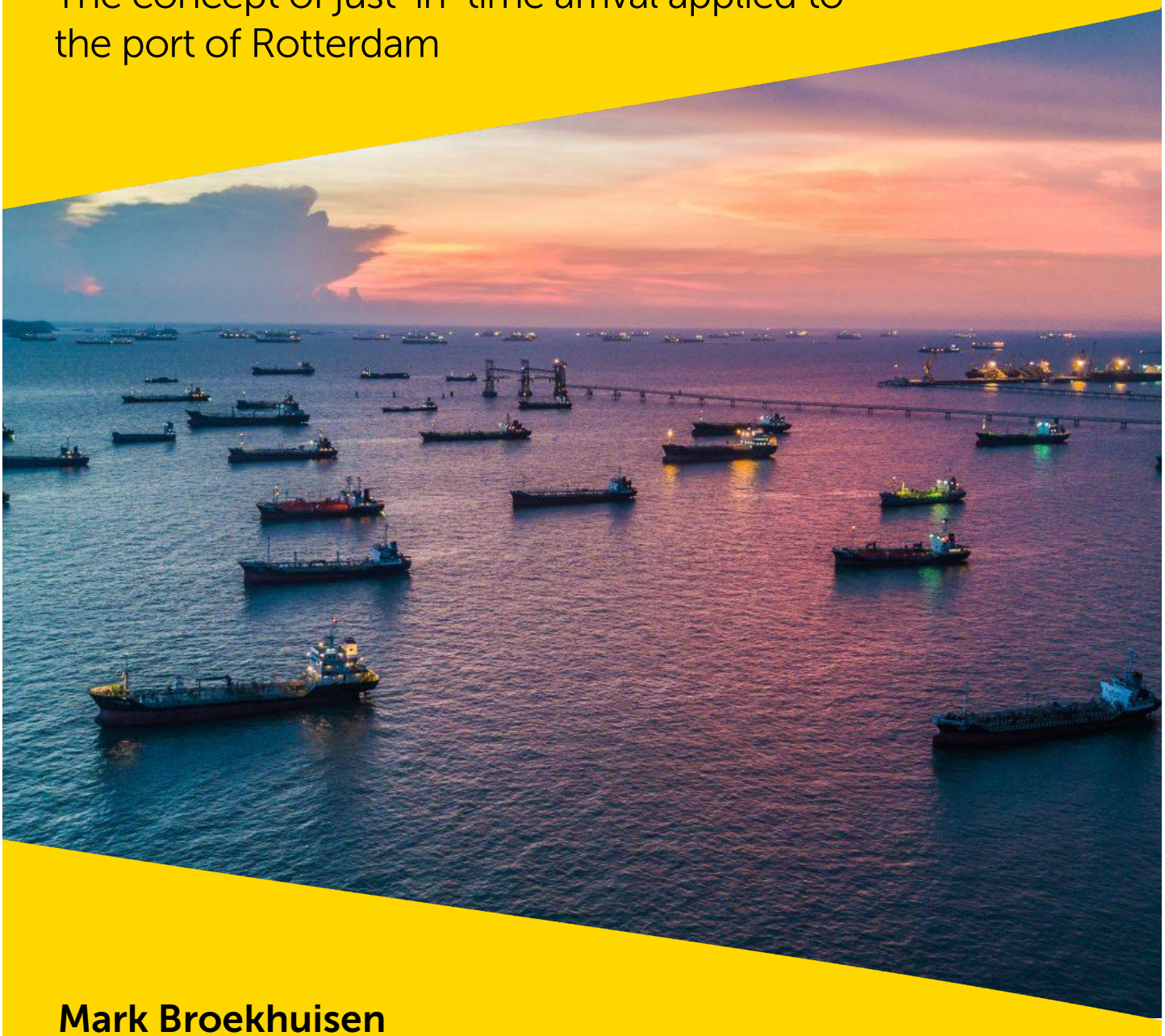
Erasmus
School of
Economics

Cooperation for just-in-time arrival

The concept of just-in-time arrival applied to the port of Rotterdam



Mark Broekhuisen

ERASMUS UNIVERSITY ROTTERDAM
Erasmus School of Economics – Bachelor

ERASMUS UNIVERSITY ROTTERDAM
Erasmus School of Economics – Bachelor

Cooperation for just-in-time arrival

The concept of just-in-time arrival applied to the port of Rotterdam

Thesis Bachelor Economics & Business Economics

Name Student:	Mark Broekhuisen
Student ID Number:	460511
Supervisor:	Martijn Streng MSc
Second assessor:	Niels van Saase MSc
Date Final Version:	28 January 2021

Abstract

In this research the concept of just-in-time arrival in the shipping industry is investigated. There is a specific focus on the role of and advantages for a port authority when implementing this concept. First a literature study was performed on the concept of just-in-time arrival, the current port call process and port cooperation in general. The second part of the research applies the obtained knowledge on the port of Rotterdam. AIS data of arriving and departing vessels in the port of Rotterdam is analyzed to get a better insight in the current port call process. This analysis showed that the port call process in Rotterdam is not fully optimized. The research is concluded with an analysis of the benefits of implementing just-in-time arrival in Rotterdam and what the role would be of the port authority, both within the port as well as in cooperation with other ports.

Keywords: Just-in-time arrival - Port Call - Shipping
Port of Rotterdam - AIS data analysis - Port economics

Table of contents

Abstract 2

Table of contents 3

List of abbreviations 5

1. Introduction 6

1.1 Research question and report outline 7

2. Port Cooperation 9

2.1 Port Competition vs. Port Cooperation 9

2.2 Port Cooperation 10

2.2.1 Shifting from competition to cooperation 10

2.2.2 Reasons for cooperation 11

2.2.3 Types of cooperation 12

2.2.4 Limiting factors 13

2.3 Summarizing 14

3. Just-in-time arrival 15

3.1 Current port call process 15

3.1.1 Process description 15

3.1.2 Problems of the current process 18

3.2 Just-in-time Arrival 18

3.2.1 Just-in-time arrival and port call optimization 18

3.2.1 Process description 19

3.2.3 Advantages of just-in-time arrival 22

3.2.4 Required cooperation between ports 24

3.3 Summarizing 26

4. Port call process in the Port of Rotterdam 27

4.1 Data 27

4.1.1 Data collection method 27

4.1.2 Data limitations 29

4.2 Methodology 29

4.3 Results & Analysis....30
4.3.1 Irregularities....30
4.3.2 Time at anchor and time in port....32
4.3.3 Effect of the number of port calls....33
4.4 Summarizing....34
5. Just-in-time arrival in the port of Rotterdam....35
5.1 Can just-in-time arrival be beneficial to the port of Rotterdam?....35
5.2 Implementing just-in-time arrival....36
5.4 Summarizing....37
5. Conclusion & Discussion....38
Literature List....41
ANNEX 1: Median and standard deviation of time at anchor per port area 2020....44

List of abbreviations

AIS	Automatic Identification System
GIA	Global Industry Alliance to Support Low Carbon Shipping
IMO	International Maritime Organization
PortCDM	Port Collaborative Decision Making
SOLAS	Safety of Life at Sea Convention
UNCTAD	United Nations Conference on Trade and Development
VHF	Very High Frequency
VTS	Vessel Traffic Service

1. Introduction

The transportation of goods over sea is the foundation of international trade and the global economy (Grzelakowski, 2009). As a result, the world fleet consist out of more than 90.000 vessels transporting all kinds of goods. In the Netherlands alone more than 100.000 ships arrive in a port each year (UNCTAD, 2019). With so many arrivals and departures every day one would expect that this process is running efficiently. This is unfortunately not the case as port call operations worldwide are not generally optimized. Ships usually sail as fast as possible to the next port. Just before arrival they however find out for example that the berth is not ready for them or that their cargo has not yet arrived at the terminal. As a result, ships must wait at anchor just outside the port for hours or even days sometimes. AIS data shows that ships spend approximately 9% of their time at anchor, waiting. This way of operating ships is highly inefficient and has many disadvantages (GIA, 2020).

Environmentally the current mode of operation results in extra fuel and emission due to the waiting before arrival. By arriving on time ships can sail slower which usually results in consuming less fuel and lower emissions. Next to that they spend less time in an anchor area close to land where they heavily pollute the port environment. The GIA (2020) estimates that if ships would arrive on time this could reduce the fuel consumption of ships by 15% and the CO_2 emissions by around 10%. For the Port of Rotterdam alone this would have been a reduction of 188.000 tons of CO_2 in one year (Port of Rotterdam, 2018). Besides the environmental concerns of the current mode of operation it also affects the safety of shipping and simply costs money.

Although it is clear that the current port call process could be improved this is unfortunately not simple. The IMO therefore proposed the idea of just-in-time arrival. Just-in-time arrival enables the captain of a ship to adjust the speed in such a manner that they arrive at the port when the terminal, fairway and other nautical services are ready for them. In order to do so the captain needs reliable and accurate information from various parties involved in the port call process. Although the idea of just-in-time arrival is conceptually very simple, in practice this it is not. just-in-time arrival requires the many parties involved in port call operations to cooperate and share data. This includes for example shipping companies, terminal operators, maritime service providers and port authorities. These parties are however not used to sharing data or to collaborate intensively with each other (GIA, 2020).

This research will specifically focus on the role of and benefits for the port authority in just-in-time arrival. It is currently not very clear what the benefits of just-in-time arrival are for port authorities as most research is focussed on the benefits for shipping lines, terminal operators or maritime service providers. Por authorities do however play an important role in the implementation of just-in-time arrival for two reasons. First of all, cooperation between

ports is required in order to implement an international system for just-in-time arrival. Port cooperation is however not standard practice and has its limitations and concerns. Secondly the port authority must promote and facilitate data sharing and cooperation between the various stakeholders in the port. This requires major investments for the port authority (GIA, 2020).

The exact benefits and required role will differ for each port authority when implementing just-in-time arrival. The reason for this is that ports can differ a lot in for example size, type of cargo, location and government structure. This makes it almost impossible to give a general definition of the benefits for and role of a port authority. The theories and insights from this research will therefore be applied to the Port of Rotterdam.

1.1 Research question and report outline

The described problem has resulted in the following research question for this thesis:

"What are the benefits of just-in-time arrival for the port authority of the Port of Rotterdam and what is their required role in the process?"

This thesis will contribute to the scientific debate of just-in-time arrival. Since the concept is relatively new there isn't a complete overview of the theory. By focusing specifically on the advantages and requirements for port authorities it will try to fill a gap in the existing literature making it scientifically relevant. Socially the research is relevant as well as it can give port authorities and other parties advise on how to deal with just-in-time arrival.

In order to give a structured answer to the main question this paper is divided into three sub questions:

1. *What is port cooperation?*
   Cooperation between ports is required in order to successfully implement just-in-time arrival. The concept of port cooperation is unfortunately rather complex. In chapter 2 of this report the fundamental theories of port cooperation will be discussed by means of a literature review of the most relevant academic papers on the topic. This includes the reasons why ports cooperate, how they cooperate and factors that can affect the success of cooperation.

2. *What is the role of the port authority in the process of just-in-time arrival and do they benefit from it?*

   The second sub-question will be answered in chapter 3 of this report. The chapter will first discuss the current port call process and its problems in more detail. Afterwards the concept of just-in-time arrival will be explained including the requirements and advantages in relation to a port authority. The chapter will be based a literature review of the most relevant academic papers on the topic and the IMO guidelines and resolution regarding just-in-time arrival.

3. *Are there problems for the port authority with the current port call process in the Port of Rotterdam and would just-in-time arrival benefit them?*

   In chapters 4 and 5 the theory from the previous chapters will be applied on the Port of Rotterdam. It focusses on the current issues in the port related to just-in-time arrival and if the implementation of just-in-time arrival would benefit the port authority. To analyse the current problems AIS data from MarineTtraffic will be investigated in chapter 4. Reports and opinions of the Port of Rotterdam and PortXchange will be investigated as well to get better overview of their opinions on the matter.

In the last chapter the research will be concluded with a conclusion and discussion of the results found.

2. Port Cooperation

Containerization, forming of megacarriers and the lowering of trade barriers are just some of the important trends that changed the shipping industry in the past decades. As a result, the role of the port changed as well. Where ports previously had a natural monopoly over their own hinterland they now have to compete more and more with other ports. Instead of competing some ports however chose to cooperate.

In this chapter I will briefly discuss the concept of port competition as this is necessary knowledge in order to fully understand the concept of port cooperation. Next I will discuss in more detail why ports started cooperating and the reasons behind a cooperation. Lastly the various forms of cooperation will be discussed as well as factors that determine if ports will cooperate.

2.1 Port Competition vs. Port Cooperation

The maritime industry is a very broad sector that includes actors operating in very different fields. Deep-sea shipping for example has very different characteristics as short-sea shipping but are both part of the maritime sector. There is also a large variety of transported cargo such as passengers, containers and wet bulk. These different types of cargo require different types of port infrastructure and hinterland connections. Although shipping is a very broad market it is in all cases a derived demand (Stopher & Stanley, 2014). This demand is driven by economic activity and international trade.

The portion of freight that can be attracted by a specific port is largely determined by its competitive position and its capacity (Meersman, Voorde, & Vanelslander, 2009). In the last few decades ports have become key nodes in the complex logistics chain that is connecting the origin of a good to the destination of a good. Many parties are usually involved in this logistic chain, each with a different strategy and sometimes conflicting interests. Due to this it is very complex to determine the competitiveness of a port as many factors play an important role and not only the ports own organization and infrastructure (Ng, 2006).

Because of the complexity of port competition scientists have come up with a variety of theory's and models. Some say that port competition is actually a variety of smaller competitions between actors in the maritime industry such as terminals, shipping lines and logistic service companies (Notteboom & Yap, 2012). Others connect the competitiveness of a port to the effectiveness of a port where effectiveness concerns how good the port provides services to her customers (Talley, 2012). Although the sometimes huge differences in these theory's they all see ports as competitors that need to fight for their share of the transported cargo. In order to win the game a port authority or other form of governance is required.

Not everyone agrees on the fact that ports should compete with each other. Port Authority's hardly gain anything if more ships decide to come to their port. Service providers such as terminals gain the most, but they usually operate in the competing ports as well (Shinohara & Saika, 2018) Therefore competition could lead to unnecessary rivalry between the various actors in the shipping industry.

If competition, cooperation or even another option is the best strategy for a port remains unclear. As a result, there is hardly any consensus on what governance model is most appropriate for a port or what services should be provided to their customers (Brooks, Mary R. & Pallis, 2012) .

2.2 Port Cooperation

As discussed in the previous paragraph there is both competition and cooperation between ports. This is especially the case between ports in the same region and thus share the same hinterland. Ports with comparable characteristics compete and cooperate with each other as well (Trujillo, Campos, & Pérez, 2018). Although competition has its advantages more and more ports start to cooperate instead of competing with each other. In this paragraph I will discuss the characteristics of port cooperation.

2.2.1 Shifting from competition to cooperation

Port cooperation is the response of port authorities worldwide to the changing shipping industry in which they operate (Heaver, Meersman, & Van De Voorde, 2001). In the past decades the industry has seen major trends that affected port authorities. One of them is the changing structure of shipping companies, terminals and logistic service providers. In the early 90's they started to form strategic alliances in order to achieve efficiencies of scale and improve their services. This has resulted into horizontally and vertically integrated terminal operators, shipping companies and logistic service providers that form powerful negotiating partners (Notteboom, Theo E., 2010). Additionally, carriers grew extensively in the past years and integrated into megacarriers with a strong position in the market. As a result, port authorities now have to deal with terminals, carriers and logistic companies that have a strong bargaining power. They can use this bargaining power to let ports compete against each other and forcing them to lower their prices and improve their services (Notteboom, Theo E. & Winkelmans, 2001).

Containerization is the second major trend that resulted into cooperation between ports (Slack, 1993). Before containers revolutionized long-distance transport ports usually had a natural monopoly over their own hinterland. The container makes it possible to efficiently switch between transport modality and resulted in intermodal transport chains. As a result,

goods did not need to be transported anymore via their usual port and the traditional hinterland disappeared. Carriers are no longer dependent on the natural location of a port and can choose the most efficient port in the region for their services. The role of the port in a certain region decreased and competition between ports intensified.

Lastly the role of the government in shipping has changed as well in many countries. Many ports that were previously controlled by the government are now privatized or corporatized. Public policy also minimized trade barriers and liberated the market. This has led to significant increase in word trade and globalization. Since transport is a derived demand driven by international trade this resulted in a significant increase in sea-transport worldwide. Due to the globalization carriers started operating on the global market offering door-to-door transport solutions worldwide. This worldwide network gives them the opportunity to switch to a different port in the region if this is more efficient (Notteboom, 2004).

Due to these trends the role of the port in a certain region decreased and competition between ports intensified. Port authorities now have to implement new strategies in order to maintain or increase their share of transported freight. One of these strategies is cooperating with other port authorities (McCalla & Palla, 2011).

Besides a strategy to deal with the changing competitive position of a port intra-port cooperation can serve many other purposes as well. A good example is the cooperation between the port of Malmo and Copenhagen. By collaborating on the areas of marketing and operations they were able to realize economies of scale (Li & OH, 2010). Juhel (2000) describes a form of cooperation in order to deal with congestion by implementing a joint flexible traffic distribution scheme. The United Nations Conference on Trade and Development actively promotes cooperation between ports. They suggest cooperation in order to achieve common goals on the areas of tariffs, technical training, port call harmonization and information for common services (UNCTAD, 2017).

2.2.2 Reasons for cooperation

The trends and developments in the industry has led to a great variety of forms of port cooperation around the world (Tang, 2010). Although cooperation between ports can be very different it is usually triggered by a common need or common threat. A common threat usually exists between two or more ports in the same region that face a combined loss of market share or a new common competitor. Common needs on the other hand rise when ports in the same region all need something with the same requirements. This could for example be the construction of a new deep-water channel for ports in the same bay or mutual environmental policy's to improve the port environment (Inoue, 2018).

A good example of the mutual benefits of port cooperation is the HAROPA agreement between 3 ports in the north of France. After years of competing with each other they teamed

up and developed a highly efficient logistics network in order to meet the requirements of customers in the region (Ducruet, Joly, & Le Cam, 2013). The ports will each specialize in their own function: Le Havre as modern deep-sea port, Rouen as a logistic centre of the region and Paris as river port located in the nation's capital. The reason behind the cooperation is the common threat of neighbouring ports. Before the cooperation more than 40% of the traded goods in the regions were transported via ports outside the region such as Antwerp and Rotterdam. By combining the strength of the three ports they hope to bring some of these shipments back to their own port network.

An example of cooperation because of a common need can be found closer to home. Both the port of Rotterdam an Amsterdam needed a better railroad connection from their ports to the German Ruhr Area. Together with ProRail, the Dutch rail infrastructure administrator, they founded the company Keyrail. On their behalf Keyrail efficiently divides the available slots for rail transport to Germany between the customers that are in need of rail transport (Donselaar & Kolkman, 2010).

2.2.3 Types of cooperation

Ports that decide to cooperate can do so by many types of cooperation. The chosen type depends on factors such as the scope of cooperation, relation between ports and the reason behind the cooperation (Tang, 2010). Inoue (2018) investigated the scope of cooperation of various port cooperation initiatives around the word and concluded that the scope of cooperation can be divided into four groups of goals. The first goal can be joint terminal management between ports in order to efficiently spread the ships and cargo over the available terminals. Secondly ports cooperate in order to improve the hinterland and foreland access. Thirdly there can be cooperation to organize logistic services and marketing. Quality port programs are the last group of goals for cooperation.

The scope of the cooperation largely determines the type of cooperation as not all types are suitable for all scopes. Mergers are the strongest form of cooperation and deal with all four groups of scopes. When two ports merge a new company or authority arises that will control both ports with a single and coherent set of goals. Joint management is an alliance between two ports that primarily deals with the core business of a port: terminal management (Airriess, 2001). Although not required it is likely that ports with a joint management will also cooperate on the other scopes of cooperation. Due to the nature of joint management there will be no competition between the ports of the alliance anymore (Inoue, 2018).

The structure of a joint project enables competing ports to cooperate on projects that improve the service of the ports within the alliance. As they will only cooperate on specific projects it is not likely that they will cooperate on terminal management and logistics service & marketing. This is because the ports will still be competing against each other on the market

for freight (Inoue, 2018). Ports that specialized in different fields will not be competing with each other, even before the cooperation. When they form an alliance, they can use each other's strengths to grow together as an alliance. Terminal management and hinterland connection will not be covered by the cooperation as each port operates in its own field with its own requirements. They can however benefit from cooperating in logistic services & marketing and quality port programs (Li & OH, 2010).

Table 1 shows an overview of the various scopes and structures of port cooperation. Next to these common forms of cooperation there can also be cooperation on a very specific problem or on a voluntary base. Examples are the sharing of knowledge and training of employees (Tang, 2010).

		Scope of cooperation			
Type of cooperation		**Terminal management**	**Hinterland & foreland acces**	**Logistics service & marketing**	**Quality port programs**
	Merger	One new company that operates both ports with a single coherent set of goals			
	Joint management	Required	Optional	Optional	Optional
	Joint project	Not suitable	Optional	Not Suitable	Optional
	Alliance of complementary ports	Not suitable	Not suitable	Optional	Optional

Table 1: Type and scope of port cooperation, table partly from Inoue (2018) and adjusted by author.

2.2.4 Limiting factors

Although cooperation between ports could be a sensible strategy not in all cases ports actually start to cooperate (Galvao, Gharehgozli, & Mileski, 2018). There are a number of factors that can prohibit ports from cooperating. The economic cycle is one of them as the maritime industry is always affected by fluctuations of the economic cycle. In times of an economic recession the competition between ports usually intensifies which can affect the willingness to cooperate. During economic expansion ports sometimes face a surplus of ships. Therefore, they do not always see the need for cooperation as business is booming (Wang, Ng, Lam, & Fu, 2012).

The governance model of the port plays a role as well. Ports can be owned and operated both privately and publicly. Between these two models there are also alternatives that involve both private and public parties that operate the port together. Public and private ports usually operate on a different way and have different goals (Brooks, Mary & Pallis, 2011). This is an issue for port cooperation because ports that operate on a different governance model are less likely to cooperate (Wang et al., 2012). Stakeholders such as

shareholders and local governments sometimes even refuse to cooperate with another port and block the decision to do so (Jacobs, 2007).

The geographical location of the port can also be a limiting factor for cooperation. Ports that are located close to each other or share the same hinterland are more likely to be each other's competitor (Ng, 2006). As discussed before this competition can lead to cooperation.

Finally, the market influences the likelihood of cooperation as well. Strategies of market players such as competing ports or terminal operators can affect the process cooperation (Shinohara & Saika, 2018).

2.3 Summarizing

The share of freight a port can attract is largely determined by the competitive position of a port. In the literature there is little consensus on how to achieve the best competitive position. Traditionally ports try to improve their position by strong competition with their competitors. Trends and developments in the maritime industry have changed this approach as more and more ports see opportunities in cooperation instead of competition. Ports cooperate for a variety of reason and on many different areas. As a result there are different forms of cooperation each with their own strengths and limitations. Although cooperation with other ports can be a good strategy there are some factors that prohibit ports from actually doing so.

3. Just-in-time arrival

The port call process is complex and involves many variables and stakeholders. Planning of a particular voyage starts in some cases already months ahead of the shipment. Due to the complex environment it is important to first establish how the port call process looks like in practice before it is possible to implement just-in-time arrival.

In this chapter I will first give an overview of the port call process in the current state. Secondly the concept of just-in-time arrival will be explained including the advantages of the concept. This chapter will end with the steps that are needed in order to successfully implement just-in-time arrival in the current port call process

3.1 Current port call process

In the academic literature it is hard to find a complete and extensive overview of the port call process. Most academic papers and books only focus on a particular part of the process or on a particular trade such as container shipping. Without a complete overview it is impossible to determine the issues of the current process and resolve them. To solve this issue, the International Taskforce Port Call Optimization was formed in 2014. The taskforce exists out of many stakeholders in the port call process such as carriers, shippers and agents but also port authorities and maritime knowledge institutes.

One of the goals of the taskforce was to establish a common understanding of how the port call process looks like in practice. Based on contracts, law, IMO resolutions and the day to day operations in ports around the world they established a framework of 11 phases that describes the port call process from the signing of the contracts until the final departure of the vessel after delivering the goods (International Taskforce Port Call Optimization, 2017).

3.1.1 Process description

The 11 stages of the port call process can be divided into two phases: the contractual phase and the operational phase. In this paragraph both stages will be explained briefly focussing on the elements that are of importance for this research.

PHASE 1: Contractual phase

In the first phase the contracts needed for transports are negotiated and signed by the parties involved in the transport. It usually involves three contracts: the sale of goods, chartering of a vessel and hiring terminal services. The contract for the sale of goods is different depending on the specific trade. About 85% of global shipping deals with the carriage of bulk goods. This can either be dry-bulk such as grain or wet-bulk such as crude oil. Bulk goods are generally commodity goods sold by means of a direct agreement between the cargo buyer and the cargo

seller. The contract of sales already specifies the port of loading and discharge but also the time window between when loading and discharging takes place. Depending on the contract terms either the buyer or the seller of the goods is responsible for contracting the vessel and terminal services. This is usually different for containerized goods which mainly consist out of consumer goods that are transported by a consignor (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020). The consignor is the legal owner of the goods and arranges usually the multimodal door-to-door transport of the goods. Often the consignor contracts a freight forwarder who, as logistics expert, will be responsible for the transport and contracting the needed sub-carriers (Baughen, 2019).

The second contract deals with chartering a vessel and is needed if the shipper does not operate his own vessels. Charterparties have many different forms dependent on for example the type of cargo, route and volume of the cargo. Especially the following clauses in a charter party are important for the port call process:

- *Laycan*

  This is the time and location of delivery and redelivery of the vessel. The charterparty commences after the ship owner has given a notice of readiness. This notice has to be given within the agreed time window or the shipper will have the right to cancel the charterparty. After discharging the vessel in the port of destination a is redelivered to the ship owner by a new notice of readiness after which the vessel can start the next agreed charter. To maximize his profit the shipowner will try to minimize the time between charterparties. Small delays can therefore sometimes lead to losing the next agreed charter. It is therefore essential for shipowners that they have accurate and predictable information of the time the port call will take (Baughen, 2019).

- *Agreed time for loading and discharge*

  After the notice of readiness the loading can start. Voyage charters often contain a clause that specifies the time allowed for loading and discharge. If loading or discharge takes longer than the agreed time the charterer has to pay additional demurrage costs. The shorter the agreed loading and discharge time the lower the price of the charter party making swift cargo operation and minimizing waiting time in port essential (Baatz, 2020).

- *Obligation of due despatch*

  In most charterparties the shipowner has the obligation to proceed to the port of discharge without any reasonable delays or deviations in route. This causes problems when the port or terminal services in the port of arrival are not ready to receive the

vessel. Even if the captain has this information well in advance he is legally not allowed to sail slower in order to avoid waiting in the anchorage area of the port of arrival.

Lastly a contract for terminal services is negotiated if the shipper has no continuous contract with a specific terminal. The contract contains details on the expected time of arrival and the time needed for loading or discharging the goods. For both parties it is therefore essential to have accurate estimates of these times (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

PHASE 2: Operational phase

After the required contracts are signed the operational phase commences. During this phase the voyage is planned and executed. Under the SOLAS convention the master is obliged to plan the voyage from berth to berth. Depending on the trade there are some requirements that this voyage plan has to meet by law or by contract (Yvonne Baatz, 2020). For bulk-cargo it is not unusual that the port of arrival changes multiple times during the voyage. This is the result of the shipped goods being resold to another buyer during the voyage. Every time the destination changes the master of the vessel has to re-plan the voyage. Due to the obligation of due despatch the master has to plan the voyage based on the service speed of the vessel and the shortest safe route (Baughen, 2019). Slowing down to prevent arriving before the terminal is ready to receive the vessel is often contractually not allowed. Container vessel on the other hand usually sail on a fixed schedule and route. As most container transports are time charters the master is often allowed to adjust his speed to arrive on time (International Taskforce Port Call Optimization, 2020).

Besides the master planning the voyage the terminal will plan berthing at the terminal. Many factors have to be taken into account by making this planning such as the others vessels arriving but also the availability of equipment and personal. After the planning is made the master will be informed on the time he is requested to arrive at the terminal. Most terminals operate on a first come, first served base. This is often not an issue if only one vessel is arriving but can cause problems when multiple vessels are arriving at the same time. Often the terminals give priority to important regular customers or their own vessels if the terminal and vessel are owned by the same party. This can lead to unexpected extended waiting times for incoming vessels. Delays can also be caused by the loading and discharge taking longer than expected (Geerlings, Kuipers, & Zuidwijk, 2018).

The port authority makes, based on the berth planning of the terminals, a port planning. This is needed to ensure that port services such as pilots, tugs and the VTS are ready to assist the vessel during arrival and departure. As the berth planning in most ports is done by the terminals it is crucial that the port authority is supplied with accurate arrival and departure

information. Inaccurate or wrong information can lead to the in availability of port services making it impossible to arrive or depart at the desired time (International Taskforce Port Call Optimization, 2017).

Finally the master has to make a service planning for services such as bunkering, repairs and provisioning. These services often need to be reserved in advance based on the expected time of arrival. If the vessel arrives late or services are delayed the vessel will not be ready to depart as soon as loading or discharge is finished. This can cause delays at the terminal as the next vessel can't arrive (Geerlings, Kuipers, & Zuidwijk, 2018).

3.1.2 Problems of the current process

The issue with the current port call process is that it is far from optimized. After departure ships often travel at full service speed to their destination. On arrival at the port the terminal or other needed services are often not ready and the vessel needs to wait at anchor outside the port. Analysis has shown that 30% of global shipping gets delayed on route or in port (PortXchange, 2020) The waiting time can be hours or in some cases even days or weeks. This mode of operation has major economic, environmental and safety disadvantages (GIA, 2020). These disadvantages will be discussed in more detail in the next paragraph.

3.2 Just-in-time Arrival

In contrary to the current port call process the concept of just-in-time arrival allows vessel to continuously adjust their speed to arrive at the port when the port, terminal and other services are ready to receive the vessel. This allows vessels to reduce their anchor time and safe fuel by sailing at a lower speed. Research at European ports has shown that vessels only spend 60% to 70% of their time in port at the birth. The remaining time is spent waiting at anchor just outside the port (Port of Rotterdam, 2018). Just-in time arrival aims to minimize this time at anchor and should not be confused with the concept of slow steaming. Contrary to slow steaming the total voyage duration will not change only the time at anchor will be reduced (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

Although the concept may sound easy it is in practice hard to implement. In this paragraph the concept, advantages and implementation requirements of just-in-time arrival will be discussed.

3.2.1 Just-in-time arrival and port call optimization

As discussed in the previous paragraph the port call process is complex and involves many stakeholders that are dependent on each other. A small disruption or delay at one of the stakeholders could have a major impact on the operations of the vessel itself but also on other

stakeholders in the port. The port can improve its efficiency by ensuring that all the processes in the port are synchronized and available just in time. This is called port call optimization and is a prerequisite for just-in-time arrival (Lind et al., 2018). Although port call optimization is outside the scope of this research some basic knowledge is needed to fully understand the concept of just-in-time arrival.

Research has shown that the port call process is far from optimized in European ports. This is rather strange as one would expect that given the enormous amount of port call each year the process should be routine and predictable. There are large differences from port to port but also from arrival to arrival. Container vessels for example arriving in a Scandinavian port spend on average 7 hours longer in the port than in a port in the Mediterranean. Although there are many reasons why these differences occur in all cases it makes the port call unpredictable and inefficient. As a result predicting turnaround times an forecasting arrivals and departures are extremely hard (Lind, Ward, Bergmann, & Haraldson, 2019). In order to resolve this problem the various actors in the port need to start collaborating and share their data. By collaborating and sharing data every port call can be managed in such way that delays are minimized and that all port resources are used as efficient as possible. In the literature this concept is named Port Collaborative Decision Making or PortCDM (Lind et al., 2018).

The concept of PortCDM is not new and has been successfully implemented in the aviation industry for years. Flights and airport operations are extensively managed which reduced turnaround times for airplanes to a minimum. Key to this mode of operation is that accurate data is shared between the involved actors in real-time (Lind, Ward, Bergmann, & Haraldson, 2019). Only by continuously sharing data all actors can adjust their operations to smoothen the port call. This will not only improve the efficiency of the port but has many other advantages as well. The key advantage for just-in-time arrival is that a port call becomes predictable making it possible to extensively plan a voyage. If PortCDM is implemented successfully the terminal and port authority can give a accurate requested arrival time. Only if this requested arrival time is accurate in almost all cases vessels are able to adjust their speed just right to avoid waiting at anchor (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

3.2.1 Process description

The process of just-in-time is straight forward and is still quite comparable with the current process. In figure 1 an example is given of a voyage executed in the traditional mode of operation and with just-in-time arrival. On day 0 the vessel leaves at the port of loading and sails on full service speed to the port of destination. Originally the arrival was scheduled for

day 14 based solely on the time needed to reach the destination at full service speed. In the traditional mode of operation the vessel will continue sailing on full service speed and arrives at the port at the scheduled arrival time. The port, terminal and other services are however not ready to receive the vessel on this day. As a result the vessel has to wait at anchor for four days until it can finally dock at the terminal.

When just-in-time arrival is successfully implemented in the port of arrival the vessel will be informed well on time when the requested arrival time will be. This requested arrival time is accurate and can be determined well in advance due to the successful use of PortCDM. After the master is informed that the requested arrival time is on day 17 and not day 14 he can reduce the speed of the vessel for the rest of the voyage in order to arrive in port just in time. Compared to the traditional mode of operation the voyage does not take longer but fuel is saved by sailing at a lower speed and waiting at a crowded anchor area can be avoided.

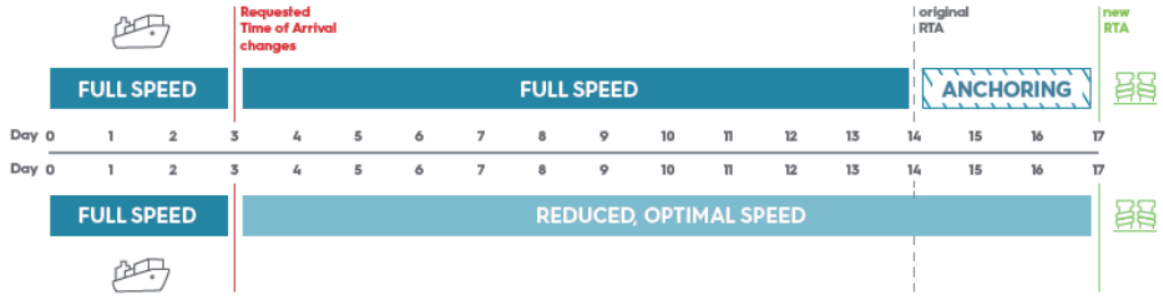


Figure 1: Current port call process compared to just-in-time arrival (source: IMO)

As mentioned before, the concept of just-in-time arrival is quite simple but many major barriers prevent easy implementation. Since this research is focussed on the role of the port authority in the concept of just-in-time arrival only the most essential barriers that are not related to the port authority will be discussed. Barriers relevant to a port authority will be discussed in more detail.

In the contractual phase there are some legal barriers that prevent the implementation of just-in-time arrival. The difficulty in removing these barriers is caused by the large differences between charter parties. The obligation of due despatch in voyage charters prevents the master to adjust the speed of is vessel to meet the requested arrival time. Slowing the vessel down will often lead to breach of contract and the payment of demurrage. Implementing just-in-time arrival would therefore need changes in the current legal system. In order to change the legal system there needs to be general agreement to do so by the involved actors (IMO & Port of Rotterdam, 2019). History has shown that the maritime industry is very traditional and is not very willing to make changes to their current mode of operation making

it extremely difficult to achieve this change. For time charters this is no issue as the charter has the right to decide on the ships speed and direction. As the charterer pays for the fuel he immediately benefits from implementing just-in-time arrival due to the reduced fuel costs (GIA, 2020).

During the operational phase most barriers are related to the needed data sharing. This already starts when collecting the data and communicating it to the different actors as there is no standardized codification system for the different time stamps such as the estimated time of arrival and the requested time of arrival. The terminology and meaning of these time stamps can vary from port to port and even from actor to actor within the port. An international standard is therefore needed to ensure that all actors speak in the same language (International Taskforce Port Call Optimization, 2017).

It also need to be clear who is responsible for supplying the data and who needs access. If one of the actors misses data the whole port call process can be disrupted. The data should therefore be accurate, up-to-date and shared continuously. Many actors in the port call process are unfortunately not very willing to share data as some data is commercially sensitive. Even if they are willing to share the data there current mode of operation does not include frequent data sharing. It would therefore need structural changes to the mode of operation before the actors can actually share it with the rest of the port. A centralized port communication to which the actors can easily connect their own management system is needed (Geerlings, Kuipers, & Zuidwijk, 2018).

With a good functioning port communication system data sharing it is technically not difficult to share data over the internet. This is however not the case for vessel that not all have access to the internet while at sea. At the moment vessels often wait with contacting the port until they are in VHF radio range. This is not workable procedure for just-in-time arrival as vessels need to be informed about their requested arrival time long before they are in radio range of the port. Under SOLAS vessels are obligated to have long-range communication systems on board that meet the GMDSS standards. These systems are currently not frequently used for communicating with the port and most actors in the port do not have the capability to communicate with these systems. In order to implement just-in-time arrival it would therefore be necessary to change the current shore to ship communication systems (Johnson & Styhre, 2015).

3.2.2. Role of the port authority

The port authority has an essential role in overcoming some of the barriers and successfully implementing just-in-time arrival. They play such an important role for two important reasons. First of all the port authority can enforce new regulations and procedures in the port more easily than other actors in the port. If a port authority makes changes in regulations all actors

in the port are required to follow these changes. Secondly their independent position forces them to make decisions without favoring certain parties more than others. This could be different if some other actors in the port take the lead in implementing just-in-time arrival. Since all actors have to comply with the new regulations there will be no unfair competition as all actors in the port have to deal with the changes (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

In the contractual phase the port authority is able, in cooperation with the government, to change the current rigid legal system. Most essential is the implementation of a just-in-time-arrival clause for charter parties. Only by implementing such clause and ending the current obligation of due dispatch the concept of just-in-time arrival can be implemented (International Taskforce Port Call Optimization, 2020).

During the operational phase of a port call the port authority needs to implement a standard with regard to timestamps. Most crucial here are the timestamps for requested time of arrival and departure. As they are the central authority and usually also responsible for VTS and other port services they are best positioned to control these timestamps as well. This allows for one central location coordinating all arrivals and departures. As discussed before this requires an update of the shore-to-ship communication systems in order to communicate the requested arrival time when a vessel is outside VHF range. The port authority needs to regularly communicate the requested time of arrival and departure with an increasing frequency closer to the actual requested time of arrival or departure. In case of any delay or disruption during the port call process the port authority must be able to swiftly change the schedule for arrival and port services to prevent cascading delays to other vessels. For efficient management of arrivals and departures it is crucial that the port authority has the mandate to decide on a vessels arrival and departure time (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

As discussed before an successful implementation of PortCDM is needed before just-in-time arrival will work. Implementing and managing a good functioning port communication system is therefore another role of the port authority. These systems will only work if strict regulations are in place that deal with the quality and sharing of data enforced by the port authority (Lind et al., 2018).

3.2.3 Advantages of just-in-time arrival

In general just-in-time arrival has to major advantages: reduction of emissions and lowering the time spent at anchor The reduction of emission is caused by slowing down which saves fuel (Poulsen & Sampson, 2019). Research has shown that informing vessels 12 hours in advance about their requested arrival time already leads to a 4% reduction of CO_2 emissions.

Desktop experiments have shown that full implementation of just-in-time arrival and thus continuously communicating and updating the requested arrival time will lead to a 23% reduction of fuel consumptions. These large reduction in fuel consumptions is possible due to the fact that the relation between the speed of the vessel and the fuel consumption is quadratically. Research has shown that a speed reduction of only 2 knots on a typical very large crude carrier can for example save up to 25 tons of fuel and 78 tons of CO_2 a day (PortXchange, 2020). On container vessels that typically sail faster than a very large crude carrier this reduction in fuel can even be larger. IAME (2020) predicts that an 8.000 TEU container vessel sailing at 24 knots will burn on average 225 tons of fuel daily while only consuming 150 tons when sailing 21 knots. With the fuel price of 2020 this will be a cost reduction of around $25.000 daily. This is not only financially very attractive as fuel is a large portion of the costs of shipping it will also significantly reduce polluting ship emissions (TNO & Port of Rotterdam, 2018).

For port authorities the reduction of time at anchor is particularly interesting as it has many advantages that directly affects their operations. While at anchor vessels still use their auxiliary engines and other equipment to stay operational. These auxiliary engines and equipment are of course less pollutant than the larger main engines used for sailing but they still produce emissions in an area close to land (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020). At large ports, such as Rotterdam, a large number of vessels are using the anchor area daily for sometimes days or weeks. Research has shown that on average a vessel spends around 5% of its time at anchor waiting because the port is not ready to receive them. By reducing the time spent in the anchor area there will be less emission close to the port and city improving the air quality significantly (TNO & Port of Rotterdam, 2018). Just-in-time arrival will not eliminate anchorage completely as ships also anchor for other reasons besides waiting to enter the port. It will however reduce around 2/3 of the time at anchor.

Reduction of anchorage also has other benefits for a port authority. First of all the congestion and traffic in and around the ports anchor area will be reduced. This traffic does not merely exist of vessels at anchor but also of vessels sailing at very low speed just outside the ports. These vessels prefer to manoeuvre slowly while waiting instead of anchoring because of the additional risks involved in anchoring. This reduction in traffic will reduce the risk of collisions or other accidents. As most port authorities are responsible for the VTS in the vicinity of the port this is a huge advantage (Lind, Ward, Bergmann, & Haraldson, 2019).

Lastly just-in-time arrival allows the port authority to better plan port services such as pilots. This could not only lead to cost reductions it also improves the maximum capacity of the port as the existing infrastructure and services can be utilized more efficiently. Pilots of just-in-time arrival with vessels and terminals of Maersk and Shell have shown a reduction of

terminal idle time of respectively 20% and 36%. Less idle time means an increase in port capacity and a reduction of in port pollution (PortXchange, 2020).

3.2.4 Required cooperation between ports

As just-in-time arrival is a relatively new concept hardly any research is done focused on the dynamics of the concept in relation to port competition and port cooperation. The International Taskforce Port Call Optimization (2020) sees the successful implementation of just-in-time arrival as competitive advantage for ports. Ports that that have implemented it operate more efficiently. Vessels consume less fuel due to the lower speed which is an advantage for the carrier. As the port call process becomes predictable due to accurate planning it allows other stakeholders in the port to better utilize their limited resources. If direct competitors of the port still operate without just-in-time arrival shippers and carriers might prefer the port that has implemented it.

On the other hand Michaelides, Herodotou, Lind, & Watson (2019) have shown that cooperation with neighboring ports is needed to fully benefit from just-in-time arrival. Especially in short-sea shipping the sea leg is not long enough to adjust the speed efficiently in order to arrive just in time. In order to achieve just-in-time arrival for short sea shipping it would be required to coordinate departures and arrivals between ports. Although this will not be an issue for the majority of vessels that sail longer routes it is not something that can be ingnored. Especially since short-sea is becoming more popular in the recent years (Medda & Trujillo, 2010). Coordinating arrivals and departures can lead to less efficiency use of resources at some actors in order to improve the efficiency of the port network as a whole. It could for example happen that a vessel scheduled to arrive in port A has to slow down not because port A isn't ready to receive them but because the next port, port B isn't ready which will be visited after port A. This results in delays for the terminal, vessel and other involved actors in the port call process of A. In the end it will however serve the overall efficiency of the port network as a whole as waiting time is reduced in port B. Independent actors of the port call process therefore not always benefit from just-in-time arrival in each individual port call. In the end the actors will however benefit as the sum of their operations will be more efficient due to the coordination of arrivals and departures.

The benefits of joint management of arrivals and departures is clear but it will be difficult to achieve. As seen in the previous chapter this type of cooperation usually only works for ports that complement each other and not for ports that are competitors. It will be rather difficult to design a central management system without an independent party that ensures that none of the cooperating ports gain an unfair advantage. In order for joint management of arrivals and departures to be successful it is therefore essential that there are solid agreements

between port authorities on how to manage arrivals and departures fair and without favoring a particular port. This can be a challenge as this type of cooperation is not common for competing ports. Since jointly managing arrivals and departures can be a solution for a common threat and a common need it is not unthinkable that joint management can be implemented. The common need can be found in areas such as reducing port pollution and port congestion of which just-in-time arrival can be a solution. Port regions such as the ports in the Hamburg - Le Havre range can benefit from implementing just-in-time arrival regionally as the increased port efficiency can benefit their competitive position as a port cluster (Michaelides, Herodotou, Lind, & Watson, 2019). For port authorities intensive cooperation on arrival and departure management enables them to meet their goals on sustainability, efficiency and port safety.

On a more global scale cooperation between ports is needed to agree on the used industry standards for the timestamps a just-in-time port call. Even though these standards are currently being developed by collaborating teams of porth authorities and other stakeholders in the industry this does not mean that it will automatically be implemented by other ports. To prevent fragmentation of different systems around the world all actors, including port authorities need to cooperate in order to implement one uniform system (International Taskforce Port Call Optimization, 2020). This will be a lot easier to achieve than active cooperation on traffic management as cooperating on just this one project will not need cooperation on any other area. Although possibly easier to achieve it is more crucial for the just-in-time arrival process. Just-in-time arrival can be successfully implemented without joint management of arrivals and departures. The concept will not reach its full potential but there will still be significant benefits for the port authority as discussed before. This is however not the case if ports fail to cooperate on the standardization of timestamps. Ports and other actors need to speak the same language by means of standardized time stamps in order to arrive just in time. An effective way of achieving standardization of timestamps is if port cooperate in joint projects such as the European MONALISA project and the international taskforce Port Call Optimization. These projects have resulted in potential concepts for the standardization of timestamps where all the interests of the various port authorities and other actors in the industry are taken into account (Becha et al, 2020).

Lastly cooperation is needed in the implementation phase. As discussed before the implementation of just-in-time arrival needs investments and significant changes in the port call process. If port actors do not see the immediate benefits of changing their way of work they will most likely not be very reluctant to do so. The port authority has some power to enforce the change on these actors but this comes with a risk. If competing ports in the area do not require change they might move their operation to the other port. By cooperation between ports in the same area and agreeing on a joint implementation all the actors will have

to comply as there are no other possibilities (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

3.3 Summarizing

The port call process is a complex and involves many actors. Although large numbers of vessels arrive in a port each year the process is far from optimized. Vessels tend to sail on maximum service speed to a port only to find out that they have to wait at anchor just before the port because the port is not ready to receive them. This results in crowded anchor areas an burning more fuel than needed. A potential solution to this problem is the concept of just-in-time arrival. If this concept is successfully implemented ships will receive an accurate time of when they are expected in the port. This allows them to adjust the speed to arrive exactly on time and avoid waiting at anchor. Although the concept is easy to understand, several barriers prevent it from easy implementation. The port authority is essential to solve some of these barriers. On top of that cooperation between ports is needed as well.

4. Port call process in the Port of Rotterdam

In order to determine if the Port of Rotterdam would benefit from just-in-time arrival the current arrival process in the port is examined first. As Michaelides et al (2019) have shown in their research regarding port call optimisation in the Mediterranean Sea arrival data can give valuable insight in the current port call process. For this research data is obtained by means of AIS. AIS transponders are mandatory on most commercial vessels and transmit on a regular base ship information such as position, course and speed. This allows tracking of all arrivals and departures in anchorage areas and ports.

This chapter will start by discussing the used data and methodology. Next the results from the various statistical analysis will be discussed. Lastly the results will be analysed in light of just-in-time arrival.

4.1 Data

Although AIS data can be publicly accessed by anyone with an AIS receiver, historical AIS data is much harder to obtain. Historical data is not publicly available and is of great value for all kinds of commercial parties such as carriers and terminals. Obtaining this data is therefore costly and limited to what commercial parties have to offer. For this research historical data is used from MarineTraffic. MarineTraffic is one of the leading companies in ship tracking and marine intelligence. They offer a large database of AIS data collected by both land and terrestrial stations.

4.1.1 Data collection method

For this research the MarineTraffic port data is used for the port of Rotterdam in 2020. In order to collect this data MarineTraffic monitors the whole port region continuously with AIS receivers. This data stream is enormous as all ships in the area transmit their data by AIS multiple times per minute. In order to process this enormous amount of data MarineTraffic has determined the boundaries of the port and anchorage area. Every time a vessel arrives or leaves these geofenced areas the event is logged. This enables MarineTraffic to determine the time in port and at anchorage for every vessel that arrives in the port of Rotterdam. Figure 2 shows an example of this process.

Figure 2: Overview of the logged events by MarineTraffic (source: MarineTraffic)

A filter is applied to exclude service and inland vessels from the data. These vessels are not relevant as they support the arrival process instead of being the subject. Vessels that only anchor but not enter the port are removed from the data as well. After processing and filtering the data the following variables are reported weekly:

- *Median time at anchorage*
- *Median time in port*
- *Standard deviation of the time at anchorage*
- *Standard deviation of the time in port*

The median is used instead of the average as the mean tends to be less skewed by outliers, especially in port areas with a limited number of arrivals per week. The following port areas are separately measured:

- *City-centre*
- *Maasvlakte*
- *Europoort*
- *Botlek*
- *Petroleumhavens area*
- *Waalhaven area*

In figure 3 an overview can be found of the exact locations of the various areas. The time in port is measured from the moment the vessel enters the destination port area and not from the moment the vessel arrives at the Nieuwe Waterweg. The time in port in areas further inland is therefore not biased by the longer inland travel time.

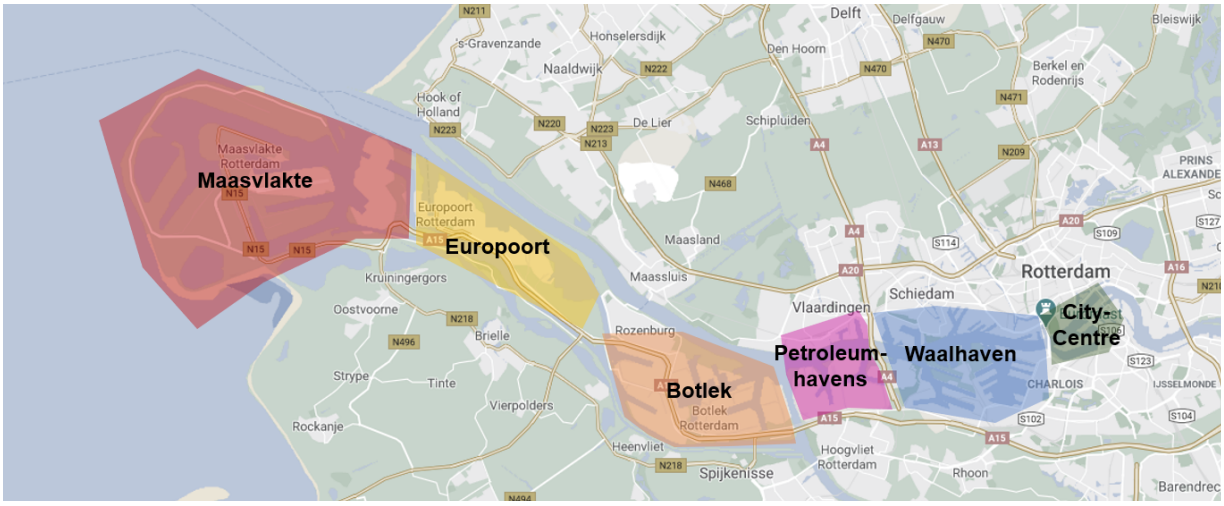


Figure 3: Geofenced port area's

4.1.2 Data limitations

The data used is of the whole year of 2020. Ideally it would have been better to look at a longer period than one year. This would allow a deeper analysis where for example trends over time could be observed. By measuring over multiple years, the number of observations would also increase which would improve the validity statistical analysis. This is especially the case in 2020 where the COVID-19 crisis was an important factor for most of the year. Many ports reported a decline in port calls during the crisis which would affect the measurements. Although the port of Rotterdam stayed operational during the entire crisis and the port authority it is still very plausible that the data is biased in some way. Unfortunately, data of previous years could not be obtained from MarineTraffic or other providers as it was either not available or not accessible without paying high fees. This potential bias can therefore not be ruled out and needs to be taken into account during any further analysis.

The data of 2020 will however still have explanatory value for other years. As Notteboom, Pallis & Rodrigue (2021) describe in their analysis of the first six month of the year, the ports in Europe are affected by COVID-19 but this is limited to a decline in port calls and throughput of a few percent. Compared to the last disruption caused by the economic crisis in 2008-2009 shipping worldwide is affected much less by the COVID-19 pandemic. Notteboom (2021) expects that due to a stabilization in demand for shipping in the second half of 2020 the throughput and port calls for European ports will only show marginal declines of a few percent. This is confirmed by the harbour master of the port of Rotterdam who expects only a small decline of 4% in port calls compared to 2019 (Port of Rotterdam, 2021). COVID-19 will thus potentially have some effect on the data obtained but since there were no major disruptions or large changes in port calls and throughput the data will still have explanatory value for other years.

The variables that are observed are limited as well. Only the actual arrival and departure time in the port is recorded. Ideally also the expected arrival and departure time is needed which would allow a more thorough analysis like performed by Michaelides et al (2019) on Mediterranean ports. This data is however not available as it cannot be solely determined from AIS data. The port authority has access to this data but were not able to easily generate a dataset with the required variables nor did they want to share this data.

4.2 Methodology

The obtained data is processed in Excel and STATA. By means of Excel the general descriptive statistics were determined. Secondly the data of the various areas are also combined to get a week by week overview of the port as a whole. The mean time in port and

at anchor of the various areas is weighted against the share of port calls to compensate for variation in the number of calls between the different areas.

In STATA the correlation between the number of calls and the time in port and at anchorage is examined. Secondly multiple linear regression models are used with the median time at anchorage or in port as dependent variables and the number of calls as independent variables:

(1) $\gamma_{median\ time\ at\ anchorage} = \beta_0 + \beta_1 * X_{number\ of\ calls}$

(2) $\gamma_{median\ time\ in\ port} = \beta_0 + \beta_1 * X_{number\ of\ calls}$

The time in port and at anchorage is also determined by many other factors such as the type of vessel or cargo and the port area it is arriving in. Therefore, two additional models are tested that account for fixed effects of the port area.

4.3 Results & Analysis

In 2020 more than 25.000 vessels arrived in the port of Rotterdam and were detected by AIS tracking. Unfortunately, the official arrival count is not yet released by the port authority which makes verification of the figure hard. In 2019 more than 29.000 vessels arrived in the port of Rotterdam. The difference can be explained by an expected 5-10% decrease of cargo throughput in 2020 due to the COVID-19 pandemic (Notteboom, Pallis, & Rodrigue, 2021). Secondly there is the possibility that a small number of vessels is missed by the automated vessel detection system of MarineTraffic. When taking this into account it can be assumed that the port call figures will be close to reality.

4.3.1 Irregularities

On average around 500 vessels arrive in the port of Rotterdam weekly. As can be seen in figure 4 the number port calls fluctuate weekly between 420 and 580 port calls. These fluctuations are approximately normally distributed (see figure 5).

In 2020 a downward sloping trend is visible. Although outside the scope of this research it is important to notice some major events throughout the year. Especially between week 18 and week 23 a strong decline is visible that might be related to the COVID-19 pandemic. Between these weeks the government imposed the firs measures to fight the virus including a partial lock-down at the end of this period. The increasing number of port calls between week 35 and 40 can be caused by the lift of most COVID-19 related measures in the Netherlands. In week 51 The Netherlands entered in a second lockdown that lasted into 2021.

Again, the port calls show a similar drop as during the first lock-down. Although it is not certain that these fluctuations are entirely caused by the measures against COVID-19 it is likely that they might have some effect on the number of port calls in Rotterdam.

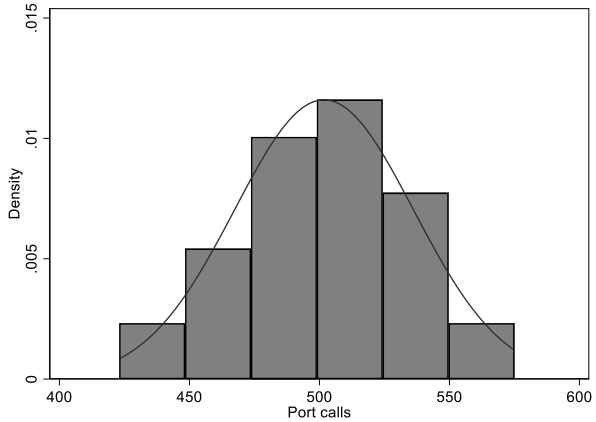


Figure 4: Distribution of weekly port calls 2020

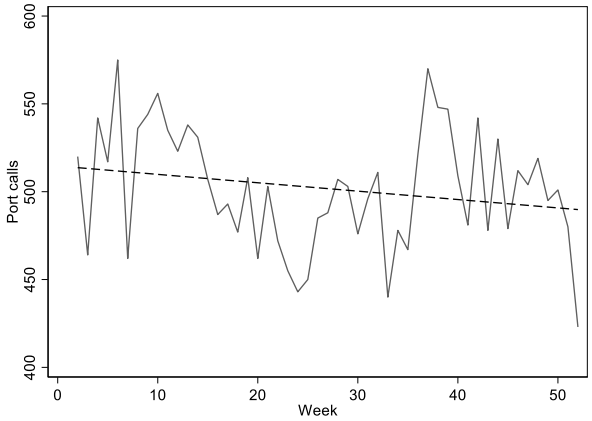


Figure 4: Weekly port calls 2020 and linear trend

In table 2 and figure 7 an overview can be found of the general statistics per port area. Like the overall statistics there is fluctuation in the number of port calls per week (see figure 6) In the centrum area only as very small number of vessels arrive weekly with large differences between the weeks. As no major cargo terminals are located in this area it only handles vessels in special circumstances that are not representative for the rest of the port. As a result, the data contains large outliers on both sides of the spectrum. The centrum area will therefore be excluded from further analysis to avoid biased results.

	Port area's						Total
	Botlek	Centrum	Maasvlakte	Europoort	Petroleumhavens area	Waalhaven area	Port of Rotterdam
Port calls (2020)	4.264	991	7.288	5.140	1.997	5.910	25.590
Average port calls (week)	84	19	143	101	39	116	502
	(17%)	(4%)	(28%)	(20%)	(8%)	(23%)	(100%)
Median time at anchor (days)	1,1	0,7	0,6	1,2	1,0	0,6	0,8
Median time in port (days)	1,3	0,7	1,2	1,2	1,3	0,8	1,1
Standard deviation of time at anchor (days)	1,9	0,4	2,0	3,0	2,0	2,4	2,3
Standard deviation of time in port (days)	1,9	2,2	1,4	2,5	1,3	2,7	2,1

Note: week 1 and 53 are excluded from the figures

Table 2: Port call statistics of the port of Rotterdam 2020

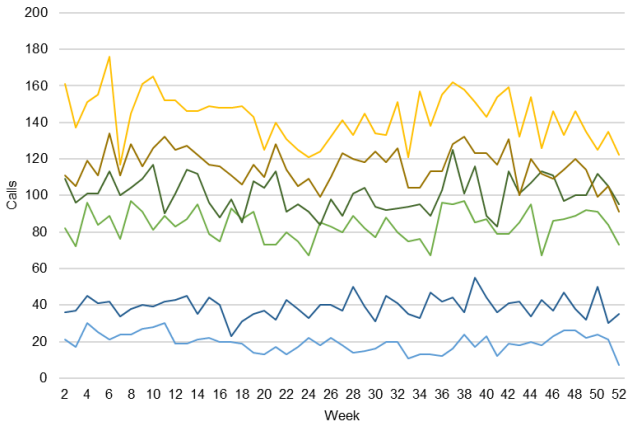


Figure 6: Weekly port calls in the port of Rotterdam 2020

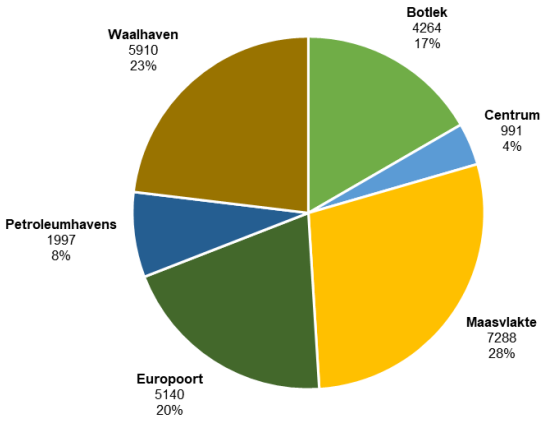


Figure 5: Distribution of port calls per area 2020

4.3.2 Time at anchor and time in port

Further analysis of the general statistics shows that there are major differences in time spent at anchorage between the various port areas. The area's can roughly divided into two groups that each serve approximately half of the arriving vessels. The first group consists out of the Europoort, Botlek and Petroleumhavens area. In these port area's the median time spent at anchor is between 1 and 1,2 days which is roughly twice as long as in the other port areas. As discussed before the time spent at anchor is largely dependent on the specific trade of the vessel. Bulk vessels generally spend more time at anchor than other vessels. This is not different in the Port of Rotterdam as these port areas primarily deal with liquid bulk and chemicals while the other areas serve mostly container and dry-bulk vessels.

Looking at the weekly figures both the median time spent in port and at anchorage shows great variance. In figure 8 and 9 an overview can be found of the median time at anchorage and in port including the standard deviation of these figures. An overview of the median time at anchor per port area can be found in annex 1 of this report. When analysing

the figures it becomes clear that the median time in port is relatively stable over time. This also holds for the standard deviation of time in port which fluctuates around 3 almost the entire year. The time at anchor fluctuates more especially when looking at specific port areas. Especially the standard deviation fluctuates massively which indicates that the time spent at anchor varies a lot from ship to ship in some weeks while not in others. This large variation makes planning the port call unpredictable.

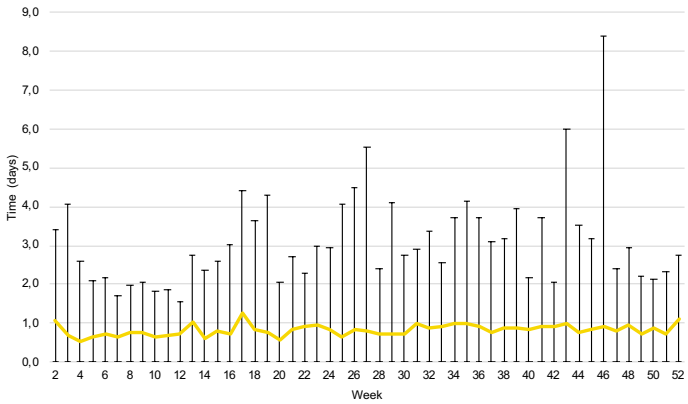


Figure 8: Median time and standard deviation of time at anchor 2020

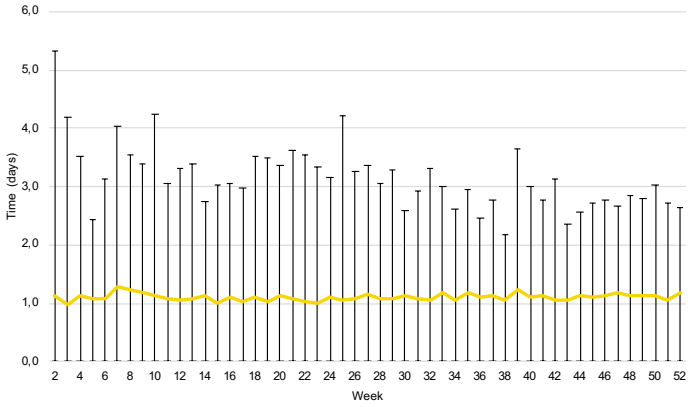


Figure 6: Median time and standard deviation of time in port 2020

4.3.3 Effect of the number of port calls

Lastly the relation between the number of port calls and the time spent in port or at anchor is investigated. A first analysis shows that there is no significant correlation (+3,7%) between the number of calls and the median time spent in port. This is the case both on the port level as well as on the area level. This is however different for the relation between the number of port calls and the time spent at anchor which shows a low negative correlation of around 13% on a port level. When looking on an area level there are again significant differences. A negative correlation of around 24% can be found in the Europoort and Petroleumhavens area while at the same time there is hardly any correlation in the Botlek and Maasvlakte (both negative around 1%).

In table 3 the relationship between the number of port calls and the time at anchor or in port is further examined by means of a OLS regression. As expected from the calculated correlation there is no significant effect of the number of port calls on the median time spent in port. There is however a significant negative effect of the number of port calls on the median time spent at anchor. On average 100 additional port calls will lower the time spent at anchor with 0,14 day or around 3 hours and 20 minutes. By adding fixed effects for the various port areas the predictability of the model increases significantly but it does not affect the effect of the number of port calls. It is counter-intuitive that the time spent at anchor is lower during busy weeks. If the port would have had capacity issues the waiting time would have increased

during busier weeks. Since this is not the case it is possible that the port has sufficient availability of berths and other services even in busy weeks. The effect could also be explained by the fact that in quite weeks the waiting time is longer not because the vessel is waiting to enter the port but because it has no next cargo assignment. This argument is supported by the global drop in shipping demand caused by the COVID-19 pandemic. It is hard to tell what causes the decrease in time at anchor during busy weeks exactly and further research would be needed to answer this questions.

	Dependent variable:			
	Median time at anchorage		Median time in port	
	OLS	OLS + FE	OLS	OLS + FE
	(1)	(2)	(3)	(4)
Total port calls	-0,014**	-0,014**	0,002	0,002
(10 calls)	(0,007)	(0,006)	(0,002)	(0,002)
Maasvlakte		-0,457***		-0,161***
		(0,045)		(0,024)
Europoort		0,098		-0,075**
		(0,063)		(0,023)
Botlek		-0,055		-0,053*
		(0,065)		(0,031)
Waalhaven		-0,445***		-0,502***
		(0,056)		(0,020)
Constant	1,582***	1,753***	1,033***	1,191***
	(0,335)	(0,282)	(0,205)	(0,120)
Observations	255	255	255	255
R-squared	0,015	0,382	0,001	0,669

*Note: * p < 0,1; ** p < 0,05; *** p < 0,01*

Table 3: OLS regression analysis of the relation between the number of port calls and the time spent at anchor or in port

4.4 Summarizing

Analysing AIS data can be a useful tool to get an insight into the port call process of a port. AIS data of all arrivals and departures in 2020 in the port of Rotterdam was collected and analysed. The data shows that on average a vessel spends around a day at anchor before entering the port. Both the median time at anchor and the standard deviation of the time at anchor varies from week to week. Where the time spent at anchor tends to fluctuate this is not the case for the median time spent in port. In the next chapter the results of this quantitative research will be discussed further in light of implementing just-in-time arrival.

5. Just-in-time arrival in the port of Rotterdam

In the previous chapter the current port call process in Rotterdam was examined by means of AIS data. Together with the knowledge of the first two chapters it is now possible to analyse if just-in-time arrival would benefit the port authority of the port of Rotterdam. After analysing the potential benefits the implementation process will be discussed including the need for cooperation with other ports.

5.1 Can just-in-time arrival be beneficial to the port of Rotterdam?

The AIS data shows that the port call process in Rotterdam is not different than what is described in the literature. Vessels still spend on average a day at anchorage before they enter the port. From the data it is not possible to determine what the reason for anchoring is but it is safe to assume that a significant share is caused by the unavailability of the berth or other port services. For the many stakeholders in the port, such as carriers and terminals, this is inefficient and makes the port call process unpredictable. Especially since the median time spent at anchor and the standard deviation of this time varies a lot over time.

In the Europoort and Botlek vessels spend on average the most time at anchor before docking . Most vessels docking in these areas are liquid bulk carriers of which it is common to be at anchor for extensive periods of time. But even in areas such as the Maasvlakte where the median time at anchor is much lower the time is still substantial. An in depth analysis of 61 arriving deep-sea vessels in March 2019 show similar results. Of these 61 calls 30 dropped anchor or manoeuvred very slowly in the vicinity of Rotterdam before they dock (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

As a result the anchorage is busy which could lead to collisions and other incidents. A good example of the risks of a busy anchorage can be found in the incident report of the Dutch Safety Board on the collision between the MS Arklow Rambler and the MT Atlantic Jupiter back in 2016. An overly crowded anchorage area in combination with bad weather conditions resulted in a collision with significant damage for both vessels (Dutch Safety Board, 2017). Even though such major incidents are rare in the port of Rotterdam there are on average still more than 100 incidents each year of which some of them occur in the anchor area. The ambition of the port authority is to have a nautical safety score of at least 7.0. Major incidents heavily affect the safety score of the port and it is therefore top priority to prevent them from happening (Port of Rotterdam, 2019). By implementing just-in-time arrival the anchorage area will be significantly less crowded which would improve the safety of the port. This will not prevent major accidents outside the anchor area from happening but it will be a good contribution to the nautical safety index.

The busy anchorage areas also produce a significant amount of emissions close to the city of Rotterdam. This is an issue that must be solved if the port of Rotterdam wants to meet the sustainability ambitions set out in their strategy. Not only their own ambitions are demanding a change. The city of Rotterdam, the national climate agreement of 2019 and the European green deal force the port to become more sustainable (Port of Rotterdam, 2019). Of course implementing just-in-time arrival will not be the only needed measure to become a more sustainable port but it can make a significant contribution. TNO in collaboration with the Port of Rotterdam (2018) estimate that a reduction of the average anchor time with 12 hours this will lead to 35% less emissions yearly.

Lastly Nair (2020) is of the opinion that the improved predictability of a port call should not be underestimated in a large complex port as the port of Rotterdam. Although hard to quantify what the exact advantages would be it could significantly help during peak loads in the port. The AIS data has shown that the port of Rotterdam faces such peaks on a regular base. When handling these peak loads effectively this will improve the reliability of the port and ultimately the competitive position of the port of Rotterdam.

5.2 Implementing just-in-time arrival

According to GIA (2020) one of the first crucial steps for a port authority when implementing just-in-time arrival is to make it part of the port strategy. The port of Rotterdam has done so and is already working on implementing just-time arrival for quite some time (Port of Rotterdam, 2019). As member of GIA they play an active role in developing and implementing the concept. As discussed in chapter 3 implementing a good working port communication system is a pre-requisite for implementing just-in-time arrival. That's why the Port of Rotterdam launched Pronto in 2018. Pronto was designed as a collaborative vessel and terminal planning platform. Over the years pronto became a fully functioning platform that is now available to other ports as well as PortXchange. The platform now contains all the required communication and planning tools for just-in-time arrival (PortXchange, 2020).

Simulations and pilots with PortXchange have shown the potential of just-in-time arrival. In order to implement in in a larger scale the port authority has to actively motivate the actors in the port to join the platform (Port of Rotterdam, 2020). In collaboration with the GIA they wrote an implementation guide that can be used by other ports. It would to my opinion be beneficial to start cooperating with other ports and actively motivating them to start with just-in-time arrival. As discussed in the previous chapters cooperation between ports is essential for implementing just-in-time arrival. On their own the port of Rotterdam cannot change the industry but together with other ports they can improve the efficiency of a port call while at the same time achieving their own goals to become a safe, sustainable and reliable port.

5.3 Summarizing

Analysis of the current port call process in Rotterdam shows that the process has the same issues as the process in many other ports. After implementing just-in-time arrival the port authority would benefit from lower emission, higher safety and more efficient planning of port services. The port authority has already made some important progress by developing the PortXchange platform and motivating the industry to implement just-in-time arrival. By cooperating with other ports and promoting the concept they can move to the next stage where just-in-time arrival becomes reality.

5. Conclusion & Discussion

This researched focused on the concept of just-in-time arrival in the maritime industry The goal was to answer the following main question:

"What are the benefits of just-in-time arrival for the port authority of the Port of Rotterdam and what is their required role in the process?"

In order to answer the main question this research started with an literature study into port cooperation. A necessity as port cooperation is a needed element for successfully implementing just-in-time arrival. Traditionally ports compete with each other in order to attract the largest share of freight. Trends and developments in the maritime industry have motivated ports to also explore the potential of cooperation. Cooperation between ports is becoming more and more common on all kinds of areas such as knowledge sharing and traffic management. By cooperating ports gain all kinds of advantages such as a stronger competitive position or economies of scale. Depending on the area of cooperation different structures are possible each with their own strengths and weaknesses.

After the topic of port cooperation the current port call process was examined. This showed that the port call process is complex and involves many different actors. It also clearly showed the flaws of the current port call process and why just-in-time arrival is needed. The current mode of operation is that most vessel rush to the port of arrival only to find out that the port or its services are not ready to receive the vessel. As a result they spend hours and sometimes even days waiting at anchor before they can finally make their final approach to the berth. The concept of just-in-time arrival aims to solve this issue by adjusting the speed of the vessel in such way that it arrives at the port when it is ready to receive the vessel. Although the concept is simple many barriers need to be passed before it can be successfully implemented. The port authority plays a key role in overcoming some of these barriers. They can however not do this on their own and need to cooperate with other parties including other ports. If they succeed the benefits of just-in-time arrival for port authorities are substantial. This includes the reduction of emission in the vicinity of the port, the more efficient use of port services and infrastructure and less traffic in the anchor zone. In order to achieve this port cooperation with other ports is essential as it requires for example standardization of timestamps. Additionally to reach the full potential of just-in-time arrival extensive cooperation between ports is needed on the field of joint management of arrivals and departures.

With the needed knowledge on port cooperation and just-in-time arrival collected the research focused on the port of Rotterdam. By means of AIS tracking data the port call process in the port of Rotterdam was examined. The results show that the known flaws of the current

port call process are likely to be present in Rotterdam as well. Most vessels arriving in Rotterdam have to wait at anchor for some time before they can enter the port. Implementing just-in-time arrival could be a good solution to tackle this problem. The port authority will likely benefit from a reduction of emissions close to the city, increased safety in the anchorage area and the ability to manage port services more efficiently. Although some important steps are already made by the port authority there is still work to be done to actually implement the concept.

Although this research gives some insights in the port call process in Rotterdam further research is needed to fully understand and improve it. First of all it would be better to analyse the unprocessed AIS data from marine traffic instead of the weekly median figures. This would allow a day to day analysis which could give a better understanding of the port call process. With the current data a busy start of the week could for example be compensated by a relatively quiet end of the week giving on average results that are not an accurate display of reality. It would also be interesting to see if the anchor time during weekends or during night time is different from the anchor time during week days or daytime. Unprocessed AIS data would also allow individual analysis of specific terminals, ships and trades. This would allow lead to a better understanding of the flaws in the current port call process which is not possible with the current dataset.

Further analysis would also benefit from observing more variables. By collecting more data such as the expected arrival time, the requested arrival time and the availability of berths and port services it would be possible to examine if vessels are waiting in the anchor area due to the unavailability of a berth or port services or because of another reason. With the used dataset it is not possible to distinguish why vessels are waiting at anchor. Not all anchor time can be eliminated by just-in-time arrival such as anchoring for maintenance or waiting for the next cargo assignment. Determining the reason for waiting at anchor is therefore important if you want to know what the exact reduction of anchor time could be when implementing just-in-time arrival. With the current dataset it is only possible to roughly estimate this effect based on figures in academic literature regarding the port call process in general and not specifically of the port call process in Rotterdam. Lastly it would be recommended to conduct a broader research into the port call process. This includes observing the port call process in Rotterdam over multiple years and comparing the performances of Rotterdam with other ports that have comparable characteristics.

It would also be interesting to take a closer look at the effect of just-in-time arrival on the competitive position of a port. Existing studies primarily focus on the direct benefits of just-in-time arrival but it would be beneficial for port authorities to know what implementing just-in-time arrival does to their competitive position. As the competitive position of the port is a major concern for the port authority it is important for them to know what the effect of implementing

just-in-time is on their competitive position. Also the direct benefits of just-in-time arrival need some more attention. Most existing literature describe the advantages of the concept without quantifying them. It would be beneficial for all actors involved in the port call process to know what their exact benefits are when implementing just-in-time arrival

Due to the limitations of the research no final conclusions can be drawn with regards to the port call process in Rotterdam and the exact benefits of implementing just-in-time arrival. Nevertheless this research can be seen as an indication that implementing just-in-time arrival could be beneficial for the Port of Rotterdam and as a solid reason for further research on the topic .

Literature List

Airriess, C. A. (2001). The regionalization of hutchison port holdings in mainland china. *Journal of Transport Geography, 9*(4), 267-278. doi:https://doi.org/10.1016/S0966-6923(01)00020-5

Baughen, S. (2019). *Shipping law* (Seventh edition ed.). London: Routlege. Retrieved from http://bvbr.bib-bvb.de:8991/F?func=service&doc_library=BVB01&local_base=BVB01&doc_number=031582099&sequence=000001&line_number=0001&func_code=DB_RECORDS&service_type=MEDIA

Becha, H., Lind, M., Simha, A., Bottin, F., & Larsen, E. (2020, May 14). Standardization is Key to Boosting Economies of Scale. The Maritime Executive. https://www.maritime-executive.com/blog/standardization-is-key-to-boosting-economies-of-scale

Brooks, M. R., & Pallis, A. A. (2012). *Port governance* doi:10.1002/9781444345667.ch25

Brooks, M., & Pallis, A. (2011). Port governance. (pp. 491-516) doi:10.1002/9781444345667.ch25

Donselaar, P. W., & Kolkman, J. (2010). Societal costs and benefits of cooperation between port authorities. *Maritime Policy & Management, 37*(3), 271-284. doi:10.1080/03088831003700660

Ducruet, C., Joly, O., & Le Cam, M. (2013). *The french port complex of the seine corridor.* (). Retrieved from https://www.espon.eu/sites/default/files/attachments/TIGER_working_paper_16_-_portlehavreCS.pdf

Dutch Safety Board. (2017). *Collision in anchorage area - incident report.* ().

Galvao, C. B., Gharehgozli, A., & Mileski, J. (2018). Being left at the altar: A content analysis of the ports of houston and galveston merger case that never happened. *Research in Transportation Business & Management, 26*, 34-44. doi:https://doi.org/10.1016/j.rtbm.2018.02.002

Geerlings, H., Kuipers, B., & Zuidwijk, R. (2018). *Ports and networks* (1st ed.). Florence: Routledge. doi:10.4324/9781315601540 Retrieved from https://www.taylorfrancis.com/books/e/9781315601540

GEF-UNDP-IMO GloMEEP Project and members of the GIA. (2020). *Just in time arrival guide: Barriers and potential solutions.* ().

GIA. (2020). *Just in time arrival guide – barriers and solutions.* (). London: IMO.

Grzelakowski, A. S. (2009). Maritime transport development in the global scale – the main chances, threats and challenges . *International Journal on Marine Navigation and Safety of Sea Transportation, 3*(2), 197-205. Retrieved from https://www.transnav.eu/pdf/0155.pdf

Heaver, T., Meersman, H., & Van De Voorde, E. (2001). Co-operation and competition in international container transport: Strategies for ports. *Maritime Policy & Management, 28*(3), 293-305. doi:10.1080/03088830110055693

IMO, & Port of Rotterdam. (2019). Shipping, ports, terminals and service providers tackle barriers to the just-in-time operation of ships. Retrieved from https://www.portofrotterdam.com/en/news-and-press-releases/shipping-ports-terminals-and-service-providers-tackle-barriers-to-the-just

Inoue, S. (2018). Realities and challenges of port alliance in japan — ports of kobe and osaka. *Research in Transportation Business & Management, 26*, 45-55. doi:https://doi.org/10.1016/j.rtbm.2018.02.004

International Taskforce Port Call Optimization. (2017). *A reliable port starts with reliable information.* (). Retrieved from https://portcalloptimization.org/images/Flyer%20port%20call%20optimization%20201012%20(1).pdf

International Taskforce Port Call Optimization. (2020). *Appendix to port call process.* (). Retrieved from https://portcalloptimization.org/images/Business%20process%20appendix%20200406.pdf

Jacobs, W. (2007). PORT COMPETITION BETWEEN LOS ANGELES and LONG BEACH: AN INSTITUTIONAL ANALYSIS. *Tijdschrift Voor Economische En Sociale Geografie, 98*(3), 360-372. doi:10.1111/j.1467-9663.2007.00403.x

Johnson, H., & Styhre, L. (2015). Increased energy efficiency in short sea shipping through decreased time in port. *Transportation Research Part A: Policy and Practice, 71*, 167-178. doi:https://doi.org/10.1016/j.tra.2014.11.008

Juhel, M. (2000). Globalization and partnerships in ports: Trends for the 21st century. *Ports and Harbours,* (45), 9-14.

Li, J., & OH, Y. (2010). A research on competition and cooperation between shanghai port and ningbo-zhoushan port. *The Asian Journal of Shipping and Logistics,* (26), 67-92.

Lind, M., Bergmann, M., Haraldson, S., Watson, R., Park, J., Gimenez, J., & Andersen, T. (2018). *Port collaborative decision making (PortCDM): An enabler for port call optimization empowered by international harmonization the shipping industry seeks increased efficiency in port operations.* (). Retrieved from https://www.researchgate.net/publication/329673607_Port_Collaborative_Decision_Making_PortCDM_An_enabler_for_Port_Call_Optimization_empowered_by_international_harmonization_The_shipping_industry_seeks_increased_efficiency_in_Port_Operations

Lind, M., Ward, R., Bergmann, M. & Haraldson, S. (2019). How to boost port call operations. Retrieved from https://www.globalmaritimeforum.org/news/how-to-boost-port-call-operations?utm_content=bufferd6823&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer

McCalla, R. J., Palla, A., & Van der Lugt, L M. (2011). Strategic cooperation in peripheral ports: The case of atlantic canada's ports . *Canadian Journal of Transportation,* (4) Retrieved from https://journalhosting.ucalgary.ca/index.php/cjt/article/view/15838

Medda, F., & Trujillo, L. (2010). Short-sea shipping: An analysis of its determinants. *Null, 37*(3), 285-303. doi:10.1080/03088831003700678

Meersman, H., Voorde, E. v. d., & Vanelslander, T. (2009). *Future challenges for the port and shipping sector*. London: Informa Law. Retrieved from https://eur.on.worldcat.org/oclc/299365772

Michaelides, M., Herodotou, H., Lind, M., & Watson, R. (2019). Port-2-port communication enhancing short sea shipping performance: The case study of cyprus and the eastern mediterranean. *Sustainability (Basel, Switzerland), 11*(7), 1912. doi:10.3390/su11071912

Nair, A. (2020). Just in time arrivals– what's in it for port authorities? Retrieved from https://port-xchange.com/blog/just-in-time-arrivals-whats-in-it-for-port-authorities/

Ng, K. Y. (2006). Assessing the attractiveness of ports in the north european container transhipment market: An agenda for future research in port competition. *Maritime Economics & Logistics, 8*(3), 234-250. doi:10.1057/palgrave.mel.9100158

Notteboom, T. (2004). Container shipping and ports: An overview. *Review of Network Economics, 3*, 86-106. doi:10.2202/1446-9022.1045

Notteboom, T. E. (2010). Concentration and the formation of multi-port gateway regions in the european container port system: An update. *Journal of Transport Geography, 18*(4), 567-583. doi:https://doi.org/10.1016/j.jtrangeo.2010.03.003

Notteboom, T. E., & Winkelmans, W. (2001). Structural changes in logistics: How will port authorities face the challenge? *Maritime Policy & Management, 28*(1), 71-89. doi:10.1080/03088830119197

Notteboom, T., Pallis, T., & Rodrigue, J. (2021). Disruptions and resilience in global container shipping and ports: The COVID-19 pandemic versus the 2008–2009 financial crisis. *Maritime Economics & Logistics,* doi:10.1057/s41278-020-00180-5

Notteboom, T. (2021, January 19). Guest Lecture - Covid-19 pandemic and port resilience [Slides]. Canvas EUR. https://canvas.eur.nl/courses/31965/files/37392729?module_item_id=548939

Notteboom, T., & Yap, W. Y. (2012). *Port competition and competitiveness* doi:10.1002/9781444345667.ch27

Port of Rotterdam. (2018). 'Just-in-time' sailing saves hundreds of thousands of tonnes of CO2. Retrieved from https://www.portofrotterdam.com/en/news-and-press-releases/just-in-time-sailing-saves-hundreds-of-thousands-of-tonnes-of-co2

Port of Rotterdam. (2019). Blijven werken aan de toekomst - jaarverslag 2019.

Port of Rotterdam. (2021, January 21). Nautische cijfers haven Rotterdam: een veilig en druk jaar, iets minder schepen. https://www.portofrotterdam.com/nl/nieuws-en-persberichten/nautische-cijfers-haven-rotterdam-2020

Poulsen, R. T., & Sampson, H. (2019). 'Swinging on the anchor': The difficulties in achieving greenhouse gas abatement in shipping via virtual arrival. *Transportation Research Part D: Transport and Environment, 73*, 230-244. doi:https://doi.org/10.1016/j.trd.2019.07.007

Shinohara, M., & Saika, T. (2018). Port governance and cooperation: The case of japan. *Research in Transportation Business & Management, 26*, 56-66. doi:https://doi.org/10.1016/j.rtbm.2018.02.009

Slack, B. (1993). Pawns in the game: Ports in a global transportation system. *Growth & Change, 24*(4), 579. doi:10.1111/j.1468-2257.1993.tb00138.x

Stopher, P. R., & Stanley, J. (. p. (2014). *Introduction to transport policy : A public policy view*. Cheltenham, UK ;: Edward Elgar. Retrieved from https://eur.on.worldcat.org/oclc/865491986

Talley, W. K. (2012). *The blackwell companion to maritime economics*. Malden, Mass.: Wiley-Blackwell. Retrieved from https://eur.on.worldcat.org/oclc/778431594

Tang, O. (2010). Ports in proximity - competition and coordination among adjacent seaports, edited by theo notteboom, cesar ducruet, and peter de langen. *Maritime Policy & Management, 37*(5), 541-542. Retrieved from https://eur.on.worldcat.org/oclc/668997557

TNO, & Port of Rotterdam. (2018). Just-in-time' sailing saves hundreds of thousands of tonnes of CO2. Retrieved from https://www.portofrotterdam.com/en/news-and-press-releases/just-in-time-sailing-saves-hundreds-of-thousands-of-tonnes-of-co2

Trujillo, L., Campos, J., & Pérez, I. (2018). Competition vs. cooperation between neighbouring ports: A case study in chile. *Research in Transportation Business & Management, 26*, 100-108. doi:https://doi.org/10.1016/j.rtbm.2018.03.005

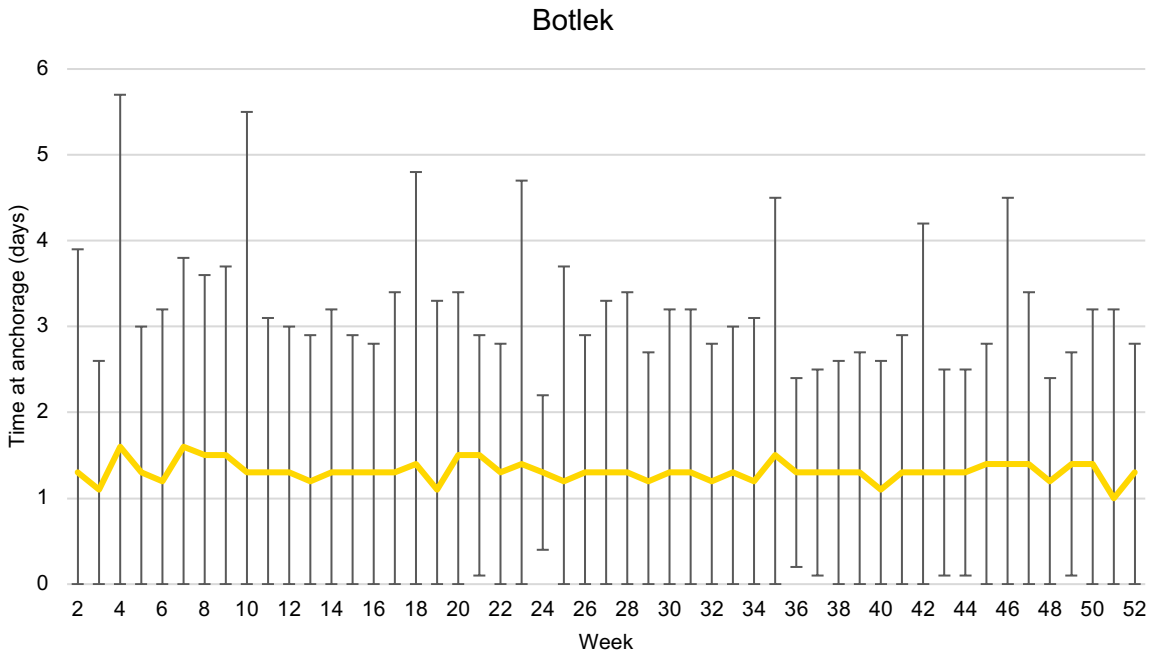
UNCTAD. (2017). *Review of maritime transport, 2016.* ().

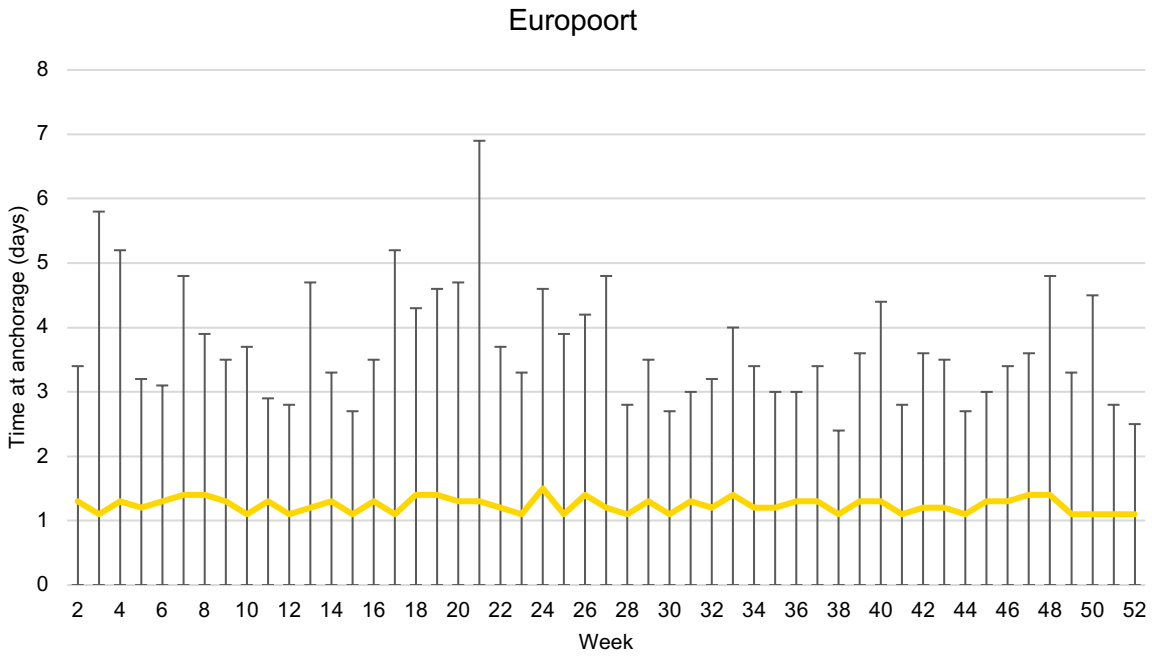
UNCTAD. (2019). *Review of maritime transport 2019.* (). New York: United Nations Publications. Retrieved from https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf

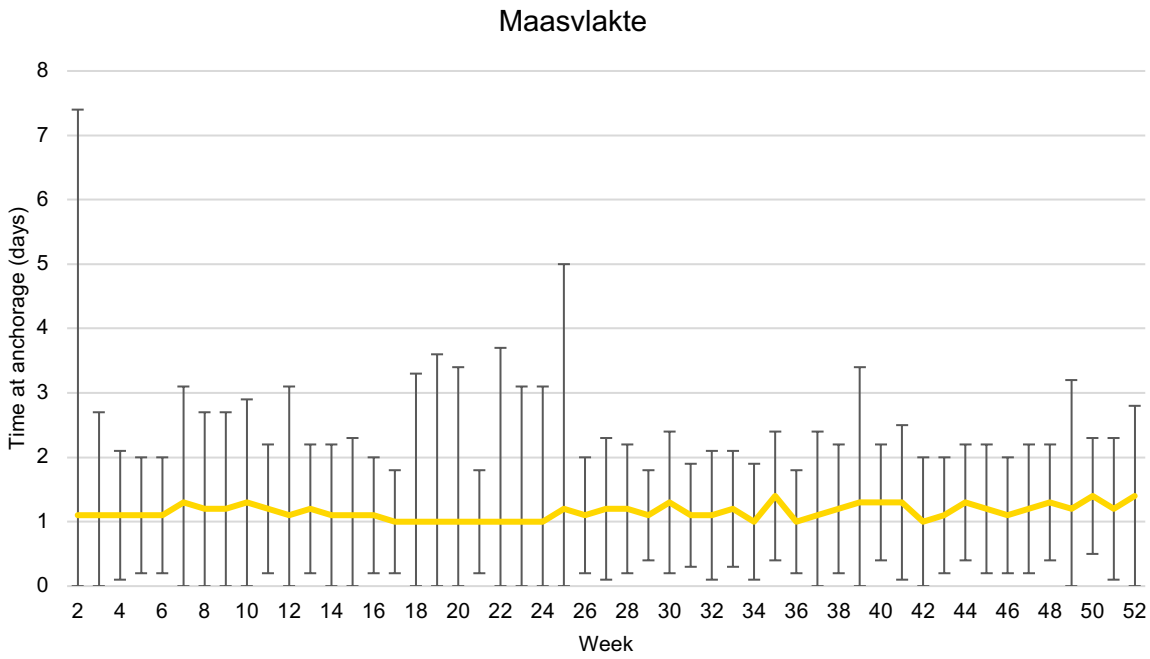
Wang, K., Ng, A. K. Y., Lam, J. S. L., & Fu, X. (2012). Cooperation or competition? factors and conditions affecting regional port governance in south china. *Maritime Economics & Logistics, 14*(3), 386-408. doi:10.1057/mel.2012.13

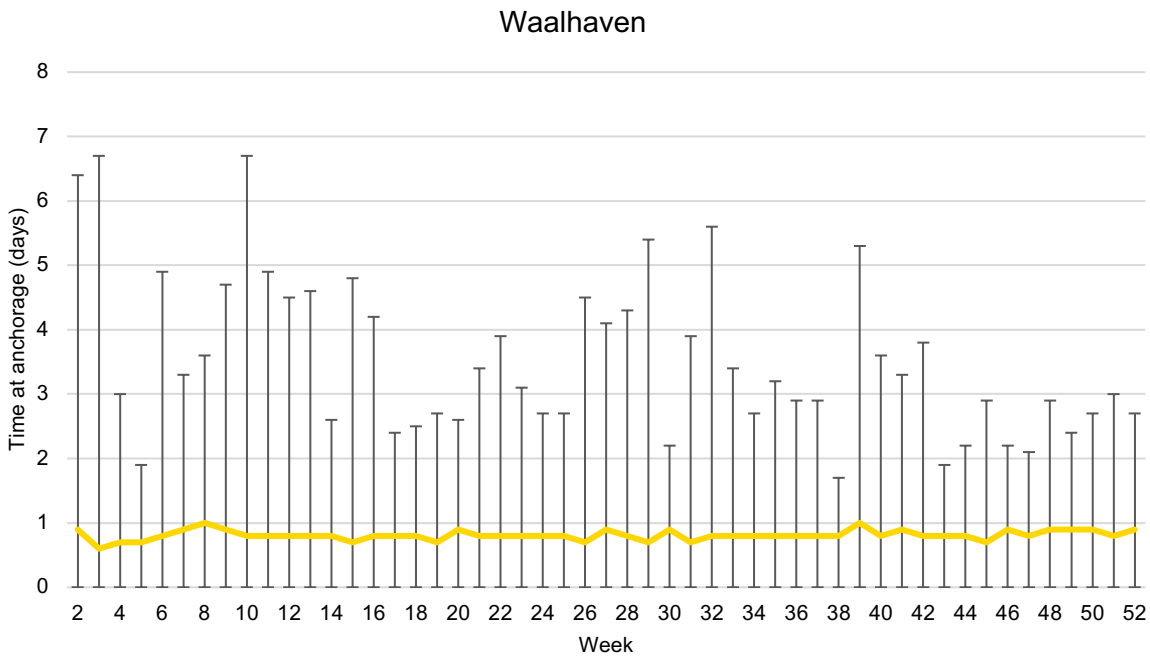
Yvonne Baatz. (2020). *Maritime law*. Milton: Taylor and Francis. doi:10.4324/9781003046943 Retrieved from https://www.taylorfrancis.com/books/9781000202786

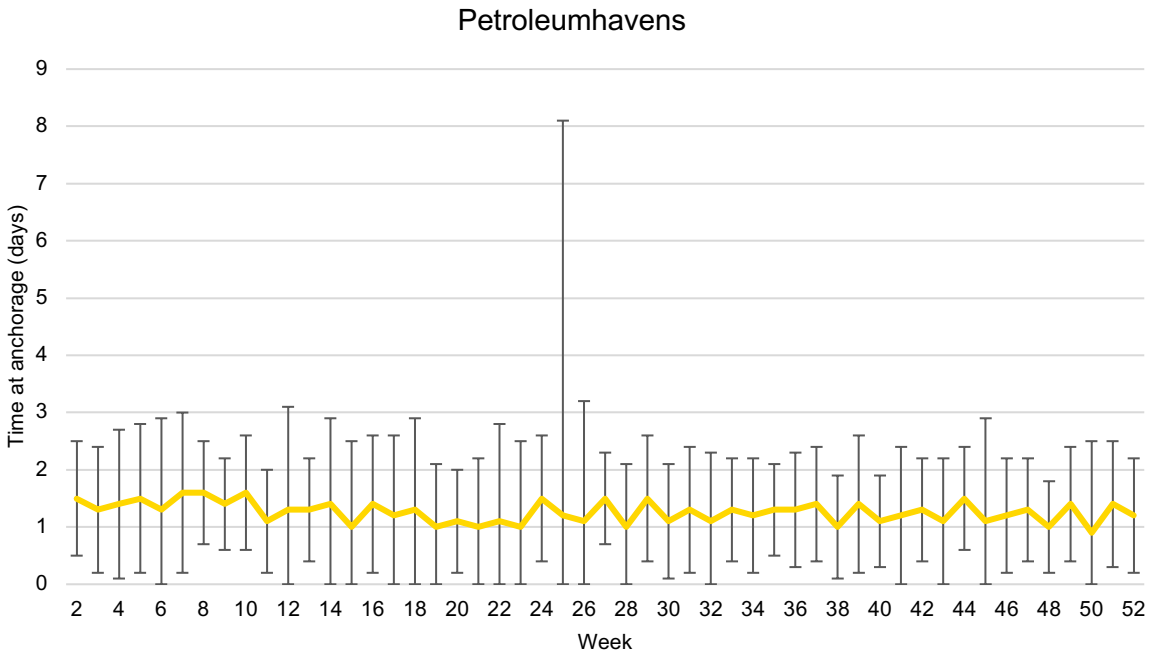
ANNEX 1: Median and standard deviation of time at anchor per port area 2020






Maasvlakte
Time at anchorage (days)
0
1
2
3
4
5
6
7
8
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Week


Waalhaven
Time at anchorage (days)
0
1
2
3
4
5
6
7
8
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Week


Petroleumhavens
Time at anchorage (days)
0
1
2
3
4
5
6
7
8
9
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Week