potential on energy efficient transportation, and 2) How business models and policies can contribute to increased energy efficiency in transportation. MODIG is funded by Fossil Free Freight (Triple F), i.e., research program dedicated for research and solutions for fossil free freight transport sector, initiated by the Swedish Transport Administration.

The research process of the work presented in this thesis started in October 2020, when the author enrolled as a PhD student. The research process contained two studies – a quantitative study and a qualitative study.

The time-period for the quantitative study started in October 2020 and was ended in January 2022 with a published paper (Paper I) in *Maritime Transport Research*. The focus in the study corresponds to RQ-1, i.e., to estimate the potential of JIT arrival regarding fuel and emissions savings. The study was presented at the Swedish conference Transportforum (2021) and in a seminar held by the Swedish Maritime Authority (SMA) in 2023.

The time-period for the qualitative study started in January 2021 and was ended in May 2023. The focus in the study corresponds to both RQ-1 and RQ-2 and resulted in the writing of Paper II and Paper III. In Paper II, the focus was on utilizing the PCS to coordinate port calls, and how the utilization is influenced by different factors. Moreover, the potential of improved planning and resource utilization associated with the utilization of information in the PCS was studied. In Paper III, the focus was on the implementation process of the PBP that is necessary to implement JIT arrival. Paper-II was presented at Swedish National Transport Conference (2021) and NOFOMA (2022). Paper III was presented at the Swedish National Transport Conference (2022) and in NOFOMA (2023).

The time-period for writing the Kappa of the thesis started in January 2023 and submitted for examination by June 2023.

In Figure 4, the research process and the relationships between RQs, studies, and papers are presented.
3.3 Research design

The research design of this thesis is structured in three sections. In the first section, the literature review process is presented. The purpose, type of the literature review, and the used keywords and databases to conduct the review are presented. In the second section, the methodology and the data related to the first study is presented. In the third and last section, the methodology for the second study is presented. Case selection strategies and data collection methods are presented and explained.

3.3.1 Literature review process

An exploratory literature review was conducted (Arksey and O'Malley, 2005). The reason for choosing an exploratory review process is that as the researcher becomes more familiar with the literature, the more adjustments to the search terms are needed. As a result, the conducted review process is not linear, but instead is iterative, requiring the researcher to adjust the search terms frequently. This adjustment and flexibility in search are restricted in systematic review as it relies on defined search strategy.

The purpose of the literature review is important to specify (Seuring and Müller, 2008). In this thesis, the purpose of the review is to synthesize the current state of knowledge related to barriers and coordination mechanisms associated with JIT arrival in maritime transportation. Some of the review process aimed at creating conceptual models that are used to analyze the empirical data. The key topics that were reviewed were related to the RQs of the thesis, and include the following:

- Studies on the fuel and emissions savings potential of JIT arrival
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- Studies within the “berth allocation problem” domain that are related to JIT. One example is studies that integrate the berth allocation problem with speed optimization problems.
- Coordination and information sharing studies. Both, within the maritime transportation field and the logistics field in general.
- Studies related to the implementation of JIT arrival in real-world settings.

To cover these topics, the exploratory search process was conducted using mainly Google Scholar. Some of the searched keywords were: “port call process”, “Just-in-Time arrival”, “port call optimization” “information sharing in maritime transportation”, “information sharing” “freight transportation” “port call coordination”, “port community systems”, “first-come-first-served”, “virtual arrival”, “berth allocation policy”. The search strategy also considered potential synonyms for the searched keywords. For instance, searching for “vessel arrival process” instead of “port call process”, “cargo” instead of “freight”, or “transport” instead of “transportation”. The snowballing technique was also used to find relevant literature (Wohlin, 2014).

During the iterative search process, the author identified specific journals where research related to JIT arrival in maritime transportation is published. These journals were Maritime Economics and Logistics, Maritime Transport Research, and Transportation Research (mainly Part E and Part D) journals. These journals were frequently revisited for new publications associated with JIT arrival. The author also identified specific researchers and research groups who published within the area of JIT arrival in maritime transportation. The profiles of those authors in Google Scholar were frequently visited to check for new publications.

The review process was not limited to scientific, peer-reviewed articles. White (2014) emphasized on the importance of including and synthesizing the technical press and grey literature. By doing so, the wider experience of a particular transport sector is considered (White, 2014). In this thesis, the grey literature associated with the JIT arrival phenomenon in maritime transportation is reviewed to consider the perspective of other actors than academics, e.g., practitioners, and public authorities. Svanberg (2020) expressed similar argument while elaborating on the relevance in logistics research. The inclusion of grey literature contributes to identifying timely and relevant problems by complementing the scientific literature (Svanberg, 2020). Therefore, the grey literature related to JIT arrival in maritime transportation is purposefully included in the review process.

3.3.2 Study-1: Quantitative modelling
The intended outcome of this study is related to RQ-1, i.e., related to the potential JIT arrival in port calls:
Research Methodology

• **What is the potential of Just-in-Time arrival in the port call process?**

More specifically, in this study, the focus is on estimating the fuel and emissions savings associated with the implementation of JIT arrival. Quantitative modelling approaches, AIS data, and the specific modelling approach to estimate the fuel and emission savings JIT arrival are presented in this section.

In research based on the quantitative modelling approach, the aim is to create rational knowledge (Meredith et al., 1998). Quantitative modelling can be classified into axiomatic and empirical modelling (Bertrand and Fransoo, 2002). In axiomatic research, the aim is to obtain solutions for a defined model and assure that these solutions are related to the structure of the problem as defined in the model. Additional aim in this approach is to create knowledge about the behavior of a specific variable in the model, based on assumptions about the behavior of other variables. The axiomatic research can be normative or descriptive (Bertrand and Fransoo, 2002).

In empirical modelling research, the aim is to ensure model fit between observations and actions, and the model made of that reality. Like the axiomatic research, empirical modelling can be descriptive or normative. In descriptive empirical modelling, the researchers aim to create a model that adequately describes the casual relationships that may exists. By doing so, better understanding of the modelled process is obtained. Whereas in normative empirical modelling research, the aim of the researchers is to develop policies, strategies, and actions to improve the current situations (Bertrand and Fransoo, 2002).

Based on the approaches mentioned above, study-1 is positioned within the descriptive empirical modelling approach. The relationship that is modelled is how the sailing speed of vessels affects fuel consumption, which in turn affects the fuel and emissions savings resulting from JIT arrival.

**Automatic Identification System (AIS)**

The AIS was originally designed to avoid vessel collisions by sharing vessel information to the surrounding vessels (Yan et al., 2020). The AIS includes the following types of data: dynamic (type 1-3 messages) and static and semi-static (type 5 messages). The different data types, and the description of the data are summarized in Table 2 (Svanberg et al. 2019; Yang et al., 2019).

<table>
<thead>
<tr>
<th>AIS message type</th>
<th>Field name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1-3</td>
<td>MMSI</td>
<td>Identification number</td>
</tr>
<tr>
<td></td>
<td>Navigation status</td>
<td>Indicate if the ship is at anchor, moored, or underway</td>
</tr>
</tbody>
</table>
The use of AIS is applied to different research areas. Svanberg et al. (2019) listed collisions, emissions, monitoring, noise, fishing and logistics and transport economy as research areas where AIS is used. Yang et al. (2019) discussed navigational safety, environmental analyses, and vessel and port performance as AIS application areas for research. In this thesis, the AIS data is mainly used to estimate fuel and emissions savings from vessels during port calls. This is a common use of AIS data, as the data enables the movement of vessels to be analyzed. For example, instances of vessels delay at anchorage can be identified through the AIS. This would also lead to the possibility to estimate the potential of fuel efficiency if these delays were eliminated by adjusting the speed during the voyage (Yan et al., 2020; Jia et al., 2017).

Identifying instances of anchorage is essential to estimate the fuel and emission savings associated with the implementation of JIT arrival. To do so, vessel-specific position data derived from the AIS was used to determine the vessels that were delayed at anchorage, and the duration of these delays. The AIS data used in study-1 covered all vessels calling Swedish ports during 2019, and is filtered for tankers, dry bulkers, and general cargo. The filtration is due to JIT arrival being more relevant to the tramp segment compared to the liner segment which sails normally on pre-defined schedules. The AIS data was combined with port call statistics provided by the SMA. Combining the two data sets provide more validity in that the sampled vessel did not only wait at anchorage, but also proceeded to the port. This reduces the possibility of including anchorage instances referred to as “in transfer” in the analysis, i.e., vessels that are at anchorage, but do not call the port.
By identifying the vessels that were delayed during 2019, a “pseudo speed” can be calculated in which the vessels reduce their sailing speed to avoid or reduce delays at anchorage. Reducing the sailing speed results in fuel and emissions savings. The methodology from the IMO’s fourth GHG study, fuel consumption functions, and vessel-specific data are used to determine the fuel savings obtained by the “pseudo speed” of JIT arrival. The fuel savings were converted using emission factors (EF) specified by the IMO to estimate the CO$_2$-emissions savings.

3.3.3 Study-2: Qualitative case study

The intended outcome of this study is related to both RQ-1 and RQ-2, where the aim is to explore how actors can be coordinated to implement JIT arrival in port calls. The potential of JIT arrival, focusing on aspects related to actors’ resource planning and utilization was also explored in this study.

- **RQ-2: How can port authorities facilitate the implementation of Just-in-Time arrival in the port call process?**

A case-study approach was used in the second study. Several justifications behind the choice of using case studies as a research approach are listed in the literature. For example, the case-study approach is justified for gaps in existing literature, theory building, and explanatory research (Barratt et al., 2011; Meredith, 1998; Benbasat et al., 1987). The case approach is also suitable to investigate phenomena that are poorly understood (Eisenhardt, 1989). Moreover, case studies are suitable to explore and understand emerging phenomena in their real-world settings (Barratt et al., 2011). The empirical literature about the required coordination mechanisms to enable the implementation of JIT arrival in the context of port calls is limited. As little is known about the phenomenon, the choice of the case approach is justified. Moreover, case studies have the capability of explaining complex connections between phenomena and their context (Dubios and Gadde, 2002). For this thesis, the case approach is suitable to understand the interaction between the studied coordination mechanisms, and how these mechanisms interact for the implementation of JIT arrival in the context of port calls.

**Case selection and description**

Purposeful case selection entails that cases can be selected from the perspective of the research purpose (Dubois and Araujo, 2007). Purposeful case sampling is used in this research. As part of the purpose is related to the implementation of JIT arrival, case-selection was constrained to ports that are working with the JIT arrival phenomenon. In the Swedish context, the Port of Gävle (PoG) is one of the first Swedish public ports that implemented a PBP and a PCS to coordinate actors in port calls. PoG is located on the Swedish east coast, about 200 kilometers north of Stockholm. The annual number of port calls is approximated
Research Methodology

to 1,000, from the container and the bulk sector. For container transportation, PoG is considered as the largest container port on the Swedish east coast. For bulk transportation, various bulk products for the wood, steel, and aviation industries are handled in the port. For example, large quantities of the liquid products such as jet fuel that are supplied to aviation companies in Stockholm’s airport Arlanda is distributed from PoG.

The PBP and the PCS are both relevant mechanisms to coordinate the implementation of JIT arrival in port calls. For this reason, the PoG was selected due to its relevance to the purpose and RQs of the thesis. These mechanisms also motivated the choice of a single case approach. Most ports still coordinate port calls based on FCFS berth allocation policy (Cho et al., 2022). Hence, an implemented PBP represents an unusual and extreme case. Here, it is important to mention that the PBP is implemented for vessels that are specifically calling the energy-product berth only, and not all PoG’s berths. As the literature review revealed, PCS designed specifically to coordinate actors in port calls is under-explored. The PCS studies in the literature focus on potential benefits that can be realized by utilizing PCS. However, seldom is the focus of PCS utilization to realize its potential benefits while focusing on a specific business process like port calls. Empirical studies connecting PCS benefits with specific processes are limited. This makes the single case approach reasonable to choose, as it allows the researcher to capture detailed insights about how the PCS is connected to the benefits of the implementation of JIT (Barratt et al., 2011; Voss et al., 2002).

Data collection methods

A key feature of case studies is offering the opportunity to adopt and match different data collection methods, allowing for better understanding of the studied phenomena. The multiple data collection methods are important in the field of management, e.g., specific managerial process that are difficult to investigate, which is the case in this thesis as port calls are managerial process (Runfola et al., 2017). Examples of these methods are interviews, observations, written reports, published sources, artefacts, and visual methods (Barratt et al., 2011). The data collection methods and analysis for the two papers included in this study are presented separately below.

The empirical data for this study was collected through interviews, observations, and document reviews. In total, 24 semi-structured interviews were conducted during the study period. These interviews were conducted with the following actors: managers representing the port authority, tug-boat operators and VTS, managers from shipping and chartering companies, pilots, agents, and terminal operators. The interview questions are provided in Appendix 2.

13 observations (participatory and non-participatory) were conducted. Three of these were in workshops initiated by PoG. Two were related to risk identification and mitigation workshops, while the third is when PoG presented the PBP to the port call actors. The actors that participated in these workshops were agents, shipping and chartering companies, pilots, port authority staff, and terminal operators.
operators. Eight follow-up meetings between the port authority, and the shipping and chartering company related to the implementation of the PBP were also observed. All these observations were participatory. For the non-participatory, two presentations about the PCS and the PBP held by the managers of PoG to other actors were observed.

10 documents were reviewed to collect data from. These documents included an implementation plan of the PBP. Two reports about risk identification and mitigation associated with the PBP. An instruction document to guide users about how they can book the berths and conduct other formalities associated with port calls. A document which summarized the feedback and the perception of different actors that participated in a large workshop in which the PBP was presented to them. This document included for example different actors’ preferences about when at the latest they should be able to book berth. One report in which the potential of implementing JIT in PoG is modelled based on historical data. Three presentations related to the policy, including its aim and purpose. Lastly, one document describing the PCS and the information that is shared through it is also included.

In Table 3 below, a summary of the collected data between 2020-2022 is provided.

<table>
<thead>
<tr>
<th>Data collection method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews</td>
<td>24 semi-structured interviews were conducted with actors representing the port, shipping companies, chartering companies, terminal operators, agents, and pilots.</td>
</tr>
<tr>
<td>Observations</td>
<td>13 participatory and non-participatory observations were conducted. The observations were conducted during large workshops, internal meetings, and presentations conducted by the PoG.</td>
</tr>
<tr>
<td>Document reviews</td>
<td>10 documents related to the pre-booking policy and the PCS were reviewed.</td>
</tr>
</tbody>
</table>

3.4 Research quality

The trustworthiness of this thesis is discussed here. For the qualitative study, the concepts of credibility, transferability, dependability, and confirmability were used to facilitate trustworthiness (Halldórsson and Aastrup, 2003). These concepts were recommended to use for qualitative methods in logistics research, which is the case for study-2 in the thesis.
Credibility refers to viewing the reality as a subjective construct and is about the fit between the respondents' perception of reality, and how the researcher perceives this reality (Halldórsson and Aastrup, 2003). The transcripts and notes from the interviews contributed to the credibility of the research conducted in this thesis. They allowed the researcher to identify instances where the interview data is not fully understood to allow the researcher to build a perception of the respondents' reality. These instances were later clarified through phone calls or during participatory observations, which allowed the researcher to ask follow-up questions to the respondents to clarify their answers. The use of multiple data collection methods also contributed to the credibility. Triangulation refers to using multiple data sources to confirm the data or find rival explanations in the data. The case study data was triangulated by using data from interviews, observations, and documents (Barratt et al., 2011). Confirmed data contribute to matching the researcher’s perception of reality of the respondents, whereas rival explanations allow the researcher to ask follow-up questions to the respondents to clarify their answers.

Transferability describes the applicability of findings beyond the specific context examined in the thesis. In this thesis, the aim is to reach contextual generalizability, which is ensured through rich descriptions and rich data about the case study context. This allows the reader to understand to what extent the case was representative with regards to similar organizations (Halldórsson and Aastrup, 2003; Gibbert and Ruigrok, 2010). The characteristics of the PoG, together with the actor constellation, and the coordination mechanisms used in the port call process are described. Rationales behind the case selection are also important for the transferability (Gibbert and Ruigrok, 2010). The PoG was selected due to two reasons that are aligned with the purpose of this thesis. These reasons are the development of PCS for information sharing within port calls, and the implementation of pre-booking berth allocation policy that allow for the possibility to implement JIT arrival in port calls. Providing this information can potentially improve the transferability of the findings to other ports and maritime actors. During the research, meetings with the Port of Gothenburg were held. The meetings revealed that the Port of Gothenburg had a similar view regarding the importance of PCS to implement berth allocation policies that allow for JIT arrival. This is important for the relevance of the study, as the Port of Gothenburg is the largest port in Sweden. The analytical framework about information deficiency and information utilization, which is constructed by theories, provide a conceptual argument to shape the readers thinking (Siggelkow, 2007). This framework is transferable and can be used by actors in maritime transportation.

Dependability refers to the possibility of replicating the results and its findings. One mean to ensure dependability is through the traceability of methodological decisions. The traceability in this thesis is ensured by documenting the research process and the data collection methods. The interview guide is attached in Appendix 2, and the selected actors for interviews are described. The content of the reviewed documents, and the type of observations conducted are also
described. The reader is also informed about the data analysis approaches used to analyze the case study data. A case study database was created to retain the notes, transcripts, and all the reviewed documents. These aspects are important to ensure research dependability.

Confirmability refers to how the data is interpreted by the researcher to maintain objectivity. This was ensured by comparing the data and the findings with the literature. Paper I was presented to the SMA, paper II was presented in two conferences, whereas paper III was frequently discussed with representative from the PoG and the Port of Gothenburg. These discussions help to reduce the biases of the author and maintain the objectivity of the research.

Regarding the quantitative study, the use of AIS data to analyze vessel movements and to estimate fuel consumption and emissions is well established in the literature. The combination of using the AIS data with port call statistics adds to the quality of the study. This is because doing so removes vessels that have anchored but not proceeded to Swedish ports from the analysis, which is important to obtain accurate estimates. Experts from the SMA were consulted to address reasonable operational assumptions about the timing when speed reduction can commence. This is relevant to ensure that the used assumption do not overestimate the potential. The vessel-specific data is obtained from IHS Markit which is considered as a reliable data source.
4. SUMMARY OF APPENDED PAPERS

In this chapter, a summary for each appended paper and its contribution to the thesis is provided.

Paper I: Port call optimization and CO₂-emissions savings – Estimating feasible potential in tramp shipping

Speed reduction measures hold a promising potential to reduce emissions from maritime transportation. Virtual Arrival (VA), which is an agreement to reduce the sailing speed of vessels given a known delay at the destination port, is considered a win-win for shipping companies, charterers, and operators in the port. However, in recent studies, the potential of VA for fuel and CO₂ emissions savings is questioned and discussed as overestimated. This overestimation is due to technical and operational assumptions used in the previous studies modelling the potential of speed reduction measures like VA. The cubic law is commonly used in the modelling of the effect of speed reduction measures in the previous studies. However, it is only valid for vessels sailing close to the design speed. Several studies rely on the cubic law to estimate the potential of speed reduction, assuming that the cubic law holds true regardless of the operational sailing speed of sampled vessels. As a result, these studies risk to systematically overestimate the effect of speed reduction measures like VA. In addition, the detection of delays associated with VA is in some studies assumed to be captured during an early stage of the voyage, making speed reduction viable for almost the entire voyage. Though, in practice, this is highly unlikely. Thus, it is important to consider more practical and realistic scenarios when the speed reduction commence during the voyage. This would enable more accurate estimates of speed reduction potential in terms of fuel and CO₂ emission savings.

The purpose of this paper is to estimate the potential of VA for fuel efficiency and CO₂ emissions savings while considering technical and operational voyage characteristics simultaneously. Two modelling approaches were used to estimate the potential of VA for the tramp segment calling Swedish ports during 2019. In the first approach, the fuel and emissions savings potential of VA are estimated based on the cubic law. Whereas in the second approach, the potential is estimated based on speed-dependent elasticities. The speed-dependent elasticities mean that the speed-power relationship varies based on the actual sailing speed of the vessels. In both approaches, three sets of data are used. The AIS data is used to identify instances of delays at anchorage, and the length of these delays. Port call statistics are used to verify that the anchorage instances

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2 Virtual Arrival in this paper was used as a synonym for Just-in-Time arrival.
in the sampled voyages proceeded to call Swedish ports. IHS Markit data about vessel-specifications, e.g., vessel’s design speed and fuel type, is used to calculate fuel consumption.

The findings of the study revealed that among the 19 000 vessels that called Swedish ports in 2019, 3023 vessels experienced delays at anchorage. The median delay at anchorage for each vessel is around 13 h. The average sailing speed of the sampled vessels 12 h before arriving to the port is 10.33 knot, which is lower compared to the average design speed of sampled vessels, i.e., 13 knot. The estimated potential of fuel and CO₂ emissions savings differs significantly based on which modelling approach is used. As the actual sailing speeds of the sampled vessels are lower compared to the design speed, the speed-dependent elasticity approach yielded significantly lower potential effect regarding fuel and emissions savings compared to the cubic law. The time at which speed reduction can commence also affects the fuel and CO₂ emissions savings potential.

The findings of the study revealed that for the 15% (the 3023 vessels) of the sampled vessels with delays at anchorage, only 60% would benefit of VA if the speed-dependent approach is used. In Table 4, the findings are summarized. The fuel and CO₂ emissions savings are presented in tonnes for the vessels that would benefit of JIT arrival, and the share of fuel savings in relation to fuel consumption during the entire voyage is also presented. The findings are presented for varying technical and operational assumptions. The technical assumptions mean if the cubic law or speed-dependent elasticities are used. Whereas the operational assumptions refer to the time at which speed reduction commence.

Table 4. Total fuel, CO₂, and share of fuel savings for entire voyage under different technical and operational measures.

<table>
<thead>
<tr>
<th>Technical</th>
<th>Operational</th>
<th>12 h speed reduction</th>
<th>8 h speed reduction</th>
<th>4 h speed reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel savings in tonnes</td>
<td>Cubic law</td>
<td>6940</td>
<td>4564</td>
<td>2363</td>
</tr>
<tr>
<td></td>
<td>Speed dependent elasticity</td>
<td>1962</td>
<td>1312</td>
<td>666</td>
</tr>
<tr>
<td>CO₂ savings in tonnes</td>
<td>Cubic law</td>
<td>21505</td>
<td>14143</td>
<td>7324</td>
</tr>
<tr>
<td></td>
<td>Speed dependent elasticity</td>
<td>6076</td>
<td>4061</td>
<td>2052</td>
</tr>
<tr>
<td></td>
<td>Cubic law</td>
<td>15.31%</td>
<td>9.89%</td>
<td>5.12%</td>
</tr>
</tbody>
</table>

Note that the technical assumptions here are the cubic law and the speed-dependent elasticities. The rows where “savings” are mentioned is not related to the technical assumptions but underline the type of savings.
### Summary of appended papers

| Share of fuel savings for entire voyage | Speed dependent elasticity | 4.68% | 3.27% | 1.65% |

**Contribution to thesis:**
The contribution of the study is modelling more accurate estimates of the fuel and CO$_2$ emissions savings obtained by the implementation of JIT arrival. The study underlines that in those market circumstances when low sailing speed of vessels are deployed compared to their design speed, the fuel and CO$_2$ emissions savings of JIT arrival is significantly lower compared to what is reported previously. The findings have an important policy implication regarding the potential of JIT arrival as a measure to reduce CO$_2$ emissions and achieve environmental targets.

**Paper II: Facilitating conditions for PCS-enabled information sharing to coordinate port calls: individual, technological, and organizational factors**

The port call process entails the planning, coordination, and execution of all the services required by vessels to enter the port, access the berth, and depart from the port. Due to the involvement of several actors providing interdependent services, efficient planning and coordination among the actors is necessary to enable a more efficient port call process. However, empirical evidence on coordination problems e.g., delays, due to pilotage, towage, or insufficient coordination of arriving vessels, urges the need for mechanisms to better coordinate the process. Port Community Systems (PCS) hold a promising potential as a coordination mechanism to coordinate the port call process. However, the utilization of PCS to coordinate port calls is influenced by a variety of individual, technological, and organizational (ITO) factors. Understanding the influence of these factors is important to utilize PCS to coordinate the port call process efficiently and prevent failed PCS projects as the case was in the smartPORT project in Hamburg.

The purpose of this paper was to explore how the ITO factors influence the utilization of PCS to coordinate the port call process. A single case study approach based on 21 interviews, document review, observations, and a literature review was conducted. The Port of Gävle (PoG) was chosen as a case because of the implementation of a PCS to coordinate port calls by information sharing. The focus of the study was the tanker segment, and the studied actor constellation involved the port authority, shipping companies, oil and gas companies, pilots, terminal operators, and load and discharge masters. The analysis aimed at first describing the information that is shared through the PCS. This was followed by addressing the information needs from the
perspective of different port call actors to address whether the PCS satisfy their needs to coordinate port calls or not. In those circumstances where the actors’ needs and demands on information are not met by the PCS, information deficiencies occur. These deficiencies limit the actors’ utilization of the PCS to coordinate port calls. The root cause of these deficiencies is discussed from the perspective of ITO factors.

The findings reveal that despite the availability of the PCS among the studied actor constellation, those actors still relied on using a combination of modalities to access and share information. Especially manual modalities such as e-mails and telephones were used. This was because many actors still suffered of information deficiencies. The influence of the ITO factors to cause information deficiency, and thereby limit the utilization of the PCS was evident in the study. For example, pilots and mooring operators elaborated on their needs of the Estimated Time of Completion (ETC) of cargo operations, but oil and gas company prefer to keep this information in-house, instead of making it publicly available in the PCS. Another example is that mooring operators lack the access to information about the agents representing the arriving vessels. Even though the PCS is connected to the Maritime Single Window (MSW) where agent-information is available, agent-information remains unavailable in the PCS.

The identified deficiencies notwithstanding, the PCS has a potential to improve information sharing among the actors. Improved information sharing is important for the individual actors’ planning process. Thus, by identifying and overcoming the deficiencies, the planning process of individual actors’ services can be improved. Moreover, the PCS and the improved planning processes of actors enable the transition from FCFS to PBP. In turn, the PBP is considered as an important coordination mechanism to coordinate actors to implement JIT arrival in ports.

**Contribution to thesis:**
The contribution of this paper is identifying information deficiencies from different actors’ perspective in the port call process. Moreover, the root causes of these information deficiencies were discussed from an ITO factor perspective. These deficiencies negatively impact the utilization of the PCS, and drive actors to rely on manual modalities to share or access information. As the implementation of PBP depends on efficient utilizations of PCS, it is necessary to overcome the identified information deficiencies for successful implementation of JIT arrival.
Paper III: The Implementation of berth allocation policies that align with IMO’s JIT strategy: Lessons from the Port of Gävle

FCFS remains the predominant berth allocation policy used to coordinate the arrival of vessels in ports. Although, fair and robust, FCFS has received criticism lately. It is discussed that FCFS drives speed competition among arriving vessels, which is inefficient in relation to fuel consumption and vessel-to-air emissions. Evidence from the literature revealed that replacing FCFS with alternative berth allocation policies such as pre-booking berth policy, or vessel prioritization policy can improve overall efficiency of the port call process. For example, the PBP would enable the implementation of JIT arrival, which is considered as a promising measure for emissions reduction. However, most of the literature takes a modelling perspective regarding the potential of these policies, and there is little that is documented about the implementation process of berth allocation policies in real-world settings. In this paper, the focus is on the PBP of berths. Understanding the implementation process of this policy is crucial to realize the potential of JIT arrival in ports calls.

The purpose of this paper is to explore the implementation process of the PBP from the perspective of the port authority. A longitudinal single case study approach was used at the PoG. The data was collected during 2020-2022 using documents review, participatory observations, and interviews.

The findings revealed that the implementation process led by PoG included six main activities: 1) Documentation and evaluation of current procedures in the port call process, 2) Risk identification and mitigation, 3) Development of PCS to coordinate the planning processes of different actors, which is important for the implementation of JIT arrival, 4) Modifications of the byelaws and the operating rules of the port, and 5) training programs and instructions for users (shipping companies and agents) about the rules of the policy and how the PCS can be used to book berths. 6) identification and measurement of performance indicators related to the PBP. Each activity is described below.

The documentation and evaluation of current activities in the port call process was an important first step. The intention of PoG was to become more familiarized with the actors that are involved in port calls, and the different activities for which these actors are responsible. A process map of the physical structure of the port call process was created. Beside the map for the physical structure, information sharing was also mapped, including the different information systems used in the port call process. Analysis based on historical data was conducted to quantify delays in the port as part of this activity. This analysis allowed PoG to model the potential of fuel and emissions savings of JIT arrival. This is important as the intention of the PBP was to enable the implementation of JIT arrival in port calls at the PoG.
Two risk identification and mitigation workshops were held during the implementation process. The purpose of these workshops is to identify risks associated with the implementation of the PBP. Mitigation strategies for the identified risks were also discussed and documented in two reports. The actors that participated in these workshops represented the PoG, shipping companies, oil and gas companies, terminal-operators and managers, agents, and surveyors as well as load/discharge masters. In total, four categories of risks emerged from the workshops. These risks were: information risks, technical risks, operational risks, and commercial risks.

Prior to the implementation of the PBP, the PoG developed a PCS to streamline the information sharing among the actors in the port call process. However, to implement the policy, the PCS was upgraded with an additional function. The purpose of this function was to coordinate the specific information and planning process of the actors that are relevant for the implementation of JIT arrival.

The PoG had to conduct regulatory modifications to enable the transition from FCFS to the PBP. The first modification was in the port byelaw, where the request to book berth before arrival became mandatory for all vessels calling the port. Beside the byelaw adjustment, the operating rules of the port was modified. An instruction document, describing the “hows” of requesting time-windows for the berths was attached to the operating rules on the port’s webpage.

The PoG provided training programs to users (e.g., agents, shipping companies) calling the port. The training programs aimed at clarifying the responsibilities and commitment required by actors to share information and coordinate the different planning processes to enable the implementation of JIT arrival. During these programs, the usability of the PCS to request berths and share information was also discussed.

The final activity included the identification of relevant performance indicators that are related to the PBP. Identifying these indicators is important to measure the potential benefits that are obtained by replacing FCFS with the PBP. The data sources that are relevant to measure these indicators were also identified and discussed. The discussion was mostly related to if one indicator can be measured by different data sources, and which source has the data with higher quality.

**Contribution to thesis:**
The previous literature has addressed the importance of PBP to enable the implementation of JIT arrival. However, little is known about how the implementation process of the PBP is conducted in an empirical setting. The contribution of the study lies in describing and analyzing the activities and challenges associated with the implementation process of PBP. Understanding these aspects is crucial to port authorities aiming to replace FCFS with berth allocation policies to support the implementation of JIT arrival for calling vessels.
5. FINDINGS

In this chapter, the research questions of this thesis are answered based on the findings from the appended papers.

RQ-1: What is the potential of Just-in-Time arrival in the port call process?

The identified potentials associated with the implementation of JIT arrival were: Improved fuel efficiency for vessels, improved resource planning and utilization, and increased port competitiveness. The different potentials are elaborated below.

The improved fuel efficiency potential associated with JIT arrival is achieved as vessels reduce the sailing speed during the voyage to avoid known delays at the called port. This potential was estimated in Paper I for all types of tramp vessels (tankers, dry-bulkers, and general-cargo) that called Swedish ports during 2019. The findings from Paper I indicate that among the sampled vessels (approximately 19,000 tramp vessels called Swedish ports in 2019), 15% (approximately 3,000 vessels) had instances of delays at anchorage where JIT arrival could possibly be implemented. The median delay for those vessels at anchorage was around 13 h. Out of the sampled vessels, with delayed port calls, 60% would benefit from the fuel efficiency potential of JIT arrival. For those vessels, the potential of JIT arrival ranges from 1-5% in fuel savings per voyage. The range between 1-5% depends on whether the speed reduction to avoid the delays commences four or 12 h before arrival to the port. The study in Paper I which estimated the fuel efficiency potential shows that the number of vessels that would benefit from JIT arrival is smaller compared to what is reported in the literature. The findings also reveal that the fuel efficiency potential of JIT arrival is smaller compared to potential estimates found in the literature (Jia et al., 2017; PortXchange, 2020, Sung et al., 2022). The smaller fuel efficiency potential of JIT arrival is in line with recent studies addressing the risks of overestimating the potential of JIT arrival to reduce emissions (Adland et al., 2020).

The small fuel efficiency potential of JIT arrival is explained by the slow sailing speed that was observed in the sampled vessels in Paper I. The average observed sailing speed of the sampled vessels was approximately 10 knots. Whereas the average design speed of those vessels was approximately 13 knots. This indicates that the operational sailing speed of the sampled vessels was significantly lower than their design speed during 2019. The validity of the commonly used cubic law to estimate the fuel efficiency potential of JIT arrival only holds true when the vessels are sailing close to their design speed (Adland et al., 2020; Norstad...
et al., 2011). However, this is not the case for the sampled vessels. As a result, the fuel and emissions savings potential were estimated based on speed-dependent approach. In this approach, the influence of operational sailing speed of the sampled vessels regarding the speed-power relation is considered. The deviation from the design speed in the sampled voyages motivates the use of the speed-dependent approach. When the speed-dependent approach is used, the fuel and emission savings potential of JIT arrival is significantly smaller than estimates based on the cubic law (See Table 4 in chapter 4). Using the speed-dependent approach is more appropriate, since the shipping segments sails at slower speeds than the design speed of the vessels. The use of the speed-dependent approach leads potentially to more reliable estimates of the fuel efficiency potential and reduces the risks of overestimating the potential of JIT arrival in terms of fuel and emissions savings (Adland et al., 2020; Berthelsen and Nielsen, 2021).

While the findings from Paper I reveal that the fuel efficiency potential of JIT arrival is smaller compared to earlier studies, the same potential was the main motive for all actors behind the implementation of the PBP to enable JIT arrival in port calls studied in Paper II and III. For PoG, the incentive to implement the PBP that enables JIT arrival contributes to their emission abatement strategy. This contribution of emission reduction is achieved within the port area, as vessels are more likely to avoid delays at anchorage due to JIT arrival. Moreover, the emissions that are saved due to speed reduction during voyage were also important, even if they are not directly emitted within the port area. Similarly, the manager of a shipping company emphasized that his company would make significant savings in fuel and emissions by the speed reduction enabled by JIT arrival. This was the key driver for the shipping company to participate closely in the implementation process of the PBP which would enable JIT arrival. Here, it is important to distinguish between the “system-level”, i.e., the findings from Paper I, and “actor-level”. The small fuel efficiency potential found in Paper I does not necessarily mean that individual actors like shipping companies and charterers would not be able to obtain large savings by implementing JIT arrival.

Improved resource planning and utilization in the port call process was another potential benefit associated with the implementation of JIT arrival as evident from the results of Paper II and Paper III. Several actors, both at the sea-side and the land-side (e.g., terminal operators, agents, pilots, and load/discharge masters), underlined that their resource planning and utilization to manage the port call process can be improved by the implementation of JIT arrival. From the sea-side perspective, the shipping company and the charterer underlined that voyage planning and execution can potentially improve due to JIT arrival (and the PBP as berths can be booked). One of the key enablers of JIT arrival is the possibility to reserve time-windows for specified berths. Managers from the shipping company and the chartering company emphasized that berth reservation can potentially improve decision-making for voyage planning and execution. Paper III shows that information sharing about berth reservation provide the flexibility in adjusting the speed during voyage execution. These
Findings

adjustments are based on the reserved time-windows of the berth. This flexibility allows for improved speed decisions that are efficient for the voyage execution, enabling to realize the fuel efficiency potential of JIT arrival.

In Paper II can be seen that the actors on the land-side, terminal managers, agents, and other actors on land provided similar statements on how the resource planning and utilization can improve with the help of JIT arrival. The implementation of JIT arrival relies on early information sharing about vessel arrival, including the ETA and the ETD of the berth reservation and vessel-specific information. Early information sharing increases the planning-horizon for actors on land, which will help them to better plan their resources. For example, as mooring-operators will potentially receive earlier information about vessels ETA and ETD, they can plan for the mooring and unmooring with less uncertainty. Early information sharing allows them to allocate the required number of resources needed within a limited future time frame, which potentially improve the resource utilization.

Another valuable potential related to resource planning and utilization enabled by JIT arrival was the planning reliability. In this context, the planning reliability, from the perspective of sea-side actors, refers to reducing the risk of the desired berth being occupied by another vessel upon arrival. It also means that actors at the land-side can plan based on known vessel service requirements. This is not always the case as in FCFS, actors do not always know which vessel will arrive first if several vessels are calling the port at the same time. As a result, actors may create slack resources in FCFS to manage the uncertainty of not knowing which vessels will arrive first. Terminal managers of oil and gas companies valued the improved planning reliability associated with berth reservation in JIT arrival. According to the managers, the planning reliability associated with the PBP would improve the working environment, reduce conflicts in operations planning at land-side, and reduce unnecessary delays caused by occupied berth upon arrival. The importance of planning reliability is derived from the fact that in the PoG, there are eight oil and gas terminals which “compete” for the same energy-product berth. Although, PoG is not a heavily trafficked port, one terminal manager mentioned how “their vessel” arrived four minutes before another vessel to the berth, prior to the implementation of the PBP. This underlines the importance of berth-reservation for planning reliability and to avoid risks of delays and other inefficiencies. One terminal manager elaborated on how he “bragged” internally within his company to other managers operating in different ports about the PBP in PoG.

In Paper III, managers from the PoG frequently elaborated on how the PBP is considered as a measure to improve the port’s competitiveness. PoG managers anticipated the improved competitiveness in terms of potential to attract more traffic to the port. This can be connected to the literature on port competitiveness and indicators, e.g., port costs and operational efficiency (Parola et al., 2017). The availability of the PBP can potentially reduce port costs for some actors. In this context, the shipping companies and charterers bear the
costs caused by congestion or lengthy port stays during port calls. These costs can potentially be reduced by the PBP. This is because the aim in JIT arrival is to avoid delays. As the PBP improves resource planning and utilization, this can improve the operational efficiency of actors’ different processes. These aspects, which can potentially improve the service quality of the port call process can lead shipping companies and charterers to ship via the PoG.

Another relevant aspect related to port competitiveness is the relationship between the PBP enabling JIT arrival, and the Carbon Intensity Indicator (CII). The CII is a mandatory emissions reduction measure adopted recently by the IMO (IMO, 2021). The CII measures the carbon emission per unit transport work for each vessel over 5 000 Gross Tonnage (GT) (IMO, 2021). Comparing the CII value of each vessel to a reference CII value determined by the IMO leads to a CII-rating for each vessel. The CII-rating ranges from A-to-D, where A, B, and C entails compliance, whereas D and E require corrective actions by shipping companies (Wang et al., 2021). The operations manager from the oil and gas company underlined and credited the PoG and their PBP as important to comply with the mandatory demands of the CII. The compliance is obtained because the PBP facilitates the implementation of JIT arrival. In connection to the literature, JIT arrival has been discussed as a measure to comply with the CII for vessels rated between E-D (Schroer et al., 2022). Thus, ports can improve their competitiveness by providing arrival policies like the PBP to facilitate the implementation of JIT arrival. The relationship between the PBP, JIT arrival, and the CII should not be underestimated with regards to port competitiveness. Especially as the requirement on the CII will be difficult to comply with as time goes, i.e., the rate is planned to be reduced 2% annually by the IMO (Wang et al., 2021).

The potential of JIT arrival can be summarized as:

- Save fuel and emissions during the voyage execution and within the port area.
- Decrease the total turnaround time of port call by avoiding delays.
- Improve the resource planning and utilization of actors both at the sea-side and the land-side.
- Increase the competitiveness of ports where the implementation of JIT arrival is possible.

**RQ-2 How can port authorities facilitate the implementation of Just-in-Time arrival in the port call process?**

Coordination is necessary among actors to enable them to realize the potential of implementing JIT arrival. Furthermore, one step to implement JIT arrival is the transition from FCFS to PBP. Arrival policies are normally “controlled” by
port authorities. Thus, the used arrival policies impact the coordination among actors. In the first part of the answer, the interaction between the PBP, PCS, and planning as coordination mechanisms to enable actors to realize the potential of JIT arrival is presented. In the second part of the answer, the implementation process of the PBP is presented.

Coordination of actors in the port call process
The coordination process, including the interaction between the different mechanisms to coordinate JIT arrival is discussed here. Three coordination mechanisms were needed to enable the implementation of JIT arrival and possibly realizing its potential benefits. These were the PBP, information sharing (PCS), and the planning processes of actors at sea-side and land-side. The interactions between these mechanisms are as follows. First, the PCS was considered as a prerequisite to implement the PBP and coordinate actors within the same information sharing modality. Later, when the PBP was implemented, rules specified by the PoG to improve information sharing and utilization of the PCS among actors in the port call process were established. In turn, these rules on information sharing can potentially coordinate the planning between the sea-side (voyage execution), and the land-side (port call services). Coordinated plans between the sea-side and the land-side enables actors in realizing the potential of JIT arrival.

In Paper III it was seen that the PBP specified new rules about information sharing in the PCS that is important to coordinate actors. These rules include the content, frequency, modality, and direction of information to enable the coordination of actors. The coordination among actors starts when vessel representatives requesting berth-reservation for a specific time-window. This request must include the following information content: Contact information of representatives (e-mails), the IMO-number of the vessel that will use the berth, the ETA to the outer port area, the time-window of the berth reservation, and the laytime of the vessel (time at berth for cargo-operation). This request is shared by vessel representatives with the PoG through the PCS. When the berth-reservation request is shared, the VTS replies with a Recommended Time of Arrival (RTA). The VTS (And the PCS) either accept the requested time-window desired by the vessel’s representative. Or, if the requested time-window is already occupied, a new, valid RTA is suggested to the vessel’s representative. The RTA (directly accept or new suggestion) is shared by e-mail with the vessel representatives. When vessel representatives receive the RTA information via e-mail, they must confirm the time, which is done through a link that is available in the e-mail. At the earliest, the confirmation of berth reservation can be made 36 h before the arrival as set by the new port rules. When this information is confirmed by vessel representatives, the requested time-window is formally allocated to the vessel. The times for berth-reservations are available in the berth planning tool in the PCS, the function that was developed in the PCS to enable the coordination of actors in the PBP. Once the vessel arrives to the berth, and cargo-operation commences, the load/discharge master, together with the agents and the vessel crew, are responsible to update the ETD. This update is
conducted manually in the PCS and is necessary to make the RTA for the next arriving vessel more accurate and based on the actual departure from the current vessel occupying the berth. In Figure 5, an illustration of the information sharing procedure is presented.

![Figure 5. Procedure for information sharing to coordinate actors in the port call process (Paper III)](image)

The information sharing procedure facilitated by the rules of the PBP and the utilization PCS improves the quality of information sharing among actors. In turn, improved quality of information streamlines the utilization of information to plan efficiently for port call services. The streamlined utilization of information allows the planning of land-side and sea-side actors to be coordinated to implement JIT arrival. It potentially ensures that the speed-decisions can be made based on the availability of the berth, and the actors at the land-side plan their resource based on the specific requirements of the vessel that has reserved the berth. The coordinated plans between the sea-side and land-side also leads to the improved resource planning and utilization potential mentioned in RQ-1.

Evidence to strengthen the argument about information quality, information utilization, and their effect on resource planning and utilization can be derived by combining the findings from Paper II and Paper III. Several information deficiencies experienced by actors were revealed in Paper II. For example, actors relied on an ad-hoc and inconsistent approach based on several information modalities to access (and share) the information they needed. Some actors also suffered from incompleteness of information, i.e., the necessary information content for coordination purposes was lacking. The information deficiencies found in Paper II also explained the “seek it by myself” phenomenon. The “seek it by myself” meant that the majority of actors had an information seeking approach based mainly on manual modalities as this enable them to assess the trustworthiness of information.
Some information deficiencies experienced by actors in Paper II are solved due to the development of new information sharing procedure. For example, many actors are more certain about information related to berth availability as berths can be reserved now. Unreliable updates of information were common information deficiency in Paper II. The training programs provided for actors increase their awareness about the importance of timely updates of information, which reduce the risk for information deficiencies to occur. These programs also clarified the required commitment from actors to efficiently utilize the PCS to coordinate the planning processes and realize the potential benefits of JIT arrival. The information sharing procedure promotes early information sharing about vessel arrival, including information about the ETA and ETD, RTA, berth availability, and laytime. Early information sharing increases the planning-horizon of actors to plan the service orders, such as pilotage and sludge-orders, more efficiently. This can also be seen in the fuel efficiency potential in Paper I, the longer the planning-horizon is for the port call, the more fuel and emissions can be saved.

The implementation of the pre-booking policy
Port authorities can support the implementation of JIT arrival by replacing the berth allocation policy in ports from FCFS to PBP. As berth can be reserved based on time-windows specified by shipping companies and charterers, these companies can adjust the sailing speed of vessels based on the availability of berths. The importance of the PBP to enable the implementation of JIT arrival is emphasized in literature (Gibbs et al., 2014; Kontovas and Psaraftis, 2011).

In Paper III the implementation process was initiated by a shipping company and a chartering company who requested the move towards the PBP. These companies have frequent vessels calling the PoG and underlined the value of implementing JIT arrival to the port call process. They emphasized on the benefits of JIT arrival, and how they already use JIT arrival when calling the private terminals/refinery to load products owned by the charterer. The PoG considered the request and identified their own incentives to implement the policy.

The implementation process of the PBP was divided into three phases: planning phase, execution phase, and performance measurement phase. The planning phase included three activities. First, a project consortium to implement the policy was established. The consortium consists of the PoG, the shipping company and the oil and gas company who proposed the initiative, and the Swedish National Road and Transport Research Institute. Second, an implementation-plan, which included the necessary activities to implement and the policy and allow the actors to be coordinated to implement JIT arrival was created. This plan also included a timeline over when and who is responsible to conduct these activities. Third, before proceeding to the execution phase, legal expertise was consulted. The PoG consulted lawyers to assess whether they are legally allowed to implement the PBP. The main task of the lawyers was to assess
the contracts that the PoG has with other actors. More specifically, the lawyers assessed how the current contracts that the PoG has with other actors may prohibit, or cause problems during the implementation of the policy. The main purpose of the legal consultant was to ensure that the transition to the new policy would reduce “contractual risks” that the PoG can be sued for due to the PBP.

The execution phase of the PBP included several activities. The first activity within this phase is an “as-is” analysis and documentation of the port call process at the PoG. During this activity, process map for the physical structure of the port call process, along with addressing the different actors providing these services in the port was created. The information sharing and quality between actors, and the different information systems that are utilized in the port call process were also mapped. The purpose of the “as is” activity was to familiarize the PoG with how the port call process is currently coordinated. Moreover, the PoG conducted analysis to estimate the fuel efficiency potential of implementing JIT arrival in their port calls. This was considered as an important step to acknowledge the expected benefit of implementing the policy as it’s an enabler of JIT arrival. Based on AIS and port call data at the PoG, and a set of assumptions, the potential savings for fuel and emissions associated with JIT arrival were estimated.

The second activity within the execution phase was risk identification and mitigation. The PoG invited several actors to participate in workshops to discuss the risks that are associated with the implementation of the policy. In total, two workshops were conducted, and the following risk-categories emerged from these workshops: operational risks, technical risks, information risks, and commercial risks, i.e., risks related to charterparties. Operational risks can for instance be vessels that arrive late to their time-window, and how this would affect the time-window of subsequent vessels. Another example is if vessels cancel their berth-reservation and what implication this would have on other vessels. Technical and information risks involve those risks that are related to “bugs” in the PCS, or that actors visiting the PoG might be unaware of the mandatory berth-reservation associated with the PBP. Commercial risks relate to how charter parties can limit the possibility to adjust the speed of the vessels. For example, if the RTA about the berth availability provided by the PoG indicates to the arriving vessel and its crew to reduce the sailing speed, the shipping companies cannot guarantee that the sailing speed will be adjusted accordingly. This was because some charterparties make the charterer as the decision-owner of speed-decisions during the voyage. In turn, charterers may instruct the vessel to sail at “utmost dispatch” to the port. Thus, contractual agreements can limit decision-making related to speed-adjustments. This risk, which is related to the principal-agent problem, is well documented in the literature (Fuentes and Adland, 2023; Rahmetulla and Smith, 2015).

The third activity within the execution phase involves the development of new functions in the PCS. Prior to the implementation of the policy, the PoG
developed a PCS to coordinate actors in the port call process. The PoG held a continuous development-program with a software company to develop new functions in the PCS that is aligned with the new policy. These functions were discussed internally and with external actors to address how they can contribute to coordinating the actors to implement JIT arrival. The main PCS function that was specifically developed for the policy was the “berth planning tool”. The berth planning tool is used to coordinate the actors through information sharing, e.g., viewing the availability of berths, booking time-windows for the desired berths, and updating of information such as ETD while berthed.

The fourth activity in the execution phase involved modifications to the port’s byelaws and operating rules. For instance, reserving a berth time-window before arrival is mandatory for all visiting vessels to the energy-product berth. Other rules are related to the allowed deviation in the Actual Time of Arrival (ATA) compared to the time-window of the berth-reservation, and a deadline for berth-reservation before arrival.

The fifth activity involved training programs provided to actors (mainly VTS staff and agents). These programs aim to increase the understanding of actors about the potential benefits and the reasons for why the policy is implemented. The programs were also used to clarify the new rules, commitment, and responsibilities of actors that come with the implementation of the policy. For example, what and when certain information must be shared in the PCS/berth planning tool. Beside the training programs, the PoG provided an instruction document related to the policy. This document is accessible on the webpage, and actors can use it as a guide for berth-reservations and other practicalities associated with the policy.

The third phase aimed at identifying relevant indicators to establish a performance measurement system. The performance measurement system is intended to measure and monitor the benefits associated with the PBP. This included for instance identifying how the sailing speed of visiting vessels have changed due to the PBP. Several indicators, and the required data to measure these indicators were identified to enable the measurement of the performance of the PBP/JIT arrival. During the writing of this thesis, a fully established performance measurement system for JIT arrival was not completed. However, some of the frequently discussed indicators during this phase are presented in Table 5:
Table 5. Indicators for performance measurement system of JIT.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel speed</td>
<td>The sailing speed of the arriving vessel 24 h before arrival to PoG. Relevant to assess environmental impact related to JIT arrival.</td>
</tr>
<tr>
<td>Maneuvering</td>
<td>The maneuvering time and speed when the vessel is within the port area approaching the berth. Relevant to assess the safety and the environmental impact related to JIT arrival.</td>
</tr>
<tr>
<td>Vessel time at anchorage</td>
<td>The time that vessel spend at the anchorage area of the PoG. Relevant to assess environmental and operational impacts.</td>
</tr>
<tr>
<td>Vessel time at berth</td>
<td>The time that vessel spend at the berth for cargo-operations.</td>
</tr>
<tr>
<td>New suggestions for the RTA</td>
<td>Refers to cases when the berth-reservation time-window requested by the vessel is occupied, and the PoG suggests a new RTA to the vessel. An indication for a “queue”.</td>
</tr>
<tr>
<td>Number of RTA to vessel</td>
<td>The number of RTA that vessels receive during the port call process from the PoG. A vessel can receive more than one depending on the operations at the port.</td>
</tr>
<tr>
<td>ETD updates during cargo-operations</td>
<td>The number of updates that are conducted to the ETD of the vessel while berthed. The reason for updating the ETD must also be documented.</td>
</tr>
</tbody>
</table>

Two important aspects emerged from studying the implementation process. These are the close interaction that PoG had with relevant actors, and the interconnection between different activities and phases during the implementation process. Many of the different activities were conducted with close interaction with other actors that are involved in the port call process at the PoG. For example, in the risk identification and mitigation workshops, a variety of actors, e.g., agents, charterers, shipping companies, and terminal operators were present. Likewise, during the introductory workshop to the PBP, and training programs that were provided, diverse types of actors were present. This diversity is internal, e.g., VTS staff from the PoG, but also external, including agents, pilots and load/discharge masters. The close interaction with actors was valuable to the PoG and the implementation process of the PBP in particular. This is because the participating actors provided insightful feedback and suggestions that aided the implementation process. These suggestions can at times be missed by the PoG, and the participating actors reminded the PoG of their importance to the PBP.

The close interaction between the PoG and the port call actors, and the new suggestions about the PBP also yielded some interconnection between the different activities. The interconnection here refers to how the outcome of one activity can serve an input for another. For instance, actors’ participation in the risk workshops contributed to identifying new risks that the PoG had not considered previously, e.g., how pilotage-availability can influence the coordination during JIT arrival. Another example is how the information deficiencies revealed from the as-is analysis was used to develop new functions.
Findings

in the PCS. The activity to estimate the fuel efficiency potential of JIT arrival was used to inform actors about the potential benefits and the reason for the transition to the PBP from FCFS. Thus, this pattern was observed on many occasions and highlights the importance of including actors in the implementation process where decisions about the PBP are made. In Figure 6, an illustration of the implementation process of the PBP at the PoG is presented.

To summarize the answer to RQ-2:

- Port authorities can facilitate the implementation of JIT arrival by making the use of the PCS and the PBP mandatory for port call actors. To coordinate the port call actors and enable them to realize the potential of JIT arrival, PCS, PBP and improved planning are critical coordination mechanisms for the successful implementation of JIT arrival. The PCS is a prerequisite to enable port authorities deploy PBP. In turn, the PBP supports information sharing as it sets rules specifying how information should be shared. Improved information sharing procedure aligns the planning processes of individual actors to realize the potential of JIT arrival.

- The implementation process of the PBP includes planning phase, implementation phase, and performance measurement phase. Each phase has separate activities such as “as-is” analysis, risk identification and mitigation, development of PCS, modified port byelaws and operating rules, and training programs for companies calling the port as well as internal staff. The Port authorities' interaction with the port call actors is important for streamlining the implementation process of arrival policies in ports.

Figure 6. The implementation process of the pre-booking policy.

![The implementation process of the pre-booking policy at PoG](image-url)
6. DISCUSSION AND CONCLUSION

The findings are discussed in this chapter, followed by presenting the contribution and conclusion of the research. Moreover, the directions for future research are also presented.

6.1 Discussion on the potential of Just-in-Time arrival in the port call process

Public authorities like the IMO and the EPA encourage the implementation of JIT arrival due to its fuel and emissions savings potential. Complementary to the encouragement of public authorities, some scientific and industrial publications have estimated the fuel efficiency potential of JIT arrival. The estimates in these publications highlight the promising energy efficiency potential of JIT arrival, and also encourage its implementation as a measure to reduce emissions (Jia et al., 2017; PortXchange, 2020; Sung et al., 2022).

Part of the findings from this thesis (Paper I) challenge the previous JIT potential publications and reveal that the fuel and emissions savings potential of JIT arrival may be smaller than expected. The analysis of the fuel efficiency potential in this thesis is based on a speed-dependent approach where the fuel consumption elasticity considers the operational sailing speed of the vessels. Using this approach yields significantly lower fuel efficiency potential for JIT arrival compared to previous estimates based on the cubic law. This is because studies using the cubic law assume that it holds true regardless of the operational sailing speed. In practice, however, the cubic law holds true only when vessels are sailing close to their design speed (Fagerholt et al., 2010; Adland et al., 2020; Berthelsen and Nielsen, 2021). While the findings from Paper I reveal smaller fuel efficiency potential of JIT arrival (compared to previous literature), actors in the studied case (Paper II and III) were driven by the fuel and emission savings of JIT arrival was the primarily driver to implement JIT arrival in the studied case. Hence, the outcome of the two studies in this thesis are in conflict regarding the fuel efficiency potential of JIT arrival. Though, here it is important to mention that the comparison (and the conflicting results) of the two studies is complicated because of the use of different methodologies. The first study is on a system-level, whereas the second is on a case-level.

Beside the small fuel efficiency potential of JIT arrival, the findings reveal that JIT arrival can in some circumstances lead to faster sailing speed of vessels, i.e., the “speed-up” phenomenon. The circumstances which allow this phenomenon to occur is when, for example, one vessel cancels its berth-reservation. This results in a new suggested RTA to the next vessel that is supposed to arrive after the vessel that canceled its reservation. The new RTA may require faster sailing
Discussion and conclusion

speed compared to the original RTA. On a voyage level, the faster sailing speed entails more emissions per voyage. However, as this occurs on a voyage level, it does not mean that the total emissions increase due to the speed-up phenomenon. How the total emissions are affected depends on how often this phenomenon occurs.

In the study behind of Paper II and Paper III discussions during workshops and meetings with shipping managers revealed that the market conditions (e.g., price of fuel, next planned voyage, type of charterparty) affect the decisions to sail faster or continue the voyage based on the original RTA. Shipping companies and charterers preferred to have flexibility in the decision-making when the circumstances resulting in “speed-up” phenomenon occur. The companies expressed clear preferences about their own speed-decisions. The flexibility in decision-making here refers to that if one vessel cancels its reservation, the shipping company and charterers should not obey speed instructions based on RTA from the port. Instead, they are the ones that want to decide if they will speed-up or continue based on the original RTA. The perception of shipping managers towards the “speed-up” phenomenon was that it is considerable and not completely infeasible. What also explain actors’ neutral position towards the “speed-up” phenomenon is that fuel efficiency is only rewarded in poor market conditions (Adland et al., 2017). The “speed-up” phenomenon also shows how berth allocation policies deployed by port authorities affect the speed-decisions of vessels, as discussed by Adland and Jia (2018).

The “speed-up” phenomenon is interesting and has not been discussed in the JIT arrival literature previously. What is interesting is how it differs from the traditional outlook on JIT arrival, i.e., a speed reduction measure to reduce emissions and fuel consumption (IMO, 2020; Schorer et al., 2022). While the “speed-up” in the context of JIT arrival has not been discussed previously, similar observations in the context of speed limits in maritime transportation were found in the literature. Cariou and Cheaitou (2011) found that shipping companies increase the speed of their vessels during the voyage to compensate for the time-loss caused by speed limit imposed in some EU waters.

The discussion above is related to one of the barriers that limit the implementation of JIT arrival, i.e., the validity of fuel and emissions savings of JIT arrival. The key message to both academics and practitioners in maritime transportation is the need for further research on the potential of JIT arrival to reduce emissions. Further research about the validity of the fuel and emissions savings potential of JIT arrival is important for policymakers to make informed decision about how appropriate JIT arrival is to reduce emissions and achieve environmental targets. For example, for the Swedish context, if the sailing speed of vessels keep deviating from the design speed, then policymakers may consider other measures than JIT arrival to reduce emissions. For other types of trade, where vessels sail close to the design speed continuously, JIT arrival is perhaps appropriate. While the findings emphasized on the influence of the sailing speed
on the potential of JIT arrival, other factors should be identified. These factors should also be considered in the estimates of the potential to ensure validity.

The planning and resource utilization potential facilitated by the implementation of JIT arrival identified in Paper II and Paper III were seen as valuable for all the port call actors. From the sea-side, shipping companies and charterers can potentially make improved speed-decisions during the voyage execution. Whereas for the actors at the land-side, the majority underlined that the implementation of JIT arrival can potentially improve their resource planning and utilization. This part of the findings confirms the findings from the previous literature. Eisen et al., (2022) simulate how the PBP improves berth utilization in the port of Amsterdam. While the berth utilization is not simulated in this thesis, the findings are complementary to Eisen et al.’s (2022) as many actors underlined how JIT arrival improves resource planning and utilization. Elbert and Walter (2014) simulated how early provision of ETA improves the utilization of resources at the land-side. This is aligned with the findings of Paper III, as JIT arrival rely on early information sharing. This entails that the planning-horizon for actors in the process becomes longer, which potentially improves the resource planning and utilization. For example, ETA and berth-reservations are made 36 h before arrival in JIT arrival.

6.2 Discussion on the importance of coordination for implementing Just-in-Time arrival in the port call process

Lack of information sharing, and coordination were among the identified barriers that limit the implementation of JIT arrival. The findings from Paper II and Paper III provided insights on how actors in the port call process can be coordinated to allow for the implementation of JIT arrival. In particular, the focus was on three coordination mechanisms: the PBP, the information sharing procedure (PCS), and the alignment of plans between different actors. The interaction between these coordination mechanisms enables the actors to implement JIT arrival. However, a variety of challenges associated with coordinating the actors emerged during the study. These challenges are discussed in this section.

The first challenge is related to the dilemma of setting the operating rules of the PBP in a way that satisfies all the actors and companies. This dilemma is called “the dilemma of timing berth reservations” or the “ETA dilemma” and refers to the timing in which berth reservation must be confirmed. In the context of the PoG, the earliest that berth reservation can be made is 36 h before arrival. Some companies, especially those with long voyages (e.g., have their port of origin in South America) prefer earlier timing for the reservation of berth, e.g., 72 h before arrival. Their argumentation was based on earlier possibility to reserve the berth provide better opportunities to plan and execute the voyage. For
example, the speed reduction can possibly commence earlier if the berth is reserved earlier. However, other companies, with ports of origin close to Gavle (e.g., Swedish west coast) preferred 36 h to confirm the reservation. This dilemma complicates the decision making for the PoG, meaning that it is difficult to satisfy all actors and companies with their respective operations. In the PoG’s case, the 36 h was determined based on data showing that most of the port calls in the PoG have a port of origin located on the Swedish west coast. The 36 h is “aligned” with the length of these voyages from the Swedish west coast.

The PoG (with the influence of shipping company and oil and gas company) was the initiator behind implementing JIT arrival. However, there are some activities that influence the coordination necessary to implement JIT arrival, that are out of the control of the port authority. For example, as the activities in the port call process are sequentially interdependent, many actors underlined how shortage in pilots can affect their operations and JIT in general. However, pilotage is regulated and planned by the SMA. This is relevant for the Swedish context as pilotage shortage is discussed on parliament level (Riksdagen, 2019). Ice-brakers, also regulated through the SMA must be coordinated within JIT arrival. This underlines the importance of governmental bodies like the SMA for the implementation of JIT arrival. This entails that the coordination efforts cannot guarantee that the potential of JIT arrival are realized, as ports lack control over some activities.

Another coordination challenge that limits the implementation of JIT arrival that port authorities lack control over is related to contractual agreements between the shipping companies and charterers. This has been extensively discussed in the literature (Rehmatulla and Smith, 2015; Fuentes and Adland, 2023). The PBP supports the shipping companies and charterers in coordinating their operations and to incorporate clauses like VA, JIT arrival and STM, but doesn’t guarantee that these will be incorporated, or the speed will be adjusted based on the RTA. Especially those vessels that operate on a VCP where the principal-agent problem exists may negatively impact the possibility to implement JIT arrival. Not only inter-organizational coordination (e.g., between vessel owners and charterers) is necessary to implement JIT, but also intra-organizational coordination within individual organizations is also important. This was found as in Viktorelius and Lundh (2019) where in some circumstances the incentives for the vessel crew regarding fuel efficiency and speed reduction may be in conflict. For example, vessel crews face uncertainty about how efficient their energy efficiency practices are, and in some circumstances have contradictory theories about the fuel consumption (Viktorelius and Lundh, 2019). Other port authorities following a similar direction as the PoG towards JIT arrival must therefore have a solid contextual understanding about their port call processes. This contextual understanding includes obtaining information about the characteristics of the voyage of calling vessels, and aggregate information about the type of charterparties calling vessels operate under. Moreover, identifying the bottlenecks within the port is also important for choosing the right coordination mechanisms. In turn,
identifying the coordination needs (and mechanisms to manage these needs) based on the context can potentially contribute to improved coordination between actors.

The PCS appeared of importance to coordinate the actors in the implementation of JIT arrival. However, one challenge that is associated with the utilization of PCS is related to the “scalability”. For example, different ports choosing different software companies for their PCS may complicate the information sharing as it is hard to integrate the systems. Agents and other actors may frequently need to adapt to different PCS to coordinate port calls at different areas. In Finland, the adoption of one PCS is more common, as reported, that 16 ports operate the same PCS (Unikie, 2021). More centralized approach in the utilization of PCS would likely streamline the implementation and coordination of JIT arrival. What is also important to consider for the coordination is integrating the local PCS with reporting systems such as MSW. Currently, agents must share information in the PCS and in MSW. Integrating the different information systems and allowing the booking of services such as pilotage to be available through the different systems would simplify the coordination process among actors.

All of the above discussed challenges underline the complexity associated with accomplishing the coordination necessary to implement JIT arrival in port calls. Part of the findings focused on the perspective of how port authorities can contribute to the coordination of actors to enable them to realize the potential of JIT arrival. However, the key message is that all actors must align their efforts to enable the coordination associated with JIT arrival. One single actor cannot ensure the implementation of JIT arrival, instead all actors must work together.

Regarding the OIPT (Galbraith, 1977) presented earlier, FCFS can be positioned within the approach to reduce the need for information processing. Whereas for the PBP and JIT arrival, it is clear that information processing capacity must increase. OIPT highlights the importance of investment in vertical information system. The PCS in the context of JIT arrival is related to vertical information systems mentioned in OIPT. It was considered as a key mechanism to coordinate planning processes of different actors in the context of JIT arrival. Moreover, new rules and procedures for information sharing were established, which in turn influenced the utilization of PCS positively. This is also part of the OIPT, as the relation between rules and procedures and vertical information systems is highlighted. Lateral relations were also observed as in how actors were coordinated in the context of operational disruptions occurring in the PBP. If one vessel cancels its berth reservation, information is shared with the next coming vessel. The next arriving vessel would then have the option to speed-up or to continue based on the original ETA. The training programs provided by the PoG to different actors to clarify the required commitment from them to realize the potential of JIT arrival is another example of lateral relations.
6.3 Contributions

The practical, policy, and theoretical contributions are summarized in this section.

6.3.1 Contributions to practice

- The information needs of different actors in the port call process are identified in Paper II. This is important for port authorities planning to implement a PCS. Understanding the needs of actors is a prerequisite for the efficient utilization of the PCS and reduces the risk of a “failed PCS attempt” as the case was in the smartPORT project.

- The description of the implementation process of the PBP in Paper III, including the modification in port byelaws and operating rules, development of PCS, and other aspects is relevant to port authorities that are considering the transition from FCFS to other alternative berth allocation policies. Close interaction with the port call actors during the implementation process is valuable for port authorities as these interactions provide insights on different actors’ perspectives and needs that would otherwise be overlooked.

- The implementation of JIT arrival is relevant for shipping companies and charterers as it can be used to improve the CII ratings of vessels. The findings addressed the relationship between how the PBP, PCS and planning enable JIT arrival, which in turn can increase the CII rating of vessels.

6.3.2 Contributions to policy

- In the existing literature, JIT arrival is recognized as a promising emission abatement measure. This recognition is challenged in this thesis, and the findings underline how the operational sailing speed of vessels significantly impact the obtained emissions savings by JIT arrival. For policy makers, this implies that the potential of JIT arrival to reduce emissions may be overestimated. The market conditions in general, and the sailing speed of vessels in particular, must be considered during decision-makings about JIT arrival. This consideration is important as it affects the emissions savings of JIT arrival.

- Public authorities, like the SMA, must be engaged in the JIT arrival. Centralized approach in PCS utilization, and integration of PCS with reporting systems like MSW would streamline the coordination process of JIT arrival. For example, if local, port-specific PCS are
integrated with reporting systems, agents do not need to report the same information in both systems.

6.3.3 Contribution to theory

- The theoretical contribution underlines how JIT arrival requires an increased capacity in information processing. Factors related to information sharing, information quality and PCS are key enablers of JIT in the context of maritime logistics and transportation.

6.4 Conclusion

Summary of the findings for each RQ is presented below:

**RQ-1: What is the potential of Just-in-Time arrival in the port call process?**

Three types of potential improvement areas were identified: fuel and emission savings, improved resource planning and utilization, and increased port competitiveness. The share of the vessels that would benefit of JIT arrival was smaller than expected. The estimated fuel and emissions savings potential of JIT arrival ranged between 1-5% for those vessels, depending on when during the voyage speed reduction can commence. The small fuel and emissions savings were explained by the slow sailing speed observed in the sampled vessels. The findings underline that the fuel and emissions savings potential of JIT arrival reported in the existing literature may be overestimated. Most of the port call actors underlined that the implementation of JIT arrival leads to improved resource planning and utilization. This potential is derived from the fact that the implementation of JIT arrival improves the planning-horizon and reliability of different actors’ planning processes. JIT arrival can be used as a compliance option and thereof potentially improve the CII ratings of vessels. Port authorities increase their competitiveness by supporting the implementation of JIT arrival as it enables charterers and shipping companies to comply with mandatory obligations imposed by the IMO and could lead to a decrease in delays for the shipping companies and charterers.

**RQ-2: How can port authorities facilitate the implementation of Just-in-Time arrival in the port call process?**

Three coordination mechanisms were necessary to facilitate the implementation of JIT arrival. These mechanisms include PBP, information sharing and PCS, and planning. The PCS is a prerequisite for port authorities to implement pre-booking policies. In turn, the PBP set up rules to create an information sharing procedure including a specified content, modality, frequency, and direction of information. The information sharing procedure supports the coordination of different actors’ planning processes for JIT arrival. For example, vessel representative share information about their arrival plan and berth reservation.
This allows the actors on the land-side to plan accordingly based on the arrival times and the required resources of vessels that are calling the port. The coordination of these plans leads to the implementation of JIT arrival. In Figure 7, the answers to the RQs are illustrated in the context of the studied system. The potential of JIT arrival with regards to the sea-side and the land-side are presented. The interaction between the coordination mechanisms to coordinate the implementation of JIT arrival are also presented.

![Diagram of JIT arrival in the port call process](image)

**Figure 7.** Findings in the context of the studied system.

### 6.5 Limitations and future research

The methodology that is used in this thesis limits the generalizability of the findings. The estimates for the fuel and emissions savings potential of JIT arrival are based on data for 2019 from the Swedish context. Estimating the potential in other circumstances and contexts can lead to varying results. To further validate the findings, the sample can be extended to include voyage for a longer period than the year 2019. Future research estimating the fuel efficiency potential could include a longer time-interval or try different countries with different maritime traffic characteristics compared to Sweden. Regarding study-2, the single case approach limits the generalizability of the findings. Multiple case approach in other ports is important to gain additional insights regarding the implementation of JIT arrival in an empirical setting. Survey studies to validate the findings from the case is necessary for the generalizability of the findings.

Different directions can be taken for future research. One direction is to widen the scope of studied actors. In this thesis, some actors providing services such
Discussion and conclusion

as bunkering and icebreaking were not included. One example for future research is the inclusion of operators for icebreaking and bunkering in the coordination process and understanding their coordination in relation to JIT arrival. The focus in this thesis was on the fuel and emissions savings, and the coordination and information sharing associated with JIT arrival. Addressing the relationship between these two and the contractual agreements and charterparties between shipping companies and charterers is important for the implementation of JIT arrival. Predictive modelling to estimate more accurate ETA, laytime, and/or RTA are also important for the coordination of JIT arrival. This may potentially improve the information quality, which in turn is essential for JIT arrival. Lastly, the focus in the thesis was on JIT arrival, the sea-leg and the port/land-side. Extending the transport chain to include the transportation from the port to warehouses or customers is another valid research direction that can be undertaken.
REFERENCES


References


References


References


References


References


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Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

https://doi.org/10.3384/9789180753203
APPENDIX 1 BIMCO’S CLAUSES

The Baltic and International Maritime Council (BIMCO) is the largest international shipping association with approximately 2,000 members in 130 countries. One of BIMCO’s core services is the standard contracts and clauses for the maritime industry. Relevant to this thesis, and the implementation of JIT, BIMCO developed three clauses described below:

**Virtual arrival voyage charter clause:** in this clause, charterers can request the vessel owners to instruct the master of the vessel to adjust the speed to meet a specified time of arrival at destination. The extra time used on the voyage should be compensated by the charterer to the vessel owner.

**Just-in-Time voyage charter clause:** This clause is similar to the VA clause about speed adjustment. Though, it is clearly stated that charterers and vessel owners should make efforts to obtain and share information regarding the vessel arrival time. The main outcome of this clause is providing a contractual framework to overcome the current obligation on vessel owners to proceed with utmost dispatch and without deviations to the port of destination. Overcoming the obstacle of utmost dispatch is necessary to avoid breaching the usual voyage charterer obligations. The extra time used on the voyage should be compensated by the charterer to the vessel owner.

**Sea Traffic Management voyage charter clause:** Like VA and JIT clauses, is related to speed adjustment. Moreover, owners and charterers should make efforts to obtain and share information regarding the arrival time. The information efforts include, or required by a STM system⁴, e.g., the arrival time can be advised by the STM system. The extra time used on the voyage should be compensated by the charterer to the vessel owner.

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⁴ The STM system is not defined. Though, the interpretation is that it is a PCS to share real-time information sharing and is related to the MONALISA II (https://www.seatrafficmanagement.info/projects/monalisa-2/).
APPENDIX 2 – INTERVIEW GUIDE

- Open question: Employment, tasks and responsibility during the port call process.

**Paper-2: Cluster-1 – first set of interviews questions:**

- What are the reasons behind the implementation of the Port Community System?
- What is the potential of implementing and utilizing the Port Community System for the port call process?
- What information is made available in the Port Community System?
  - Can you elaborate on the content of information available in the Port Community System?
  - To whom is this information accessible?
- How is this information made available?
  - Which information systems are connected to the Port Community System?
  - What is the frequency of updating this information?
- Is there a relation between the Port Community System and better coordinated arrival of vessels?
  - Is the Port Community System related for the implementation of JIT arrival?
    - How is it related?
    - Would it streamline the process of utilizing clauses like Just-in-Time and Virtual Arrival?

**Paper-2: Cluster-2 – second set of interview questions:**

- When does the port call process start and finish for your operations?
  - Can you explain your specific responsibilities you have in the process?
- What is your information-needs to coordinate the port call process?
  - How do you receive/find this information?
  - Do you send/forward information to other actors?
    - With who do you share/receive information from?
  - What information modalities do you use to send/receive information?
    - What are your thought on the Port Community Systems?
      - Does it satisfy your information needs?
      - Have you observed any deficiencies in the Port Community System?
- Are you satisfied with the current information sharing and quality procedures at the port?
  - If not, what information would you like to have?
Do you know why is this information not available?
Any clear improvement potential that you see with regarding to information sharing and quality?

**Paper-3: Interview questions (based on the main workshop for the pre-booking policy):**

- Can you summarize your thoughts on the pre-booking policy deployed by the Port of Gävle?
  - Pros and cons of the policy?

- What potential benefits do you expect to your organization from the pre-booking policy?
  - Discussion of benefits related to
    - Fuel and emission reduction by slower speed
    - Planning horizon of port call actors providing services
    - Information sharing and quality among port call actors

- Can you elaborate on the “ETA dilemma”?
  - Is it possible to satisfy all the involved actors based on their voyage characteristics?

- Can the quality of information negatively affect the pre-booking policy?
Just-in-Time Arrival in Port Calls: Potential and Implementation

Abd Alla Ali Mubder Mubder