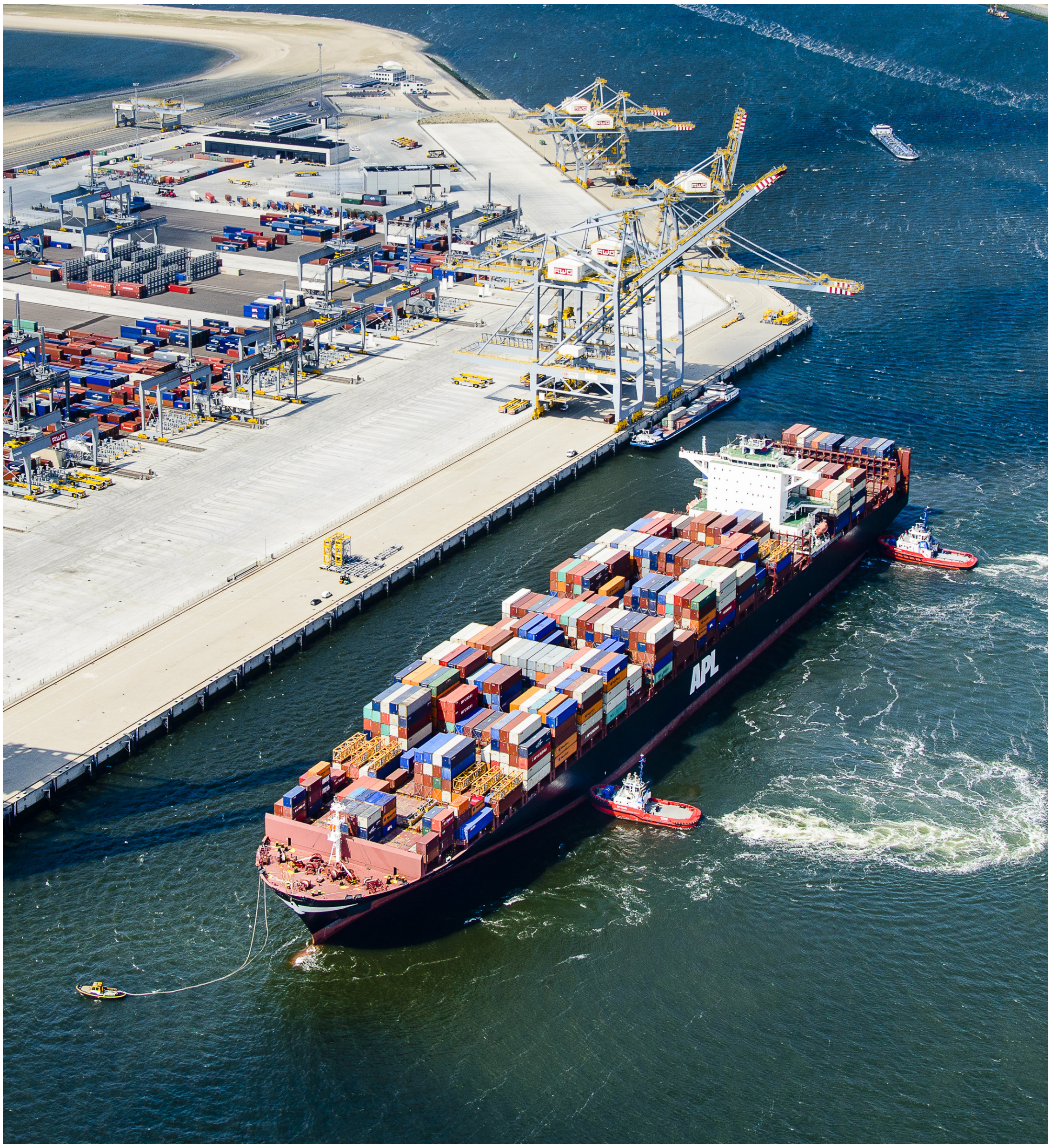
Identifying the relations between and mapping the processes of the nautical service providers in the Port of Rotterdam



MSc Thesis

A.M. Verduijn

Thesisnumber: SDPO.17.041.m

CONFIDENTIAL

20-12-2017

TU Delft   Port of Rotterdam

Thesis for the degree of MSc in Marine Technology in the specialization of Shipping Management

Identifying the relations between and mapping the processes of the nautical service providers in the Port of Rotterdam

By

Alexander Martijn Verduijn

Performed at

Port of Rotterdam

This thesis (SDPO.17.041.m) is classified as confidential in accordance with the general conditions for projects performed by the TUDelft.

20-12-2017

Company supervisor
Responsible supervisor: R. Seignette

Thesis exam committee
Chair/Responsible Professor: Prof. dr. E.M. Van de Voorde
Staff Member: Ir. J.W. Frouws
Staff Member: Dr. J. Rezaei
Company Member: R. Seignette

Author Details
Studynumber: 4008723
Author contact e-mail: sanderverduijn@gmail.com

Preface

With pleasure I present my graduation thesis. This thesis report is part of the final assignment of the master program Marine Technology, specialization Shipping Management at the Delft University of Technology.

This thesis is performed at the Harbour Master division of the Port of Rotterdam Authority. With great joy I observed and mapped all the complex processes that take place in the nautical chain of the biggest port in Europe.

It would not have been possible to finalize this thesis without the support and cooperation of many people. First of all, I would like to thank all my colleagues at the Port of Rotterdam for their support and interest in my research. Special thanks go out to Raymond Seignette, my daily supervisor at the port, whose knowledge and experience were critical to my research.

Secondly, I would like to thank Eddy Van de Voorde, Koos Frouws and Masoud Khakdaman for all their constructive feedback and advice, which guided me towards this final report. I also want to thank Jafar Rezaei for joining my exam committee and taking the time to review my thesis research.

Last but not least, I would like to express my gratitude to my family and friends, whose support was invaluable during the hard times this past year.

Sander Verduijn
Rotterdam, December 2017

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List of Abbreviations

ABM Agent Based Model

ACM Autoriteit Consument & Markt (*Authority for Consumers and Markets*)

AIS Automatic Identification System

ARAMIS Advanced Radar Monitor and Information System

ATA Actual Time of Arrival

ATD Actual Time of Departure

COS Coordination tool Oversized Ships

DANA Dynamic Actor Network Analysis

DSA Delft Systems Approach

ECT Europe Container Terminal

ETA Expected Time of Arrival

ETD Expected Time of Departure

GenCLOn Generic City Logistic Ontology

GIDS Gemeenschappelijk Informatie Dienstverleners Systeem

HaMIS Havenmeester Management Informatiesysteem (*Harbour master Management Information System*)

HCC Haven Coördinatie Centrum (*Harbour Coordination Centre*)

INSP Inspection

IPCSA International Port Community Systems Association

ISPS International Ship and Port facility Security Code

KPI Key Performance Indicator

NoA Notice of Arrival

NoD Notice of Departure

NSP Nautical Service Provider

NWO Nederlandse organisatie voor Wetenschappelijk Onderzoek (*Netherlands Organisation for Scientific Research*)

PCS Port Community System

PoR Port of Rotterdam

PV Patrol-vessel

R&D Research & Development

SBP Shore Based Pilotage

SPIL Systeem voor Planning en Inzet Loodsen

VTS Vessel Traffic Service

List of Definitions

Some definitions used in this master thesis are given here, it should be noted that this list is not exhaustive.

Administrative Clearance The clearance given by the HCC that, based on the electronic port-call notification, the vessel is allowed to enter the port. This is followed by the operational clearance

Electronic port-call notification The notification to the concerning parties that a vessel will call the port. This notification contains information on the vessel and her intentions

Gangway down For arriving vessels, this is moment that the vessel is completely moored at her berth and the nautical chain process has ended

Nautical chain 1) all the events of the nautical service providers in the operational domain performed for a vessel during the time that vessel is sailing in the Port of Rotterdam 2) and the information shared in the tactical domain to support the events in the operational domain.

Operational clearance The clearance given by the HCC that a vessel is allowed to enter the port

Operational domain The actions taken in the period that vessel starts her voyage into or out of the port until the time she is berthed or departed

Port call All the voyages of a vessel in the port from arrival to departure

Shore Based Pilotage When pilotage is amended, vessels can be piloted from shore. This is done by specially trained pilots located at the Traffic Centre Hoek of Holland.

Strategical domain The period before the vessel arrives in the VTS-area of the Port of Rotterdam

Tactical domain The information exchange and planning of the nautical service providers between ETA-24 or ETD-2 and the time the vessel start her voyage into or out of the port

Voyage A vessel movement in the port, this can be an arriving, departing, shifting or transit journey

Summary

This master thesis research is conducted in order to benefit the SwarmPort project. The SwarmPort project aims to develop an Agent Based Model (ABM) of the nautical chain in the Port of Rotterdam in order to improve its efficiency. To develop such a simulation model a consistent framework of the nautical has to be created. This master thesis creates such a framework.

To create the framework two analyses are performed, an actor analysis and a process analysis. The actor analysis encompasses a stakeholder analysis and a business model analysis. These analyses are performed to discover the drivers and interests of the actors operating in the nautical chain.
The actors analysed in this research are the Harbour Master, the pilot-organisation, tugboat-companies, the boatmen-organisation, terminals and vessels.

The process analysis consists of three parts.
First, the environment of the nautical chain is described, upon this environment the simulation model will be based. The environment consists of the port network, parameters, rules and regulations, and the voyages in the Port of Rotterdam.
The port is divided into various sections to form the network. The rules and regulations are linked to these sections. The voyages in the Port of Rotterdam are analysed with the help of data. The voyages are described with an average duration, standard deviation and number of voyages, for all voyage types.

The second part of the process analysis discusses the actors and their involvement in the nautical chain. This is done by describing the actors' relevant processes in the nautical chain and by analysing the interactions between and dependencies of the actors. The process descriptions are supported by data on, for example, capacities, locations and process durations.

Lastly, the information that is shared between the actors in the nautical chain, and the systems used for this are explained.

The framework provided in this master thesis may be used to construct the agent based model. This simulation model will be able to simulate voyages in the Port of Rotterdam and the corresponding actions of the actors in the nautical chain. By changes in the processes or information exchange the simulation model may find efficiency improvements.

The framework provided in this master thesis is the first step in developing the Agent Based Model. Recommendations are given to further improve the modelling of the actors in the nautical chain.

1 Introduction

This master thesis project is part of the larger SwarmPort project. First, the SwarmPort project will be briefly explained after which the role this thesis within the project will be discussed.

Background

Within seaports various services are provided that support a ship when it is entering or leaving the port, forming the so-called nautical chain. Examples of these services are piloting and mooring. These services play a key role in determining the turnaround time of a ship, an important factor in the competitiveness of ports. Making sure that this chain of services is a well-organised entity is thus essential.
The nautical chain in the Port of Rotterdam has no central command, there is no actor that directs the entire process. All the actors together contribute to the performance of the chain, it is self-organising. An explanation of the nautical chain regarding this research is found in section 1.1.

There are different aspects that impact the performance of the nautical chain, like the dynamic nature of the demand for services, external circumstances as the weather, the performance of the service providers as well as the collaborations between them.
The nautical chain is represented by various service providers, in this research called actors. The actors in the context of the master thesis are: the vessel, the terminal, pilots-organisation, tugboat-companies, boatmen-organisation and the vessel traffic services (Port of Rotterdam authority). All these actors take part in the nautical chain, from the moment the vessel enters the Port of Rotterdam area until that time the vessel is completely moored at the quay and vice-versa.

The continuous challenge is to find room for improvement in the efficiency of this nautical chain, on port-level. For example, through process agreements, information exchange and regulation. The evaluation of new strategies and policies can benefit greatly from quantitative models. Due to the complexity of the system or network of nautical services creating such models is not a trivial task. To be able to create the models new research is needed.
The SwarmPort project will use knowledge from complexity science in combination with logistic research to develop a quantitative model. The aim of the SwarmPort project is threefold:

1. To improve the understanding of the self-organisational properties of the chain of nautical handling processes directed at maritime ships around seaports, from arrival to departure.
2. To develop valid and practicable methods for modelling port operational processes, implementing agent based modelling from a self-organisational, complex system perspective.

3. To design strategies based on self-organisational properties of port processes to increase the resilience, reliability and flexibility of services of individual actors and of the aggregate service chain.

Thus to create an agent based model of the nautical chain of the Port of Rotterdam to find and test possible efficiency improvements, a clear and recent multi-agent framework has to be created which described the processes and the relations of the nautical chain and the service providers within the chain.

Opportunity

Currently the nautical chain of the Port of Rotterdam operates proficient. The handling of the sea-going vessels occurs in many cases efficient and safe. There is no urgent need to make big changes within the nautical chain but it is always a strive to reach a greater level of safety and higher efficiency. The reason for this strive is the pro-active attitude towards the market-demand for quality.
Greater efficiency and safety can be achieved, for instance, by changing regulations or structuring information-sharing among the nautical service providers. The goal of the SwarmPort project is to develop an Agent Based Model (ABM) that can find and evaluate possible improvements within the nautical chain.
To create such an ABM a clear and transparent picture of the nautical chain of the Port of Rotterdam is needed.
This master thesis aims to create that clear and transparent picture by performing an actor analysis and describing and quantifying the processes of the nautical chain.

Port of Rotterdam

The Port of Rotterdam wants to assure the quality of the nautical chain. To this end the Port of Rotterdam wants to closely monitor the nautical chain. Since the nautical chain is the result of the cooperation of multiple stakeholders, the Port of Rotterdam wishes to include these stakeholders in analysing and assessing the results of this monitoring (Seignette, 2015).

The simulation model that will result from the SwarmPort project may contribute to that. By simulating the nautical chain and analysing this simulation together with the nautical service providers will contribute to the quality assurance of the nautical chain.

Current literature

Models of a port have been described, be it for the Port of Rotterdam or a generic one. But none have been found that specifically observe the nautical chain of the Port of Rotterdam or have created a clear and recent process map of its activities.
Some relevant literature will be discussed now.

Huynh and Vidal (Huynh, 2010) have developed an agent based model for the truck-turn time on a container terminal in Houston. They have examined how different strategies affect the truck-turn time. This study relates to both the port aspect as the ABM aspect of this master thesis research but the scope is altogether different.

Kurapati (Kurapati et al., 2015) analysed relationships of planning and operational activities in a seaport. He did this by designing a simulation game. However the focus was more on a container-terminal and the events there that could lead to delays.

Douma (Douma, 2008), in his PhD-thesis looked, at optimising the barge handling system at a port with a multi-agent approach. He used two agents, the barge operator and the terminal operator. These two actors are outside the scope of this master thesis research. However, his works shows that this approach worked.

Lauri Lättilä (Lättilä, 2011) has modelled maritime transportation in the Gulf of Finland with agent based modelling and queuing models. The created model estimates how long queues will develop to backup seaports, if some seaports cannot be used due to disruptions. But the processes described in this model have a minimum amount of activities where as an activity of a ships behaviour within the port is not modelled.
Lättilä also mentions that ports have not been modelled before with an agent based model approach, but that the method is suited to do this.

Research gap

While searching for clear and recent map of the nautical chain of the Port of Rotterdam in the literature databases available, as seen in the previous subsection, none where found. Process maps of other ports that may serve as an example where also not found.
This research gap must be accommodated first before the SwarmPort project can continue with creating a ABM of the Port of Rotterdam

Objective of research

The main objective of this graduation research is to create a consistent multi-agent framework of the processes in the nautical chain of the Port of Rotterdam. In this research the framework is considered as a structured representation of the relations between and the processes of the service providers.
This representation will enable the creating of a simulation model.

Figure 1.1[1] shows the context of this simulation model.
The simulation model is based on the actors in the nautical chain, who together perform the processes in the nautical chain. These processes take place in the environment of the nautical chain.

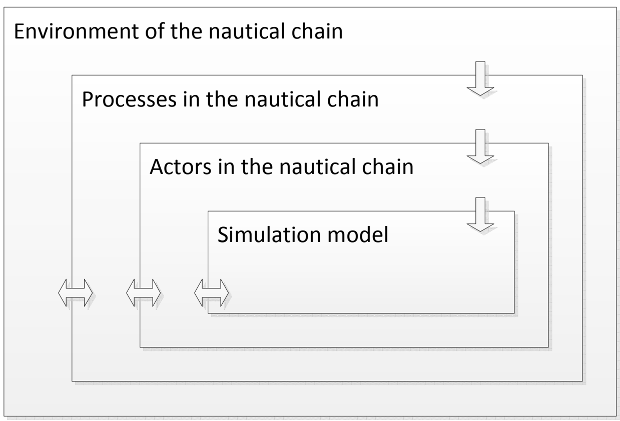


Figure 1.1: Context diagram

[1]Based on the context diagram by R. Seignette (personal communication, June 2017)

The blocks shown in the figure form the parts of this report.
In part II a stakeholder analysis and business model analysis will be performed on the relevant actors of the nautical chain. These analyses will provide information on the motives and interests of the actors.
In part III, the process analysis, the environment of the nautical chain and the processes in the nautical chain will be described and quantified.

Scope of research

The thesis research will be limited to the processes of a vessel and a selection of service providers of the Port of Rotterdam, which are: the terminal, pilot-organisation, tugboat-companies, boatmen-organisation and the vessel traffic services (Port of Rotterdam authority).
The level of mapping the decision- and business-models will be limited to a level which is sufficient to describe the relations between the decisions of the service providers and effects of these decisions within the port's nautical chain.

Summary

The SwarmPort project aims to create an agent based model of the nautical chain of the Port of Rotterdam. To develop this model a clear and recent multi-agent framework which describes the processes of the nautical service providers and the relations between these processes and the service providers themselves is needed.
A literature review shows that such a process map of the Port of Rotterdam's nautical chain does not exist. This needs to be created for the SwarmPort project to continue.
Thus, a structured representation of the relations between and the processes of the service providers needs to be developed. This will be done by analysing the processes and the service providers, and creating the process map of the nautical chain.

1.1 Nautical chain

This research will focus on the nautical chain of the Port of Rotterdam. In this section the nautical chain as used in this research will be explained.

Definition *The nautical chain in this research is defined as:*
1) all the events of the nautical service providers in the operational domain performed for a vessel during the time that vessel is sailing in the Port of Rotterdam
2) and the information shared in the tactical domain to support the events in the operational domain.

Parties

The nautical chain reflects a chain of events regarding servicing a vessel on her inbound, outbound or shifting voyage. During this process various parties support the vessel in order to reach the berth safely. In this research those parties are: the Harbour Master, the pilot-organisation, tugboat-companies, the boatmen-organisation and a terminal.
The pilot-organisation, the tugboat-companies and the boatmen-organisation are also called the Nautical Service Provider (NSP).

Scope

The nautical chain can be described for inbound and outbound voyages, as well as for shifting voyages. In this research the nautical chain begins for inbound vessels at the moment the vessel contacts the vessel traffic service that she wants to enter the port. It ends at the moment the vessel is safely moored at the quay.
For outbound vessels the process starts when the vessel indicates she wants to leave her berth and the port. The nautical chain ends for an outbound vessel when she leaves the 'Pilot Maas' area.
Shifting voyages start at the moment the vessel indicates she wants to shift and end when she is moored at the next quay. Shifting voyages in this research may be regarded as a combination of an inbound and an outbound voyage.

Domains

The nautical chain relates to physical events in the operational domain and prior to these physical events information that is shared in the tactical domain. An example of this information is the pre-arrival notification which vessels are obliged to submit at least twenty-four hours before arriving at the port. These kinds of information flows, critical for the functioning of the nautical chain, are also part of the scope.

Illustration

A description of an inbound and outbound voyage are given to illustrate the process of nautical chain and the information that is shared. Keep in mind that this is a concise description, details will be given further on in this report.
For the sake of this description the vessel is a container vessel with a length of 300 meters and a draft of 12 meters. The Amazone-harbour is the destination- and departure-berth of this vessel.

Inbound voyage
See figure 1.2. A vessel notifies the correct authorities twenty-four hours before her Estimated Time of Arrival (ETA) via the pre-arrival notification. The Harbour Master checks

this notification whether all the required information has been provided and if the vessel is allowed to enter the port.
Some time later the vessel arrives in the Port of Rotterdam area and uses the VHF-radio to state her intentions. If there are no objections to her entering the port she sails on to the 'Pilot Maas' area, here she will be boarded by a maritime pilot.
The maritime pilot will guide the vessel into the Maasmond, where, shortly after, a tugboat stands ready to connect to the vessel. Together with the tugboat the vessel will sail into the Beercanal towards the terminal.
When the terminal has been reached the maritime pilot will work together with the captain of the vessel, the tugboat and the boatmen on the quay to safely moor the vessel.
The tugboat will help manoeuvre the vessel and the boatmen collect the ropes from the vessel and attach them to the mooring construction. The maritime pilot coordinates all these activities.
When the vessel is safely moored the nautical chain has ended.

Figure 1.2: Nautical chain - inbound vessel

Outbound voyage
See figure 1.3. Several hours before the vessel is ready to leave the port she orders the nautical service providers (maritime pilot, tugs and boatmen). At the Expected Time of Departure (ETD) all the nautical service providers are at the vessel ready to assist her in her outbound voyage. The tug connects to the vessel, the boatmen are ready at the quay to remove the ropes from the mooring construction and the maritime pilot is on the bridge communicating with the captain, tug and boatmen.
Together they unmoor the vessel, guide it from the quay and out of the harbour. When the vessel no longer needs the tug-assistance to manoeuvre the tug will disconnect. The maritime pilot will guide the vessel out of the port and will disembark in the 'Pilot Maas' area. This is the end of the nautical chain.

Figure 1.3: Nautical chain - outbound vessel

Part I

Literature, Background & Methods

2 | Introduction

In this part relevant literature, background and methods for this master thesis is discussed.

As mentioned in the introduction of this report the objective of this research is to create a consistent and recent multi-agent framework of the processes in the nautical chain of the Port of Rotterdam. Creating this framework consists of two parts, first the analysis of the main decision- and business-models of the service providers. Secondly, the creation of a map or framework of the nautical chain.

This part is divided into four chapters. The first chapter will provide background information for this research. First, the SwarmPort project will be discussed. After that the concept of Agent Based Models (ABM) is explained, since this forms the basis for the second part of the SwarmPort project.

The second chapter will focus on methods used for analysing the main decision- and business-models of the service providers. Two actor analysis methods will be discussed first, the stakeholder analysis by (Enserink, 2010) and the actor analysis method of (Koppenjan and Klijn, 2004). After these two actor analysis methods the Business Model Canvas of (Osterwalder et al., 2010) will be explained, this canvas can be used to analysis a business model.

Thirdly, the mapping techniques useful for creating the map or framework will be discussed. Three books concerned with ordering and graphically representing processes will be discussed. Firstly the book by (Galloway, 1994), then the book *The Basics of Process Mapping* by (Damelio, 2011). And finally the Delft Systems Approach by (Veeke, 2008) is discussed.

The final chapter of the literature part will provide a summary of the previous chapters. This chapter will briefly reflect on all the relevant information that has been gathered from the chapters regarding the literature.

3 Background

This chapter will provide some background information for this research. First, the SwarmPort project is discussed. Secondly, Agent Based Models are explained since they will form a vital part of the second part of the SwarmPort project.

3.1 SwarmPort

This master thesis is a part of the SwarmPort project, thus in this section some background information on the SwarmPort project will be given.
First, a brief introduction of the partners of the project consortium will be given. Then the goal of the project will be shortly summarised and finally the approach and sub-projects of the project will be explained.

3.1.1 Consortium

The SwarmPort project is a four year research project funded by the NWO (Netherlands Organisation for Scientific Research) and the project consortium.
That consortium consists of the following party's:

- Delft University of Technology
- Maastricht University
- TNO
- Rotterdam Port Authority Harbour Master Division
- Intertransis (International Transport Information Services BV)
- ECT (Europe Container Terminal)
- SMARTPORT

At the core of the consortium are the TU Delft's Freight & Logistics group and the University of Maastricht's SwarmLab team. The TU Delft has experience with developing Agent Based Models for freight and logistics systems. The SwarmLab team has expertise in studying and creating self-organising, autonomous systems in various applications.
Next to these two research groups there are five other party's in the consortium that represent the user community in the Port of Rotterdam. These parties ensure that the developed knowledge gets a practical use.

The Rotterdam Port Authority Harbour Master Division is responsible for the safe and efficient vessel traffic in the port. Intertransis is an information broker, who has knowledge of port processes and logistic information. ECT is the largest container terminal in the Port of Rotterdam and plays a role in the shipping traffic in the port. TNO has a focus on port logistics and will use the developed knowledge in such a way that the models can be used operationally by the consortium members.

3.1.2 Summary of the SwarmPort research

Within seaports various services are provided that support a ship when it is entering or leaving the port, this is called the nautical chain. Examples of these services are piloting and mooring. These services play a key role in determining the turnaround time of a ship, a factor that is important in the competitiveness of ports. Making sure that this chain of services is a well-organised entity is thus essential. The nautical chain in the Port of Rotterdam has no central command, there is no actor that directs the entire process. All the actors together contribute to the performance of the chain, it is self-organising.
There are different aspects that have an impact on the performance of the nautical chain, such as the dynamic nature of the demand for services, external circumstances like the weather, the performance of the individual actors as well as the collaborations between them.
The continuous challenge is to find room for improvement in the efficiency of this nautical chain, on port-level. For example, through process agreements, information exchange and regulation. The evaluation of new strategies and policies can benefit greatly from quantitative models. Due to the complexity of the system or network of nautical services creating such models is not a trivial task, to be able to create the models new research is needed.
The SwarmPort project will use knowledge from complexity science in combination with logistic research to develop a quantitative model. The objectives of the SwarmPort project are threefold:

1. To improve the understanding of the self-organisational properties of the chain of nautical handling processes directed at maritime ships around seaports, from arrival to departure.
2. To develop valid and practicable methods for modelling port operational processes, implementing agent based modelling from a self-organisational, complex system perspective.
3. To design strategies based on self-organisational properties of port processes to increase the resilience, reliability and flexibility of services of individual actors and of the aggregate service chain.

3.1.3 Research approach

In line with the research objectives mentioned above the project has three sub-projects. The first will investigate tools for behaviour analysis in multi-agent systems that are self-organising. The second sub-project will develop an agent based model of the Port of Rotterdam's nautical chain. And the third sub-project has as a goal to develop new tools for optimising complex self-organising systems.

The first sub-project will investigate the processes of the nautical chain and its service providers. And how the combination of service providers determines the port performance. This will result in a process map of the port's nautical chain which will serve as input for the second sub-project. This process map needs to be validated by all the service providers concerned. This master thesis is part of the first sub-project.

With the results from the first sub-project an agent based model will be developed.

Finally, in the last sub-project it will be investigated whether changing behavioural policies of the individual agents will result in an efficiency improvement. New tools to do this will be developed and will be tested with the results from sub-projects 1 and 2.

3.2 Agent Based Models

In this master thesis a framework will be created that will eventually be formed into an Agent Based Model (ABM). Thus, this section will explain the general theory of Agent Based Models.

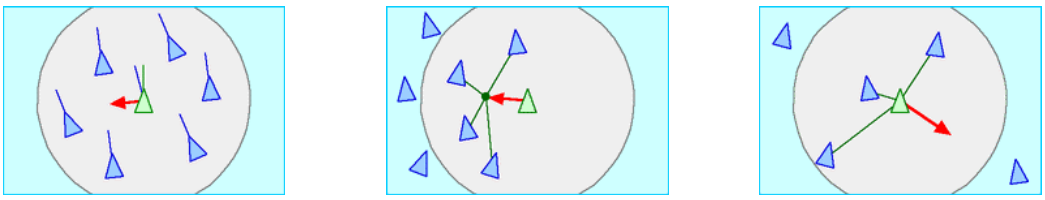
Figure 3.1: Flock of starlings (Humphreys, 2013)

3.2.1 Boids

Something that is useful in describing the idea of an ABM is a flock of starlings as shown in figure 3.1. Thousands of birds move together in intricate patterns. There is no apparent leader in the flock, they all work together in forming these patterns. This is nature's version of an agent based model. Essentially an ABM is a model where all actors are individuals, meaning that there is no overall coordination, which together form a system.
Each bird is an independent actor which reacts to what is happening around it, what the bird next to it does.

In 1986 Craig Reynolds developed a computer model of coordinated animal motion which he called Boids (Reynolds, 1995). He thought of three rules each actor or bird should comply to in order to simulate a flock:

Alignment steer towards the average heading of local flock-mates
Cohesion steer to move toward the average position of local flock-mates
Separation steer to avoid crowding local flock-mates



(a) Alignment (b) Cohesion (c) Separation

Figure 3.2: Boids rules

In figure 3.2 the three rules have been shown graphically. Each bird or actor has an area in which it 'looks', the area outside the grey area is outside their scope. When these rules are applied to a large group of actors, it will simulate a flock of birds.

Reynolds called this model an Individual Based Model, nowadays the term individual has been changed to agent. An agent has been described by Wilensky and Rand (Wilensky and Rand, 2015) in the following way: *"An agent is an autonomous computational individual or object with particular properties and actions."* And following from that: "*Agent-based modelling is a form of computational modelling whereby a phenomenon is modelled in terms of agents and their interactions."*

3.2.2 NetLogo

There are many tools to write or create an ABM. One of the most widely used is NetLogo (Wilensky, 1999) designed by Uri Wilensky at Northwestern University. According to the designer it is also the most easy to learn ABM environment. Agent based models will now be explained further by the use of NetLogo.

Within NetLogo there are four different types of agents: turtles, patches, links and the observer. Turtles are agents that move around in the world. The world is two dimensional and is divided up into a grid of patches. Each patch is a square piece of 'ground' over which turtles can move. Links are agents that connect two turtles. The observer doesn't have a location, it is the agent that oversees the other agents and gives instructions (Wilensky, 2017).

With the help of a NetLogo flocking model made by Uri Wilensky(Wilensky, 1998), NetLogo and agent based models will be further explained. This flocking model is based on the Boids model by Craig Reynolds. When starting the flocking model a screen as shown in figure 3.3 appears.

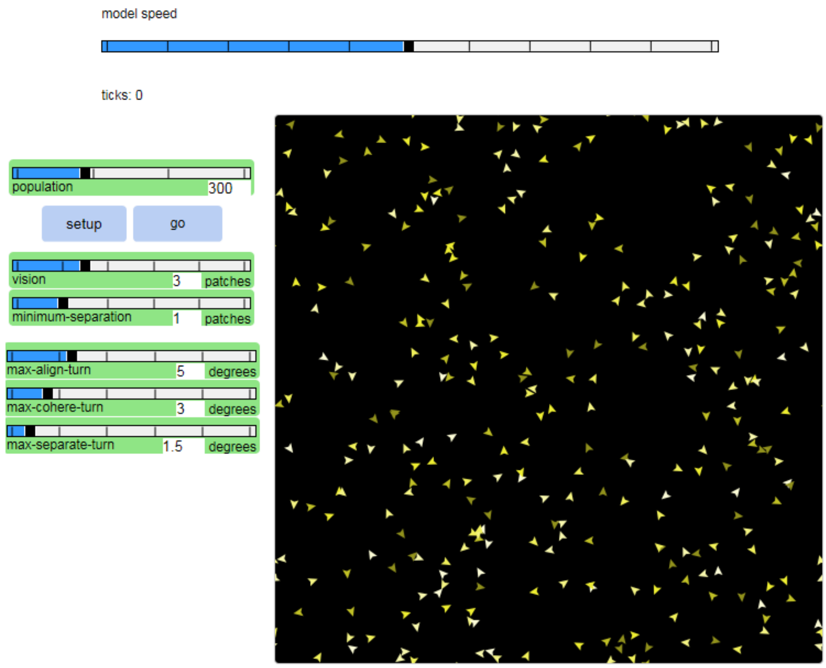
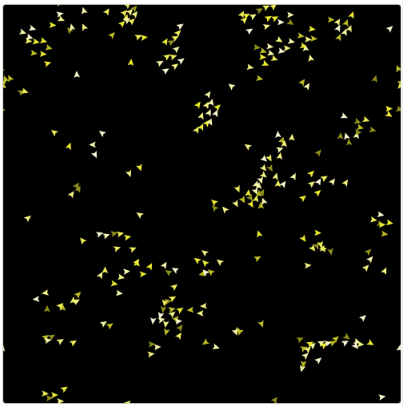


Figure 3.3: NetLogo flocking model

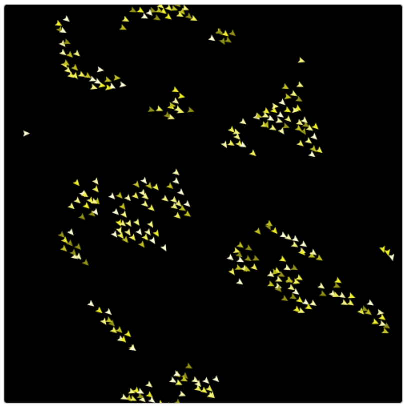
In figure 3.3 various sliders are shown. The first one is population, with this slider the user can define how many turtles (representing birds in this model) will be in the simulation. Below that the vision is represented, this indicates how far a turtle can see in a 360 degree direction. Patches have a default size but can be altered within the model. The minimum separation slider indicates how far a turtle must be away from another turtle. The three sliders at the bottom match the rules that have been mentioned before. Here a user can define the maximum angle a turtle can turn as a result of the rules.

These three rules are coded with simple lines. For example the separate rule:

```
to separate
turn-away ([heading] of nearest-neighbor) max-separate-turn
end
```



(a) 100 ticks



(b) 300 ticks

Figure 3.4: NetLogo flocking model

When the model is run it is clear to see that the turtles (or birds) flock together based on the three rules. In figure 3.4 the flock after 100 and after 300 ticks is shown. A tick is the timescale in the NetLogo environment.
In figure 3.3 all the turtles are scattered randomly throughout the plot. In figure 3.4a it is clear that some groups have formed but not all groups are moving in the same direction. Some while later, in figure 3.4b almost all turtles are part of a group and the groups are all moving in the same direction.

In this example there was one type of turtle, there were only birds and all the birds had to comply with the same rules. But within agent based modelling it is possible to create a large amount of different turtles, all with their own set of rules. It is possible to model large complex systems such as the Port of Rotterdam with agent based modelling.

3.2.3 Conclusion

As has been mentioned before, the framework created in this master will be used to create an ABM. Thus it is essential to understand the basics of modelling an ABM.
From the literature discussed in this chapter it is clear that each agents needs to be described and modelled individually so the information that will be provided on these agents needs to be complete. All the variables describing the behaviour and decisions of an actor need to be included.

3.3 Multi-stakeholder ontology's

According to Thomas Gruber (Gruber, 1993) *"a conceptualisation is an abstract, simplified view of the world that we wish to represent for some purpose"* and *"an ontology is an explicit specification of a conceptualisation"*. In other words, an ontology is a description of the concepts and relationships that can exist for an agent or a community of agents.

3.3.1 Ontology and ABM

Ontology's relating to ports are thin spread. The article by Lauri Lättilä comes close, in this article he models a seaport with both an agent based model (ABM) and system dynamics (Lättilä, 2011). Here he does not mention the word ontology but uses some kind of ontology as an input for the ABM.

In the field of city logistic some works are available regarding (multi-stakeholder) ontology's and ABM's. Matthew Roorda (Roorda et al., 2010) and Nilesh Anand (Anand et al., 2016) developed a framework for creating an agent based model. Anand did this with the help of a multi-stakeholder ontology. In his article the focus is on city logistics, which is not the same as logistics in the port but it does has some similarities. The heterogeneity of the stakeholders is a distinctive characteristic in city logistics and the stakeholders have different objectives. This is also the case with the service providers of the nautical chain, none of them are the same or provide the same service and all have their own personal objectives.
Also the *"efficiency of city logistics activities suffers due to conflicting personal preferences and distributed decision making by multiple city logistics stakeholders"* (Anand et al., 2016). He says that the key to understanding the causes of this inefficiency is understanding the interaction between heterogeneous stakeholders of the system. This is another similarity with the situation of this research. The decision making in the nautical chain is not centralised and each service provider has its own preference. One of the goals of this research is to understand the system and its interactions better.

3.3.2 GenCLOn[1]

In his doctoral thesis (Anand, 2015) and an article (Anand et al., 2012) Nilesh Anand created what is called GenCLOn, Generic City Logistic Ontology. This ontology will be further explained to get an idea of how it is build up. This will help in forming the framework of the port processes later in this research. The build-up of the GenCLOn is not necessarily the way that the port's ontology will be build, but it will help to give an indication.
Firstly the type of hierarchy of GenCLOn will be discussed. After that the various classes that make up the ontology.

Hierarchy of GenCLOn

Anand says that there are three different approaches to develop a class hierarchy (Anand, 2015):

Top-down development This process starts with the definition of the most general concepts in the domain and subsequent specialisation of the concepts

Bottom-up development Here the process starts with the definition of the most specific classes, with subsequent grouping of these classes into a more general concept.

[1]This section is based on chapter 4 of the doctoral thesis by (Anand, 2015)

Middle-out development In this process a combination of the two methods mentioned above is used. It defines the most salient concepts first and then generalises and specialises them accordingly.

None of the methods is better than another, but each has its own pros and cons. The top-down method gives better control of the level of detail but requires a very systematic top-down understanding of the domain.
The bottom-up approach can give a quick start without the need of a high level of understanding but involves a high level of detail which can result in high overall effort and risk of inconsistency.
The middle-out approach is believed to make it easier to relate terms in different areas more precisely. It avoids potential rework because the concepts in the middle tend to be most descriptive concepts. For creating an ontology of the city logistics this methods has been chosen.

GenCLOn classes

Anand (Anand, 2015) has defined eight type of classes for city logistics: stakeholder, objectives, KPIs, resources, measures, activity, R&D and value partition.

Stakeholders In the middle-out development a start should be made with the 'core' of the system. As mentioned before, the heterogeneity of stakeholders is a key characteristic of the decision making process of city logistics. So the 'core' status is given to the stakeholders. The stakeholders have been split up further in two categories, the private and public actor. The private actor can be defined as shipper, carrier or receiver, but within city logistics an actor can also have multiple of these (super) classes. To accommodate for that in the ontology the deterministic private actor has been added. As of now, this will not be necessary in the master thesis research since all the actors will probably only adhere to one class. In other words, the actors are the classes.

Objectives In the city logistics the stakeholders are driven by their own objectives, these objectives influence the city logistics activities. Some of the objectives will be opposites of each other while others complement each other.

KPIs A Key Performance Indicator (KPI) is used to measure to what extend an objective of a stakeholder is achieved. This is thus related to the objectives, but cannot be added to the objectives hierarchy due to the semantics of the ontology.

Resources The resources are used by the stakeholders. Anand starts by firstly dividing them in non-monetary and monetary resources. Non-monetary resources can for example be further split up into equipment, infrastructure and personnel. These again could be further defined.

Measures The measure class contains measures that a stakeholder can take. For example governance measures such as enforcement implemented by a public authority.

Activity In city logistics the private actors perform activities that eventually result in a successful good movement. All the activities have to be performed by a least one actor with certain resources. Also, for some activities, certain logistics or infrastructure has to be in place.

R&D In this class R&D approaches can be made available. For example the improvement of policy or transport flow.

Value partition This class has been created to take in the classes that do not have a place in one of the classes previously discussed.

3.3.3 Conclusion

The information needed to create the agent based model of the Port of Rotterdam's service providers will be plentifully. The way Anand (Anand, 2015) has described the stakeholders, their objectives, activities, KPI's, resources etcetera is a good and clear way to do so. In this format it will be clear what belongs to who and this can serve the modelling.

4 | Analysis methods

This chapter will discuss actor analysis methods, first a comparison is made between various actor analysis methods. From this comparison it turns out that the stakeholder analysis is the best suited to this research. Two stakeholder analysis methods, one by (Enserink, 2010) and the other by (Koppenjan and Klijn, 2004) will be explained.
After that the Business Model Canvas of (Osterwalder et al., 2010) will be explained. This method has been chosen on the basis of a review in the article of Slávik and Bednár (Slávik, 2014)

4.1 Actor analysis

In this chapter the actor analysis method will be discussed. It turns out there are many different ways of performing an actor analysis, among other things depending on the scope of the research and the difficulty of the method.
So, first a method(-group) most suited for this research will be chosen.
Then two variants of the chosen method will be discussed. There are some similarities between the two variants but they will also complement each other. Both variants are divided into steps and thus will also be presented this way.

4.1.1 Actor analysis methods

Before starting with an actual actor analysis the right analysis method for this research has to be found. There are many different actor analysis methods, such as social network analysis, use-full for relational data or social science data rooted in cultural values and symbols (Scott, 2000). Or Dynamic Actor Network Analysis (DANA), that *"is a descriptive actor analysis method that allows for the modelling of the perspectives of individual actors which can then be compared"* (Lei, 2009).
This research does not want to be bound by one particular method but will combine different aspects of various actor analysis methods if necessary. One method or method group will be chosen to form a basis. The actor analysis method that will be the basis for this research must have a low threshold. In other words, it is not desirable that a thorough study has to be conducted in order to be able to work with and understand the method. This also relates to applications or mathematical models that may need to be used. The chosen method must not be to specifically orientated. Especially at the start of this research a broad perspective is needed, the method must correspond with this. Also, with a method that is too specific supplementing it with other methods may prove difficult.

In the article of Herman and Thissen (Hermans and Thissen, 2009) eighteen actor analysis methods for public policy analysts are reviewed, focusing on the trade-off between analytic quality and practical usability. Those eighteen methods are represented in figure 4.1.

In the figure the methods in the top right part, represented by a large circle, will yield high analytic quality. But as is mentioned by Hermans and Thissen, *"analytic quality will come at the expense of ease of use"* (Hermans and Thissen, 2009), especially when logical interconnectedness is combined with a large number of variables. In this research there will be many variables, thus a method with a high level of logical interconnectedness is not desirable.

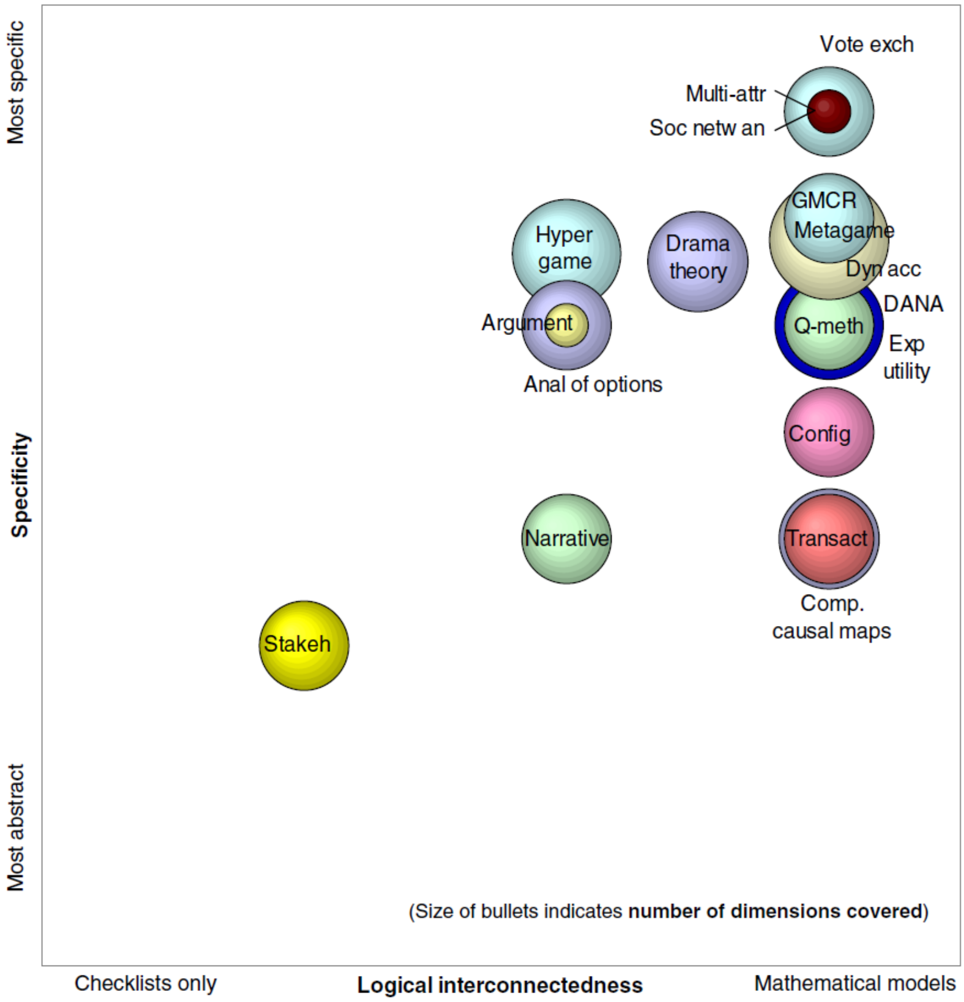


Figure 4.1: Analytic characteristics of actor analysis methods (Hermans and Thissen, 2009)

Looking at figure 4.1 this leaves only one possible actor analysis method: stakeholder analysis. This is according to Hermans and Thissen the most popular actor analysis method. This is related to its ability to accommodate gaps in input data and that is does not require any specific skills to use. And it can be used in a wide range of situations (Enserink, 2010). Enserink also mentions that it is useful for initial problem exploration and can provide a basis for the actor analysis.

The stakeholder analysis is thus a good method to start with in this research. Might the need for factors that are not covered in the stakeholder analysis method arise, other methods can provide extra insight or techniques that can be added to the existing method.
There are many explanations and guidelines and regarding the stakeholder method. For example the article *What to do when stakeholders matter: Stakeholder Identification and Analysis Techniques* by Bryson (Bryson, 2004). The book *Policy analysis of multi-actor*

systems of Enserink (Enserink, 2010, Ch. 4) uses stakeholder analysis as actor analysis method. Or the book *Strategic management: a stakeholder approach* by Freeman (Freeman, 1984) which focuses on strategic management. A chapter in the book of Hermans and van der Lei (Hermans and Lei, 2012) is also focused on the stakeholder method and steps of the process.
In their book *Managing uncertainties in games and networks* Koppenjan and Klijn (Koppenjan and Klijn, 2004), discuss an actor analysis strongly resembling the stakeholder analysis method and discuss an extra analysis focusing on networks. The latter will also be beneficiary for this research.

The books of Enserink (Enserink, 2010) and Koppenjan and Klijn (Koppenjan and Klijn, 2004) will be further explained in the next two sections. The book by Enserink has been chosen since it gives a very clear step-by-step procedure for conducting such an actor analysis. The book by Koppenjan and Klijn also has a clear step-by-step explanation and also included a network analysis, which is why the book by Koppenjan and Klijn has also been chosen.

4.1.2 Stakeholder analysis - Enserink[1]

In this section the stakeholder analysis of Enserink will be discussed and in the next section the actor analysis and network of Koppenjan and Klijn will be reviewed. The
Enserink mentions the following six steps need for a stakeholder analysis in his book (Enserink, 2010):

1. Formulation of a problem as a point of departure
2. Inventory of actors involved
3. Mapping formal relations
4. Determining the interests, objectives and problem perceptions of actors
5. Mapping out the inter-dependencies between actor by making inventories of resources and the subjective involvement of actors with the problem
6. Determining the consequences of these findings with regard to the problem formulation

These steps will now be explained.

Step 1: Formulation of a problem as a point of departure

A problem needs to be formulated as a starting point of the stakeholder analysis. This problem can be viewed in two different ways. Either as the problem owner or as the person doing the analysis.

Step 2: Inventory of actors involved

To perform an actor analysis it is vital to have actors, so these need to be identified. Doing this is an iterative process, since recognising one party as an actor usually reveals a new set of connecting parties that can also be deemed actors.
This step will not be explained thoroughly since in this master research the actors are already defined beforehand.

There are various techniques for actor identifying, such as:

[1] This section is based on chapter 4 of the book by (Enserink, 2010)

Imperative approach This approach asks the question: ”Who has an interest in or feels the consequences of the issues around which the problem revolves, or the solutions that are being considered.”

Reputational approach Here key informants related to the problem are asked to identify important actors. Those new actors can then be asked to do the same, to create an even larger group of actors. This technique is called ”snowballing”.

Social participation Actors are those who participate in activities related to the issue or problem at hand.

Demographic approach This approach evaluates by looking at characteristics such as age, sex, religion, level of education etc.

Problem diagram/causal map Here the question is asked: "Who influences, directly or indirectly, relevant system factors?"

Step 3: Mapping formal relations

The relationships between actors have a formal and an informal side. Being aware of both those sides and understanding them is essential for comprehending the actors and their environments.
The analysis should begin with mapping the formal relations of the actors with the help of available documents. This formal chart is also a good basis to start with when investigating informal relations. Legislation and formal procedures shape the interaction and influence the behaviour of actors.
This means that the laws and procedures to which actors must comply also are a part of the stakeholder analysis. Making a formal chart gives context information for the analysis of the informal relations and also about the resource dependencies between actors in a network.

Formal relations can be described in three ways:

1. *By describing the formal positions and the tasks and responsibilities of the actors* In the case of governmental organisations this is usually found in rules and regulations. For non-governmental organisations this may be found on the website or annual reports.
2. *Specifying formal relations between actors* Is there a hierarchical relationship? Is there a formal membership or arrangement, and who bears the final responsibility?
3. *Describing in short the most important laws, legislation, procedures and authorities* This will provide information to support bullets one and two. And helps to create an image on the position, interests and influence of the actors.

Step 4: Determining the interests, objectives and problem perceptions of actors

The things that matter most to an actor are interests. These are not directly linked to a problem and are relatively stable. The interest of a company for example is usually making a profit or continuity of business. For public organisations these are different, the police, for example, has as interest to keep the public safe.
Identifying the interest of an actor will help to estimate if certain objectives or solutions are acceptable for that actor.

Objectives show what an actor likes to achieve in a certain situation. They are an actor’s translation of interest into specific, measurable terms.
Many objectives that an actor has are not directly related to the problem or issue at hand. To find the objectives that are related to the issue one can ask questions like: "What does

the actor want to achieve when it comes to the problem situation?"

Each actor has a different perception on an issue, the difference between these perceptions can be significant. In complex systems it is not wise to view a particular perception as the 'right' one. It is important to map out the corresponding and opposing perceptions in an actor analysis.

For an impression of the problem perception of an actor some of the following questions can be asked. "What is the actor's perception of the problem?", "What are, according to the actor, the main causes of an issue?" and "What does the actor see as a possible solution?". For the last two questions it is wise to limit the main causes and possible solutions to three each.

To get a good overview of the interests, objective and perceptions of the actors a table can be made. An example is shown in table 4.1. This table can help spot, among other things, differences, similarities, common objectives and shared interests.

Table 4.1: Overview table of actors' problem formulations (Enserink, 2010)

Actors	**Interests**	**Desired situation/objectives**	**Existing or expected situation**	**Causes**	**Possible solutions**
Actor 1					
Actor 2					
Actor 3					
...					
Actor N					

Step 5: Analyse inter-dependencies

In this step the dependency relations between actors and networks of power are analysed. These are the resources, power and influences of actors from the point of view of formal and informal relations.
In the book of Enserink (Enserink, 2010) and Hermans and van der Lei (Hermans and Lei, 2012) the dependency relations are viewed from the perspective of the problem owner. In this research a clear problem owner has yet to be defined.

Critical actors must be determined first, those are actors key to solving the problem. In the case of this research that are all the actors. The determination of the critical actors is combined with an inventory of the resources of the actors.

These resources are the (in)formal means available to the actors. Formal means are for example authority and informal is information. Enserink mentions that Kok (Kok, 1981) distinguishes the following resources:

- Information
- Knowledge (and skills)
- Manpower
- Money
- Authority/formal power
- Position in network: support from or access to other actors
- Legitimacy
- Organisation (ability to mobilise and use resources effectively and efficiently)

Actors usually have multiple resources, but only the ones relevant for the problem or situation at hand should be included.

Resource dependency between actors is dependent on the importance of a resource and if the resource can be replaced by another resource. Enserink (Enserink, 2010) gives the following example: *"Most western countries heavily depend on oil imports to sustain their economies. Thus, they are highly dependent on OPEC countries. However, as alternative fuel technologies are being developed this resource dependency is decreasing."*
Resources can also relate to blocking power, the power an actor has to block a certain solution or process. These resources must not be overlooked in the resource dependency analysis.

Next the dedication of the actors may be determined. Their interest in the problem and their willingness to help is also part of the dependency on other parties. To determine the dedication of an actor one can assess if its core interests are affected by the problem or the possible solutions. If the actor is affected by costs or benefits this will usually mean the actor is dedicated.

With the interests, objectives and problems perceptions determined in the previous step and the identification of dedicated actors and their resources determined in this step, a complete overview can be made. This overview represents the dependencies of the problem owner on the different actors.
Table 4.2 indicates the possible reaction of certain actors

Table 4.2: Overview table for classification of inter-dependencies (Enserink, 2010)

	Dedicated actors		**Non-dedicated actors**	
	Critical actors	Non-critical actors	Critical actors	Non-critical actors
Similar/ supportive interest and objectives	Actors that will probably participate and are potentially strong allies	Actors that will probably participate and are potentially weak allies	Indispensable potential allies that are hard to activate	Actors that do not have to be involved initially
Conflicting interests and objectives	Potential blockers of certain changes (biting dogs)	Potential critics of certain changes (barking dogs)	Potential blockers that will not act immediately (sleeping dogs)	Actors that need little attention initially (stray dogs)

Table 4.2 can also be represented as seen in figure 4.2.

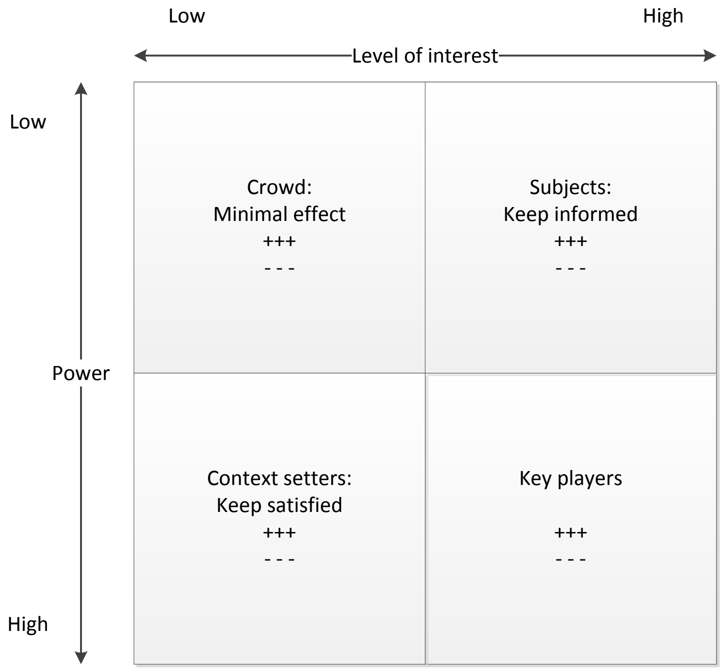


Figure 4.2: Mapping actor dependencies: power/interest matrix (Enserink, 2010)

Step 6: Confront the initial problem formulation with the findings

During the process of the stakeholder analysis various new conclusions, threats and opportunities may arise. These could have impact on the content of the problem analysis, the interaction with the actors and research activities.
Thus it is wise to review the initial formulation after all the steps have been taken to refine the problem or situation.

4.1.3 Actor analysis - Koppenjan and Klijn[2]

In the book by Koppenjan and Klijn (Koppenjan and Klijn, 2004), they generally follow the same method as Enserink but divide it into four ,and not, six steps. They also present a method to analyse a network, something that is relevant to this research. In table 4.3 these steps are shown and they will now be briefly explained.

Step 1: Take a tentative problem formulation as starting point

Firstly, the boundaries of the analysis have to be determined. There is also no substantive starting point because all the actors have a different view of the situation. It is important for the person conducting the analysis that a perspective is chosen to start the analysis. Koppenjan and Klijn give two possibilities, similar to Enserink (Enserink, 2010): Either the analyst regards itself as the problem owner or the analyst formulates its own idea of the problem on the basis of its own problem exploration.
The initial problem formulation is no more than a working hypothesis to give the analyst a place to start. Questions relating to this first step can be found in table 4.3.

[2]This section is based on chapter 7 of the book by (Koppenjan and Klijn, 2004)

Step 2: Inventory of actors

To find actors that are important from the perspective of the problem identity the following questions can be asked and answered:

- Which actors are actively involved in the problem?
- Which actors possess hindrance or realisation power, in the sense that they have authority or other resources that play a role in the emergence or solution of the problem situation?
- Which actors have the knowledge, insights and ideas that can contribute to the enrichment of the problem formulation, i.e. that can be considered for the solutions?
- Which actors can be expected to be involved at any particular moment?
- Which actors are not likely to participate, but are affected some way by the problem or the approach to the problem?

When dealing with actors something called compound actors can arise. These are actors within an actor. For example multiple departments working within a governmental organisation. When there are multiple actors within one organisation these can be listed as individual actors, but if there is only one department acting in the problem, do they represent their department or the organisation?
The rule is to select an organisational level as high as possible, but avoid analysing actors at the level of 'government' or 'private enterprise'.

Table 4.3: Steps in actor and network analysis (Koppenjan and Klijn, 2004)

Step	Intention	Important question
Actor analysis		
Take a provisional formulation of a problem or initiative as starting point	Mapping a problem situation or initiative as starting point for further analysis	• What does the current or expected situation look like? • What are the (undesirable) consequences that flow from that? • What are regarded as the causes for this situation? • What is the desired situation? • What goals and criteria underlie this? • Which solutions/policy alternatives are pursued?
Identify actors involved	Which actors need to be taken into account?	• Who can be distinguished as acting units? • Which actors in the network are important to realising one's own objectives or policy goals? • Which actors have an interest in finding a solution to the problem situation?
Reconstruct perceptions of actors	Mapping images of actors with regard to the problem, the solution and other actors	• What images do actors hold about aspects such as problem, causes solutions and (competency) of each other? • To what degree do these perceptions differ, are there clear groups? • What obstacles could be caused by differences in perception?
Analyse actor positions and dependencies	What positions do actors take with regard to the problem situation and how much do actors depend upon each other?	• What means do different actors have at their disposal? • How important are these means and can they be acquired elsewhere? • Is there unilateral or mutual dependency? • Are actors critical, dedicated and/or comparable?
Network analysis		
Inventory of interaction patterns of actors	Through mapping the frequency and diversity of interactions of actors, networks and the actors who belong to them can be determined	• Which actors interact frequently and infrequently? • Which actors have a varying contact pattern and which do not? • Which actors are central and peripheral in the network given their contact pattern?
Inventory of patterns in actors' perception	By determining the relation in perceptions between actors, one can discover which networks actors belong to	• What perceptions do actors hold with regard to problems, solutions, and their environment? • To what degree do these perceptions correspond to those of other actors?
Inventory of institutional provisions that connect parties	Make an inventory of and analyse the formal and informal rules and other organisational arrangements in the network relevant to the policy game	• What formal rules and juridical procedures apply? • What informal rules can be distinguished (for instance, with regard to information provision, access opportunities, professional codes, etc.)? • What meeting and consultation procedures or other organisational constructions exist in the network that structures the policy game?

Step 3: Inventory of problem perception

With actors problem perceptions it is possible to identify an actors objectives and perceptions. This step has many similarities with step 4 of Enserink (Enserink, 2010) as was discussed in section 4.1.2.
The questions Koppenjan and Klijn (Koppenjan and Klijn, 2004) ask to determine the perceptions are the following:

- What standard do actors use to assess the situation?
- What is their perception of the existing and/or expected situation? What is the crux of the problem? To what degree and in what sense are there gaps in the actors' perception? How do they determine this?
- What are the most important causes of the problem situation in their view?
- What influencing techniques/means do they distinguish with regard to the problem situation and it causes?

It is important that describing and comparing the perceptions of the actors is done systematically. The questions above can help in doing so.
The perceptions can be mapped in a qualitative or a quantitative way. A qualitative map would include, for instance, a description of the actor's opinions and its solution on the basis of interviews and written documents.
A survey would be useful in a quantitative approach. For example by submitting to the actors a list of questions/statements and having them rate the questions/statements within a scale.

To determine the objectives and interest Koppenjan and Klijn (Koppenjan and Klijn, 2004) present a *'quick and dirty'* method.
That means that the analyst makes guesswork based on texts and interviews about the interest and objectives, using the following questions:

1. What does the actor want to achieve with regard to the problem situation?
2. Why do these actors pursue these objectives with regard to the problem situation?
3. What costs and benefits for the actor are related to the problem situation or the suggested directions of solutions?

This will result in a table much like table 4.1

Step 4: Positions of actors: a dependency analysis

Whereas Enserink chose to work with many resources, Koppenjan and Klijn distinguish five types of resources:

- Financial resources
- Production resources
- Competencies
- Knowledge
- Legitimacy

When the resources of the actors have been mapped, the dependencies need to be determined. This can be done with Scharpf's taxonomy. Here two issues are important, the importance of a resource of one actor to others and if that resource can also be acquired somewhere else.
An organisation can be dependent upon a different organisation. For example, when company A is dependent on company B for certain resources but company B is not at all

dependent on company A, then the position of company A is weak. Analysing this within the whole network will result in a table like table 4.4.

Table 4.4: Analysing dependencies between actors (Koppenjan and Klijn, 2004)

Actors	Very important resources	Degree of replace-ability	Dependency (low, medium, high)	Critical actor?
Actor 1				
Actor 2				
...				
Actor N				

Resources that are crucial to the objectives or the situation should be taken into account, just as the actors that possess these resources. Critical actors are those whose resources are crucial to the problem owner or to the situation.
Dedicated actors are the actors that are face with clear costs and benefits, they have an interest in the problem situation.
By determining which actors have the same objectives and perceptions and combining this with the critical and dedicated actors, table 4.2 can be constructed.

Network analysis

The reason for doing a network analysis is to clarify the backgrounds of the various actors. Do they act in the same network? And what are the rules of interaction? Two steps are taken within the network analysis, first an inventory of the interaction patterns between the actors and second an analysis of the rules of the network.

Making an inventory of interactions in the network
To do this, two questions can be asked:

- Who are the central actors in the network?
- What links exist between actors in the network?

Two important concepts to answering these questions are frequency and variety. The first meaning how often a certain actor has contact with another actor. The second relates to the amount of actors another actor has contact with.

The questions can be answered in a qualitative or a quantitative manner. If there are few organisations and/or a quick scan is done then a qualitative impression of interactions will suffice. This can be presented in a table like table 4.5. In this example actor 2 has frequent interactions with the other actors thus actor 2 is the central actor. Actor 4 has few interactions, thus is a peripheral actor.

Table 4.5: Interaction frequencies between actors (Koppenjan and Klijn, 2004)

	Actor 1	Actor 2	Actor 3	Actor 4	Actor N
Actor 1	-	Frequent	Rare	Rare	Frequent
Actor 2	Frequent	-	Frequent	Frequent	Frequent
Actor 3	Rare	Frequent	-	Rare	Frequent
Actor 4	Rare	Frequent	Rare	-	Rare
Actor N	Frequent	Frequent	Frequent	Rare	-

In this master research there are few actors thus a qualitative manner will suffice. A quantitative analysis of the interactions in the network is not needed. A quantitative or qualitative analysis give insight into which actors have contact with each other and how frequent. But it will not explain why these patterns are the way they are. To explain these patterns the inventory of interactions must be linked to the positions of the actors and the analysis of rules and perceptions. It is logical to think that actors who depend on each other also have frequent contact, it they do not this could be cause for possible problems.

Analysis of the institutional context
Institutional context can ensure that some interactions take place or limit others. In analysing the institutional context rules are import, by examining the following two thing insight can be gotten.

The formal authority of actors this includes the authority of actors to make decisions, their property rights, etc.

The formal institutional characteristics of the interaction for instance legal frameworks for planning and decision making

The formal institutional context can be obtained by looking at the legally defined authorities, the legally framed plan and consultation procedures, etc. The informal institutional context is much harder to obtain. This is comprised of the informal relations and the rules that have been established during mutual interaction. Usually these cannot be found in written documents but play an important role in the contacts between actors.
The informal rules relating to the autonomy of an organisation can be highly influential for their willingness to cooperate. In networks where actors place great value on their autonomy, cooperation is more difficult to achieve then when the value placed on autonomy is less.

4.1.4 Conclusion

Both Koppenjan and Klein (Koppenjan and Klijn, 2004) and Enserink (Enserink, 2010) provide good comprehensive methods for conducting an actor analysis. Combining the two will result in a good basis for the process mapping.
The stakeholder analysis method is the chosen method because it has the ability to accommodate for gaps in input data without disrupting the analysis. It also has a good ease of use and is applicable to a wide variety of situations. This in contrast to other methods that require a lot of beforehand knowledge and are too specific for this research.

Both analysing methods use the following four steps. First they formulate the problem, then the relevant actors are determined, thirdly the stance and objectives of the stakeholders are identified and finally the position and resources of the actors are ascertained.
This results in a thorough stakeholder analyse which forms background information for the processes and model and will help investigate the business models, which will be discussed in 4.2.1.

Koppenjan and Klijn (Koppenjan and Klijn, 2004) also take a closer look at the network. The network analysis focuses on the interactions within a network, something that is relevant to this research.

4.2 Business models

A way to look at a company is to look at its business model.
A simple definition of a business model is: *"All it really meant was how you planned to make money"* (Lewis, 2014). He wrote this in relation to the dot.com bubble, he says that the term 'business model' was used to glorify all manner of half-baked plans.

More elegant definitions also exist: *"A business model describes the rationale of how an organisation creates, delivers and captures value"* (Osterwalder et al., 2010). In the eyes of Alexander Osterwalder a business plan can be something completely opposite to a half-baked plan. He has developed a method to construct and clearly visualise a business model. Andrea Ovans calls it the most comprehensive template to construct a business model (Ovans, 2015). And it is useful when comparing business models.

In their article Slávik and Bednár (Slávik, 2014) analyse various concepts to examine a business model. They distinguish two types of business models, the economic concepts and the economic-valued concepts. The first *"is an economic concept, which "produces" revenues and costs. It is a set of activities, which create profit due to the cooperation of processes and technologies"* (Slávik, 2014). Whereas the second concept views *"the business model as a system of resources and activities, which creates a value that is useful to the customer and the sale of this value makes money for the company"* (Slávik, 2014).
For both concepts they have analysed some concepts and the segments that these concepts evaluate. This is seen in table 4.6.
The economic concepts they have investigated are the book Getting to Plan B: Breaking Through to a Better Business Model by Mullins and Komisar (Mullins, 2009), the book Business Models: A Strategic Management Approach by Allan Afuah (Afuah, 2003) and the book Business Models by Watson (Watson, 2005). The economic-valued concepts that have been investigated were the article by Johnson, Christensen and Kagermann (Johnson et al., 2008) and the book Business Model Generation by Osterwalder and Pigneur (Osterwalder et al., 2010).

Table 4.6: Overview of all the business models concepts (Slávik, 2014)

Economic concepts			Economic - valued concepts	
Mullins-Komisar (Mullins, 2009)	A. Afuah (Afuah, 2003)	D. Watson (Watson, 2005)	W.M. Johnson C.M. Christensen H. Kagermann (Johnson et al., 2008)	A. Osterwalder Y. Pigneur (Osterwalder et al., 2010)
1. Revenue model	1. Position	1. Competitors	1. Value for customer	1. Customer segments
2. Gross margin model	2. Resources	2. Customers	2. Profit formula	2. Value propositions
3. Operation model	3. Industrial factors	3. Economy of company	3. Key resources	3. Channels
4. Model of working capital	4. Costs	4. Management	4. Key processes	4. Customer relationships
5. Investment model		5. Products		5. Revenue streams
		6. Suppliers		6. Key resources
				7. Key activities
				8. Key partners
				9. Cost structure

Slávik and Bednár both believe that tools to analyse a business model should be of the economic-valued concept. In table 4.6 two of these concepts are shown.
Between the two, they suggest that the concept of Osterwalder and Pigneur is the better one. This is because it uses the business model canvas that is a very useful visualisation tool. Also it is very user-friendly for the practitioners and qualified enough if you are a scientist. Furthermore, it is flexible and applicable to any industry.

Based on this review, the business model canvas by Osterwalder will be used for analysing business models in this master thesis. The next section will elaborate on this concept.

4.2.1 Business Model Canvas [3]

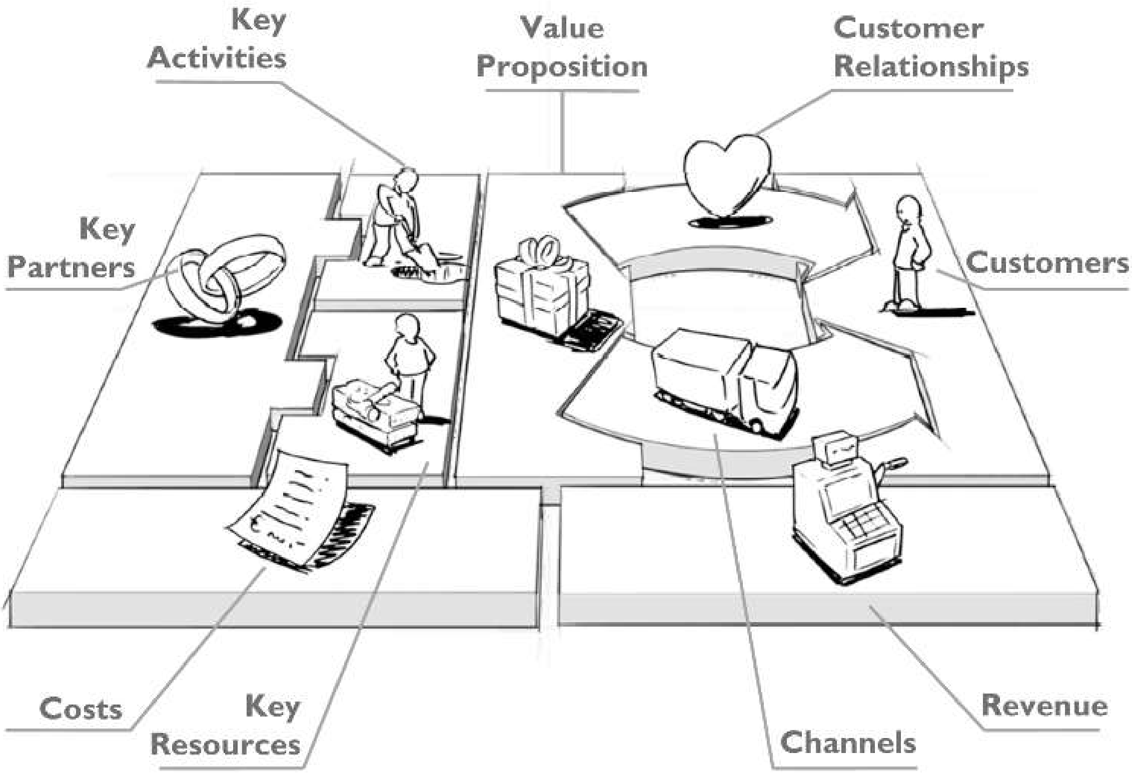


Figure 4.3: Business Model Canvas

Building blocks

Osterwalder describes his business model canvas as a concept that allows one to describe and think through a business model. With his model it is easy to create a shared language to describe and compare business models.
In the business model canvas nine basic building blocks are used to show the logic of how a company intends to make money. These nine blocks together cover four areas of business: customers, offer, infrastructure and financial viability. The nine blocks, also shown in figure 4.3, are:

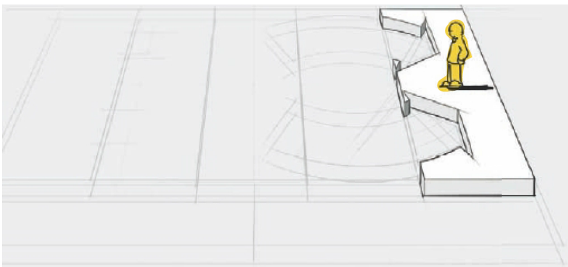
1. **Customer Segments** An organisation serves one or several Customer Segments
2. **Value Propositions** It seeks to solve customer problems and satisfy customer needs with value propositions
3. **Channels** Value propositions are delivered to customers through communication, distribution and sales Channels
4. **Customer Relationships** Customer relationships are established and maintained with each customer segment
5. **Revenue Streams** Revenue streams result from value propositions successfully offered to customers

[3]This section is based on chapter 1 of (Osterwalder et al., 2010)

6. **Key Resources** Key resources are the assets required to offer and deliver the previously described elements...
7. **Key Activities** ... by performing a number of Key Activities
8. **Key Partnerships** Some activities are outsourced and some resources are required outside the enterprise
9. **Cost Structure** The business model elements result in the cost structure

In the following subsections each building block will be explained.

Customer Segments



This building block refers to groups of people or organisations which the business tries to provide for. These people are the heart of a business model, because without them a company cannot survive. They are the ones that bring in cash. To have a better understanding of the customers a company may group them into different segments, into segments which have (roughly) the same attributes. An organisation must decide consciously to which segments it wants to provide and to which it does not. Customer groups can represent various segments if:

- Their needs require and justify a distinct offer
- They are reached through different Distribution Channels
- They require different types of relationships
- The have substantially different profitability's
- They are willing to pay for different aspects of the offer

A few examples of Customer Segments will now be given.

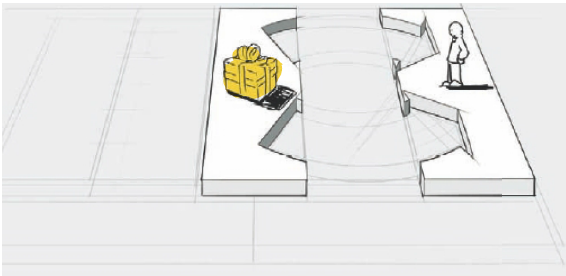
Mass market When focused on mass markets a business does not distinguish various customer groups. The focus is on one large group of customers with similar needs. This customer segment is for example found in the consumer electronics sector.

Niche market This is focused on a specialised Customer Segment. Many aspects of the business are specified for specific requirements. This kind of market is frequent in supplier-buyer relationships, for example car parts manufacturers who depend on major automobile manufacturers.

Segmented Here it is possible to distinguish between markets that are slightly different but are still related. For example, a bank has customers with a value of up to €100.000 but also clients who own more than €500.000. They both require the banks services but in slightly different variations.

Diversified When there is a diversified customer business model, then a business tailors two unrelated Customer Segments. Both with different requirements, but can be serviced with already available resources. For example when Amazon.com decided to also sell cloud-computing services next to their retail branch. This was possible because Amazon.com already had a strong IT-infrastructure.

Value Propositions



Value Propositions describe the products or services that are of value to a certain Customer Segment. These are the reason that a customer chooses one company over another. A Value Proposition is made up of a group of products/services focused on the needs of a Customer Segment. They may be new or disruptive or they are similar to already an existing product but with added features.
The value of a Value Proposition can be quantitative (price or speed of service) or it can be qualitative (customer experience or design). The following elements are some that can contribute to the value creation.

Newness This relates to an entirely new set of needs. One that a customer did not know it had because the offer was not available before. This is often technology related, for example the emergence of cell phones.

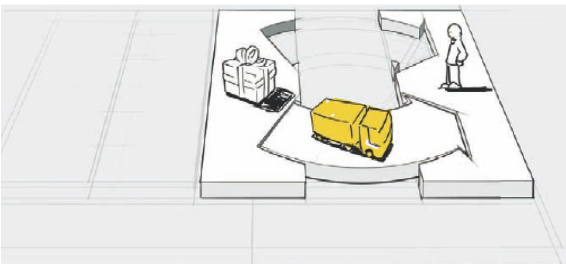
Customisation This entails tailoring products and services to specific customers. Mass customisation and customer co-creation are also part of this. This allows for customised product with the advantage of economies of scale.

Design This is an important Value Proposition but it is one that is difficult to measure. It is by its nature also highly subjective. Within the fashion and consumer electronics industries this can be a particular important part.

Brand/status A customer may find value in having or displaying a certain brand. Driving a Ferarri shows wealth for instance. Or certain fashionistas want to wear the newest, yet undiscovered fashion.

Price Offering a certain product or service with the same value but at a lower price is a common way to satisfy customers. Especially those customers from the price-sensitive Customer Segment. However, low-price Value Propositions often have other important implications for the business model. Take for example easyJet, they offer low prices but their entire business model has been modelled to accommodate for these low prices.

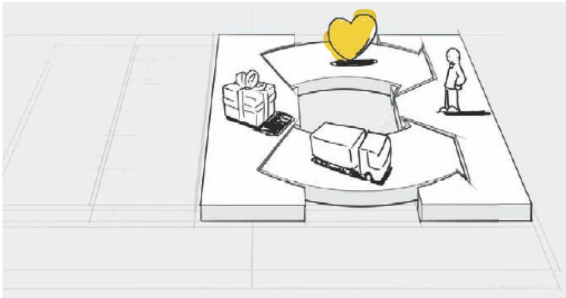
Channels



The building block Channels refers to the communication of an organisation as well as the way the organisation delivers its goods, or Value Propositions, to the customers. So this is the connection to the customer, whether that is sales, deliveries or other communication. These play an important part in how the customer experiences the organisation. Some of the functions a channel has are: raising awareness, helping with evaluation of a product or service, purchasing, delivery and customer support.

There are two types of channels, that are own channels or partner channels. An example of an own channels are a brand store or a website. A retail store is an example of a partner channel.

Customer Relationships



This building block illustrates the relationship a company has with certain customers or Customer Segments. This can stretch from automated to personal. These relationships can be driven by acquisition, retention or boosting sales. It is possible to switch to a different drive later in time. The way a company conducts its customer relations can influence the customer experience greatly.

These are several of the categories of customer relationships:

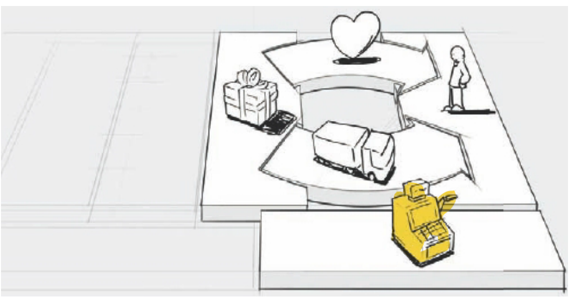
Personal assistance This is based on human interaction, face to face, via phone or email. A customer is in contact with a human representative of the company.

Dedicated personal assistance Here a representative of the company is specifically allocated to a client. This is the most intimate type of relationship and usually develops over a long period of time. This type is for example seen in the private banking world where a banker maintains a long working relationship with a high net worth client. Or in other industries where an account manager keeps contact with specific customers.

Self-service In this case there is no direct relationship with a customer. The company provides all the means necessary for a customer to service themselves.

Automated services This is a form of self-service. Automated processes are added to the self-service. An online profile that a company has of a customer will help to give specific suggestions to that customer. This is seen in online bookstores for example.

Revenue Streams



The cash that comes from the Customer Segments is depicted by the Revenue Streams. A Revenue Streams is a reaction to the value of the product or service. There are different pricing mechanisms within the Revenue Streams, such as fixed list prices, bargaining or market dependent, more examples are given in table 4.7.
Within a business model there can be two different types of Revenue Streams: revenues from a one-time payment or revenues from ongoing payments.

There are several ways to generate Revenue Streams:

Asset sale This is the most basic way. A customer buys ownership of a physical product. For example buying a book or a chair. The customer is afterwards free to do with it as he or she pleases.

Usage fee In this case a customer pays dependent of the usage of a certain service. A phone company lets the customer pay dependent on the minutes a customer has used his phone to call. Or a hotel charges a customer for the nights spent.

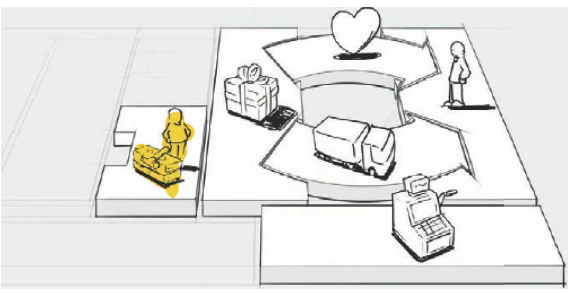
Subscription fee A company generates revenue by selling continuous access to a service. For example a membership to a gym, or a subscription to an online music player.

Lending/Renting/Leasing Here the revenue is created by giving access to a service or product for a certain amount of time. Renting a car at the airport for the duration of a vacation for example.

Table 4.7: Pricing Mechanisms (Osterwalder et al., 2010)

Fixed Menu Pricing Predefined prices are based on statistic variables		**Dynamic Pricing** Prices change based on market conditions	
List price	Fixed prices for individual products, services or other Value Propositions	*Negotiation (bargaining)*	Price negotiated between two or more partners depending on negotiation power and/or negotiation skills
Product feature dependent	Price depends on the number or quality of Value Proposition features	*Yield management*	Price depends on inventory and time of purchase (normally used for perishable resource such as hotel room or airline seats)
Customer segment dependent	Price depends on the type and characteristic of a Customer Segment	*Real-time-market*	Price is established dynamically based on supply and demand
Volume dependent	Price as a function of the quantity purchased	*Auctions*	Price determined by outcome of competitive bidding

Key Resources



This block represents the assets that are most important to have a successful business model. Every model has Key Resources, without it a business model cannot work. The resources are used to create the Value Proposition, create revenues and maintain contact with the Customer Segments. Depending on the organisation the resources may vary, a consultancy firm has

human resources as their Key Resources whereas a yard needs production facilities to build ships.
There are four different types of Key Resources: physical, intellectual, human and financial.

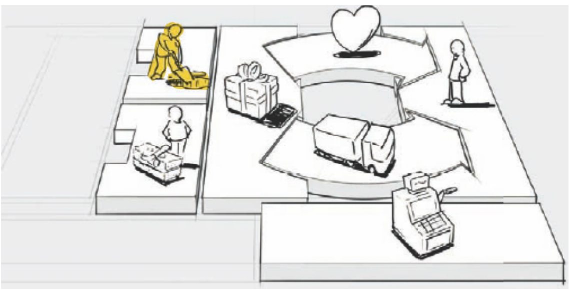
Physical This type of resources includes assets such as manufacturing facilities, vehicles, buildings and distribution networks. For big retailers this is the main resources, for example warehouses and stores. Web-based retailers also have a complex IT-infrastructure.

Intellectual Brand names, patents and copyrights are a few of the things that fall under intellectual resources. These are usually difficult to develop but when in place give substantial value to a business model. Companies such as Nike and Sony rely on their brand as a resource whereas software firms rely on intellectual property that has been acquired over the years.

Human Every organisation needs human resources but within some organisations this is the Key Resource. Consultancy firms, for example, rely heavily on their consultants to do the work.

Financial Within banks the Key Resource is obviously money, banks need cash to conduct their business. But also a company such as Ericsson, a telecom manufacturer, relies heavily on the financial resource. They borrow funds and use a part of that to provide vendor financing to equipment customers to make sure that new orders are placed with Ericsson and not with competitors.

Key Activities



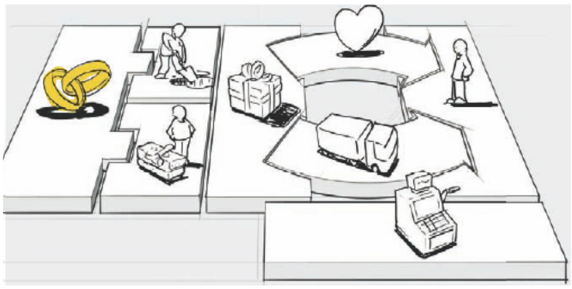
These are the activities that an organisation must perform to ensure that the envisioned business model works. The Key Activities are needed to create the Value Proposition, maintain a relationship with the customers and create revenues. Depending on the business model the activities vary widely. For software manufactures these activities involve software development and for a consultancy firm one of the activities will be problem solving.
The four different Key activities are: production, problem solving and platform/network.

Production Designing, making and delivering a product are part of the production activity. These activities are found in a manufacturing company. A shipyard builds a ship thus it Key Activity is production.

Problem solving This activity usually relates to finding a solution for a specific individual customer. Consultancy firms and hospitals have as a Key Activity problem solving. This requires knowledge management and continues training.

Platform/network A good example of a platform activity is a website such as eBay. Their business model consists of providing a platform for customers to buy and sell items. Or a credit card company which provides a platform for retailers, customers and banks. Key Activities that are performed here consist of platform management and promotion.

Key Partnerships



This building block consists of the network of suppliers and partnership of an organisation, the network is needed to make the business model function as it is supposed to. Within many business models partnership are essential for the model. Companies forge alliances with others to optimise, reduce risk or get additional resources. Partnerships can be divided into four types:

1. Strategic alliances between non-competitors
2. Coopetition: strategic partnerships between competitors
3. Joint ventures to develop new businesses
4. Buyer-supplier relationships to assure reliable supplies

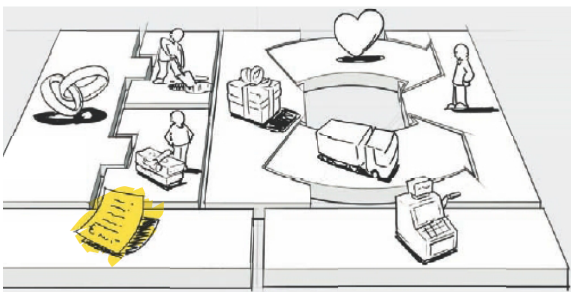
There are three main motivations for an organisation to form an alliance.

Optimisation and economy of scale This most basic alliance is designed to optimise the allocation of resources and activities. It is usually not beneficiary for a company to own all the resources and activities themselves. These partnerships exist to optimise costs and involve outsourcing and the sharing of infrastructure.

Reduction of risk and uncertainty Competitors can form alliances to reduce risk in a competitive market. It is not unusual for competitors to form alliances in one area and to compete in another. An example is the Blu-ray disc, various competitors joined forces to develop this technology but compete with one another in selling products based on this technology.

Acquisition of particular resources and activities There are not many companies that own all the resources and perform all the activities needed for their business model. It is possible to acquire certain resources and activities from third parties. A mobile phone manufacturer will license a mobile phone operating system to install on their products rather than developing such a system in-house.

Cost Structure



The ninth and final building block consists of all the costs related to make the business model function. Creating value, maintaining relations and creating revenues all incur costs. These can be calculated after defining the other building blocks such as Key Resources, Key Activities and Key Partnerships. Some organisations have a deep focus on the Cost Structure, for example low-budget airlines such as Ryanair, who have designed their business model focused on a low Cost Structure.

It is obvious that every organisation wants to minimise the costs in their business model. But as mentioned before, for some companies costs are more important than for others. Therefore, one can distinguish between two types of Cost Structures: cost-driven and value-driven. These are the two extreme types and many business models have Cost Structure that fall somewhere in between these two types.

Cost-driven Business models that are cost-driven focus on minimising costs wherever possible. This often entails low price Value Propositions, maximising automation and outsourcing. As mentioned before, airlines such as Ryanair and EasyJet are good examples of organisations with a cost-driven business model.

Value-driven Other types of companies focus more on the creation of value rather than a low Cost Structure. Premium Value Propositions and a high level of individual and personalised services often are characteristic for these kinds of companies. A Cost Structure can have some of the four following characteristics.

Fixed costs Here, the cost stay the same, no matter the volume of good or the services provided. Examples are salaries or rents. Manufacturing companies have a high level of fixed costs within their Cost Structure.

Variable costs In contrast to the fixed cost, with variable costs the costs vary depending on the volume of goods or services provided. Music festivals have business models with a high level of variable costs.

Economies of scale With economies of scale there is a cost advantage with larger quantities. For example if goods are bought in bulk a discount can be applied. This entails lower costs if the output is enlarged.

Economies of scope A cost advantage can be acquired if the scope of the operations is enlarged. For example sending multiple products via an already existing Distribution Channel.

4.2.2 Conclusion

Observing the business model of the service providers in the Port of Rotterdam will result in a useful insight in some of the motivations behind certain processes. Obtaining in-depth insight into the complete business models will probably not be possible because the businesses, logically, do not want to share all their information.
But by examining and observing certain parts of the canvass, such as the Value Proposition, Channels, Key Partners and Key Activities some of the reasons, advantages and disadvantages corresponding with the business model and processes may be obtained.
Obtaining information about the Cost Structure will prove difficult, but that is also not relevant for this master thesis research.

5 | Mapping techniques

In order to map the processes in such a way that they are explicit and useful for building an ABM, some methods to do this must be examined first.
Three books that represent techniques for mapping processes will be discussed. First, the book by Dianne Galloway (Galloway, 1994). Secondly the book by Robert Damilio (Damelio, 2011) and finally the Delft Systems Approach of Veeke (Veeke, 2008) will be discussed.
With the help of these techniques the processes of the nautical chain of the Port of Rotterdam can be mapped explicit and clear.

5.1 Mapping techniques

Since this master research will require the mapping of various processes, this chapter will discuss two books regarding the mapping of processes. Firstly the book Mapping Work Processes by Dianne Galloway (Galloway, 1994) and after that The Basics of Process Mapping by Robert Damelio (Damelio, 2011). Finally the Delft Systems Approach (DSA) by (Veeke, 2008) will be discussed.

5.1.1 Mapping Work Processes - Dianne Galloway [1]

According to Dianne Galloway *"mapping is an enabler, a means to a more important end"* (Galloway, 1994). In her book 'Mapping Work Processes' she describes the steps to map a work process. These will now be discussed.

She describes a map of a work process as a picture of how people do their work, and a process map is a graphic presentation of a process, showing the sequence of tasks. This map is a representation of the process as it is and not how it is supposed to be.
A work process consists of *steps, tasks* or *activities.* A work process uses inputs to create an output. This output could be a tangible product, such as a car, or an intangible service, for example legal counsel. The process is there to add value to the inputs.
Inputs of a process are materials, equipment, information, etcetera. The output, as mentioned, is a product or a service created by the process.

Levels

Galloway describes two levels in which process can be categorised. The macro processes and the micro processes. A macro process is defined as follows: *"Broad, far-ranging processes that often cross functional boundaries. Several to many members of the organisation are required to accomplish the process."* Examples of these processes as seen by the top executive of an auto repair shop are shown in figure 5.1. These processes look like departments within an organisation.

[1] This section is based on the book by (Galloway, 1994)

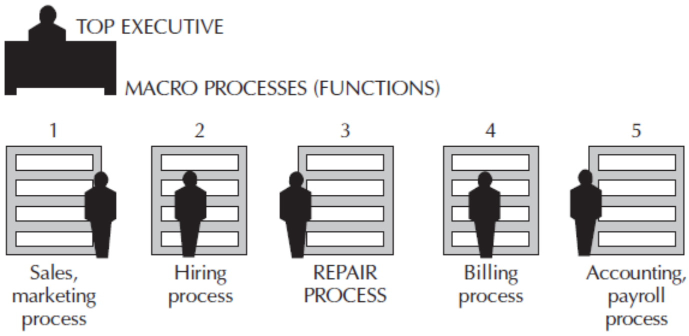


Figure 5.1: Macro processes (Galloway, 1994)

From the view of the manager of the repair shop the processes will look different than the processes as viewed by the top executive. The manager will divide the macro process 'repair shop' into various different, smaller processes. In this case, this is the view from the middle, between the macro and the micro processes.

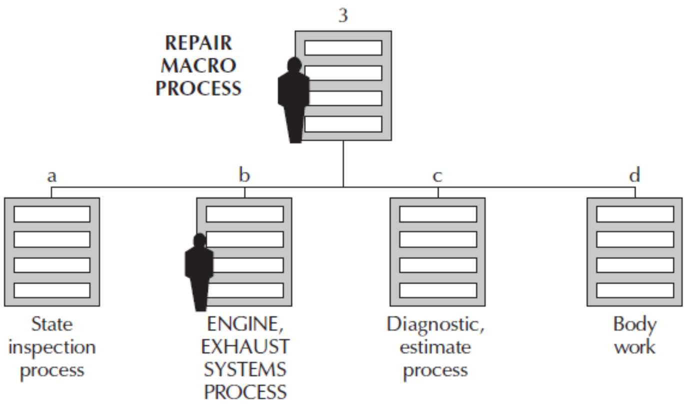


Figure 5.2: View from the middle (Galloway, 1994)

When an engineer working on the engine and exhaust systems is asked to described the business process it will result in a view like figure 5.3. These are micro processes, Galloway defines this as *"a narrow process made up of detailed steps and activities, could be accomplished by a single person."*

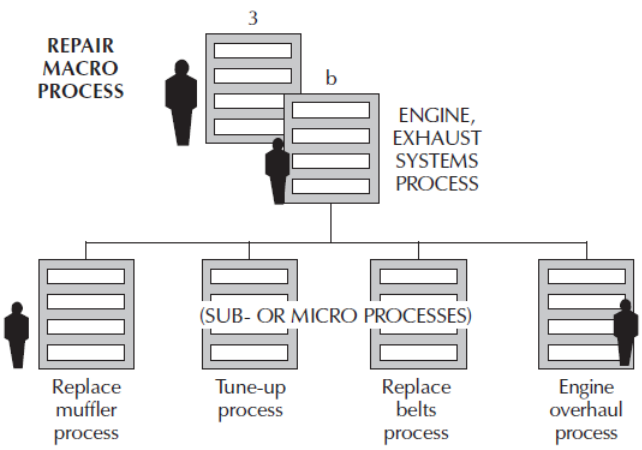


Figure 5.3: Micro processes (Galloway, 1994)

As shown above, a macro process can be broken up into smaller micro processes. Dependent on the specialisations and persons you included in the process.

Define the process

In her book Dianne Galloway gives a step by step guide to define the work process. This means naming the customer and the output of the process. These steps will now be briefly described.

State the output of the process The output is *"the product or service that is created by the process; that which is handed of the customer."* These outputs should be defined with a noun and a verb. For example 'car serviced' or 'windows washed'. These could be clarified further by adding descriptors, 'second floor windows washed'.

List the customer(s) for the output Customers are *"the person or persons who use the output, the next in line."* These customers can be both internal as external.

List the customer's requirements of the output The requirements are *"what the customer needs, wants and expect of the output."* These could be things like the quantity or ease of use.

List the process participants *"The people who actually do the steps of the process, as opposed to someone who is responsible for the process."* For example, if a parent tells his child to wash the windows, the child is the process participant and the parent is the owner/manager of the process.

List the process owner The process owner is *"the person who is responsible for the process and its output."* The process owner makes the key decisions and provides resources to the process participants. The parent decides which windows will be washed and provides the bucket, sponges, soap and water to the child.

List the stakeholders *"A process stakeholder is someone who is not a supplier, customer or process owner, but who has an interest in the process and stands to gain or lose based on the results of the process, most processes have a number of stakeholders."*

Define the process boundaries The process boundaries are the first and the last step of the process. In case of the window washing example the first step could be 'filling the bucket with water' and the last one could be to 'emptying the bucket'.

List inputs and their suppliers Inputs are *"the materials, equipment, information, people or money that are required to carry out the process."* The suppliers are the ones that deliver these inputs.

Map the primary process

The primary process are *"the basic steps or activities that will produce the output, everyone does these steps"*. It is the backbone of the process, the essential steps without which there will be no output.

Galloway recommends that activities are represented as rectangles and are placed in the order in which they occur. Inputs for the activities should be drawn as parallelograms and should be linked to the step for which they provide input. The output should also be represented as parallelograms. This is shown in figure 5.4.

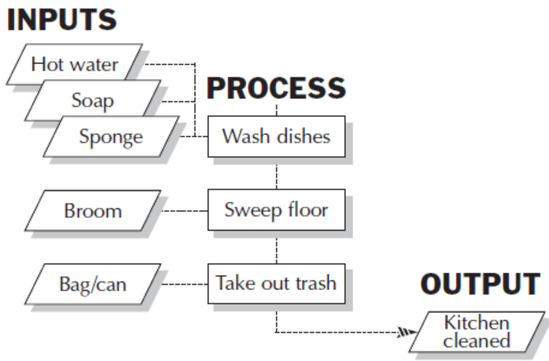


Figure 5.4: Inputs and outputs (Galloway, 1994)

A primary process can also be conducted by multiple people, this creates a parallel process as seen in figure 5.5.

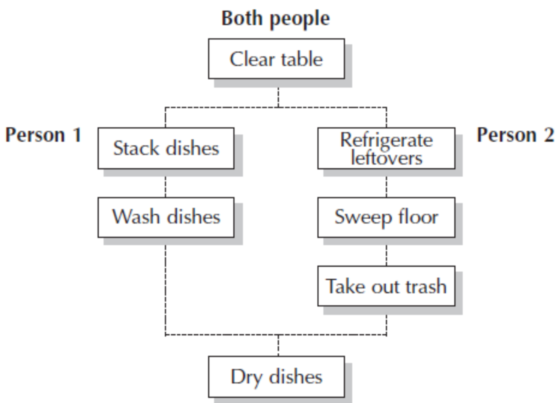


Figure 5.5: Parallel process (Galloway, 1994)

Map alternative paths

An alternative path is a path which consists of one or more optional tasks that do not follow the primary path. The alternative path is preceded by a decision diamond. This is a diamond-shaped figure that asks a question and shows that there is an alternative path or that an inspection is required.
It is suggested that the primary path keeps going the same way (horizontally or vertically) and that the additional loops run off to the sides. An example of decision diamond is shown in figure 5.6. Here the 'yes'-answer follows the primary path and the 'no'-answer the additional path. This could be reversed by re-framing the question to "Is today a holiday or a weekend?".

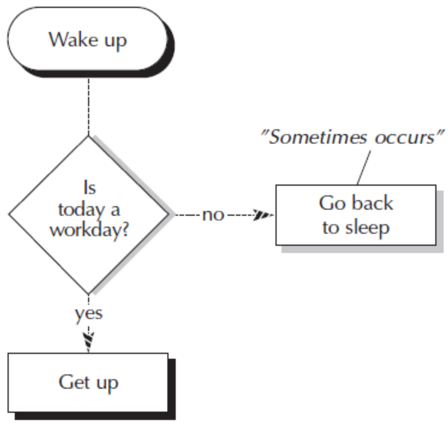


Figure 5.6: Decision diamond (Galloway, 1994)

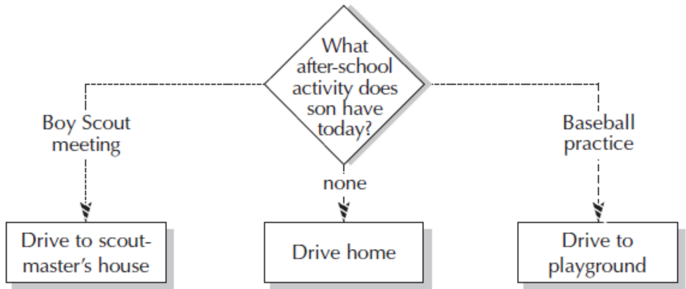


Figure 5.7: Multiple response paths (Galloway, 1994)

It is also possible that a diamond has multiple answers, which are not yes/no answers, as seen in figure 5.7. Another possibility is to have multiple decisions following each other.

To leave little room for interpretation, the questions should be as specific and measurable as possible. For example 'Have 20 minutes to eat?' is better than 'Have time to eat?'. And 'Bathed in the last 15 hours?' is better than 'Need a bath?'. In the second example the second question is based on an opinion.
A special kind of decision diamond is an inspection point. These usually have a pass/fail answer. An example is shown in figure 5.8. Here it is also key to be specific about the conditions, illustrated in figure 5.9.

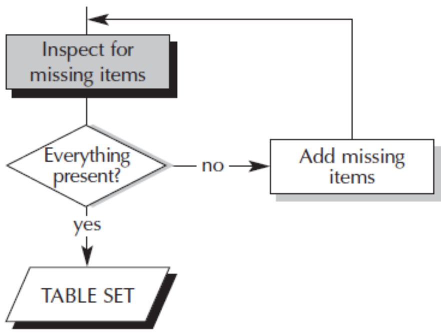


Figure 5.8: Inspection point (Galloway, 1994)

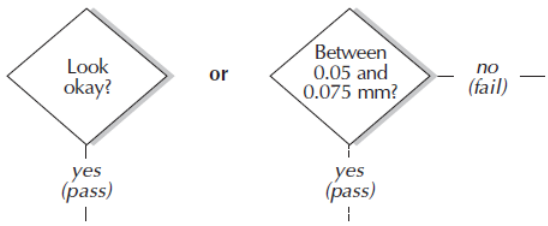


Figure 5.9: Subjective vs. objective (Galloway, 1994)

5.1.2 The Basics of Process Mapping - Robert Damelio [2]

Robert Damelio (Damelio, 2011) defines in his book three levels of performance: organisation, process and job/performer. For each level of performance he defines a certain map that can be used, this is shown in table 5.1.

Table 5.1: Level of performance and Map type (Damelio, 2011)

Level of performance	**Map used**	**View of work emphasised**
Organisation	Relationship map	**Organisation**: The supplier-customer relationships that exist between parts of an organisation
Process	Cross-functional process map (swim-lane diagram)	**Work-flow**: The path of work that crosses several functions, plus the architecture that connects the relevant activities, people, information systems, and other resources along that path
Job/Performer	Flowchart	**Activity**: The value-creating or non-value-creating work performed

These maps will be explained further in the following subsections.

Relationship map

A relationship map shows the different parts of an organisation and the internal and/or external relations between those parts. A relationship map does not show actual work activities but rather the input/output between various parts. It is usually divided into three components: suppliers, organisation and customers. An example is shown in figure 5.10. Where 'A' represents the three components, 'B' the relationship between a part and a component and 'C' represents the relationship between two parts.

[2]This section is based on the book by (Damelio, 2011)

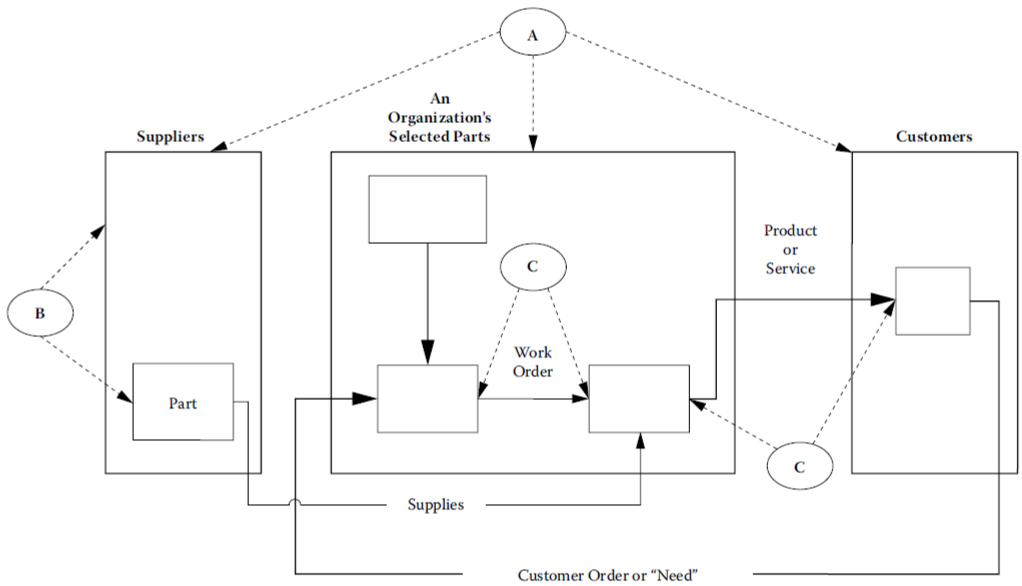


Figure 5.10: Relationship map (Damelio, 2011)

The relationship map shows the process on a macro level. It can be used to show what inputs and outputs an organisation has and which components relate to these inputs/outputs. The map also shows what the contribution of each part is. In what way they are linked to other parts of the organisation. It also illustrates the organisational boundaries.

An example of a relationship map of an oil changing company for cars, called Phil's Quick Lube, can be seen in figure 5.11.

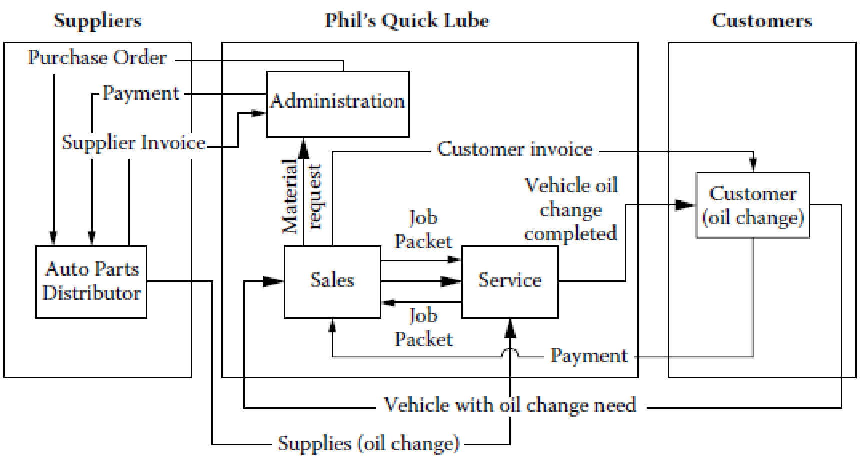


Figure 5.11: Organisation view of Phil's Quick Lube oil change (Damelio, 2011)

Cross-functional process map

The cross-functional process map (or swim-lane diagram) shows the work-flow in an organisation. This consists of activities that transform input into output. It shows the work that takes place in each part of the organisation and the relationship between the activities. It is also called a swim-lane diagram because the horizontal bands look like the swimming lanes in an Olympic swimming pool.

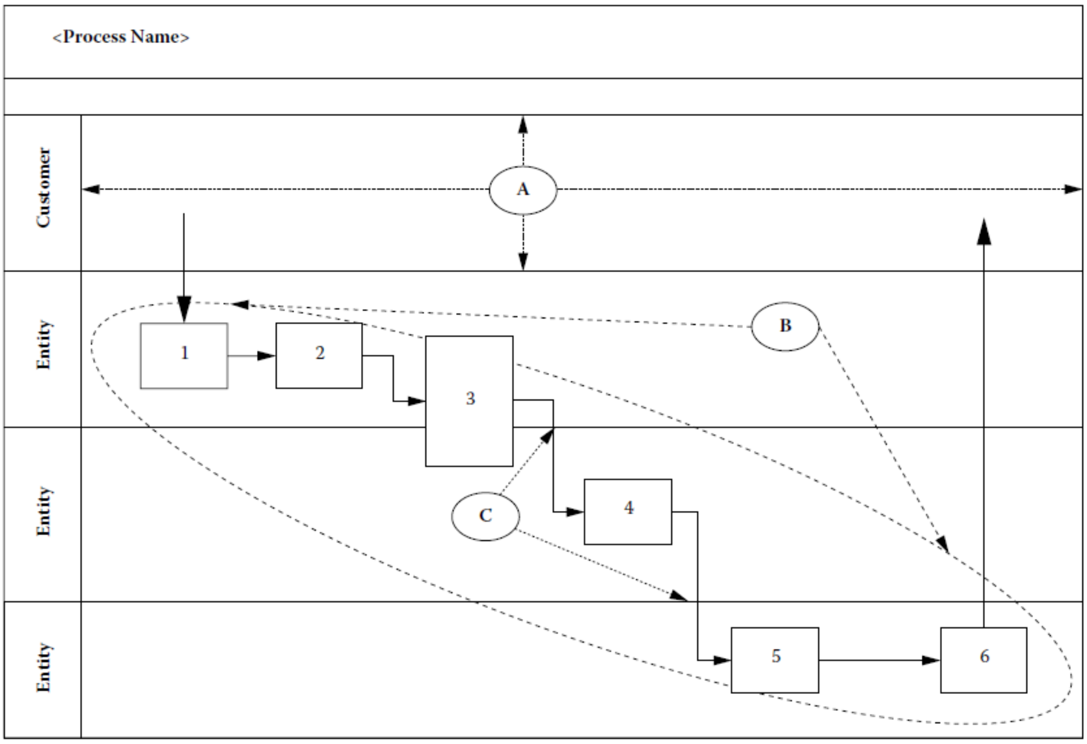


Figure 5.12: Cross-functional process map (Damelio, 2011)

In figure 5.12 a cross-functional process map is shown. 'A' represents a 'swim-lane', which shows a part of the organisation. 'B' is the total work-flow. 'C' represents the hand-off between two parts. It is a supplier-customer relationship, which in this case is internal. A swim-lane diagram shows the boundaries of the work-flow as well as when and where work takes place. It shows what part provides input to another part.

It is use-full to put the customer of the created value in the top most swim-lane and one guideline suggests ordering the other entities accordingly with their interaction with the customer.

Conventions

There are some conventions relating to creating a cross-functional process map.

A box is used to represent activities, a box should be shaded if there is a separate map or flowchart for this activity, see figure 5.13.

Inputs and outputs should be labelled and need to be represented by an arrow to show the direction. The input is the resource that is transformed by the activity. See figure 5.14.

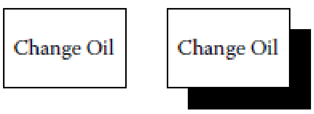


Figure 5.13: Symbols for activity (Damelio, 2011)

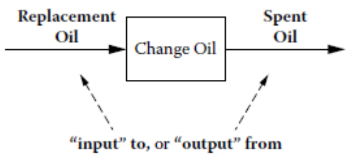


Figure 5.14: Symbols for inputs and outputs (Damelio, 2011)

The overall direction of the work-flow should be from left-to-right. Input on the left is converted to output on the right, as shown in figure 5.15.

Arrows within the work-flow should pass under or over each other, instead of intersecting (figure 5.16).

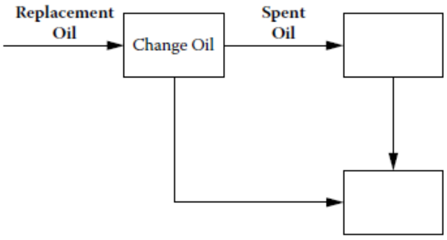


Figure 5.15: Left-to-right (Damelio, 2011)

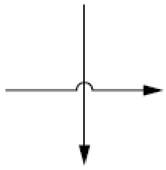


Figure 5.16: Arrow passing over (Damelio, 2011)

As mentioned in section 5.1.1, the diamond symbol should be used when a decision should be made.

If several entities within the work-flow perform the same activity, they collaborate on the same activity, a box should be drawn to show the inclusion of those entities, as shown in figure 5.17. If an entity does not collaborate but is between the collaborating entities a dotted line, see figure 5.18, should be used.

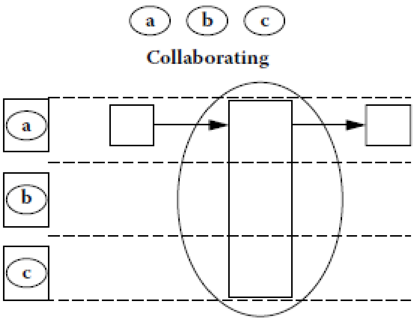


Figure 5.17: "a", "b" and "c" collaborating (Damelio, 2011)

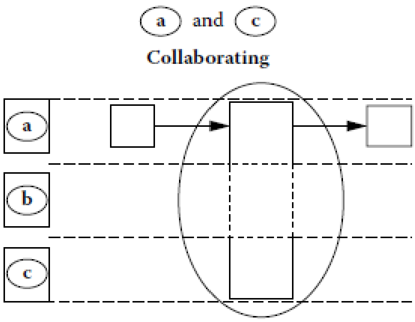


Figure 5.18: "a" and "c" collaborating (Damelio, 2011)

It is possible to split up a swim-lane if a subset of similar work is being done within an entity, as shown in figure 5.19.

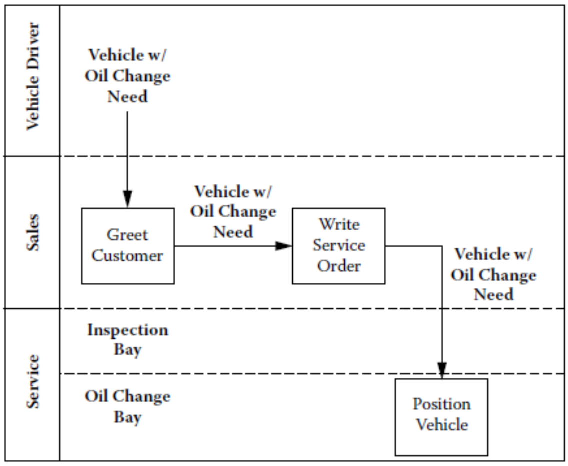


Figure 5.19: Split swim-lane (Damelio, 2011)

An example of a swim-lane diagram of Phil's Quick Lube can be seen in figure 5.20.

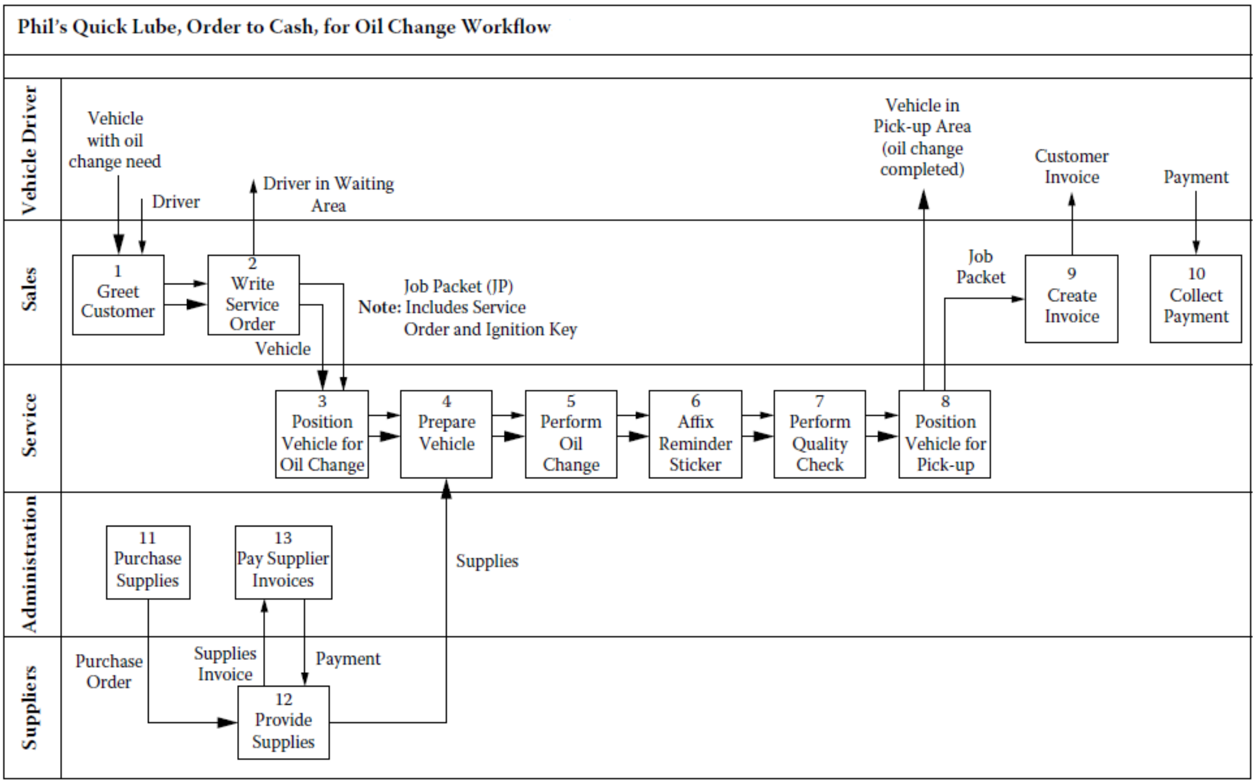


Figure 5.20: Swim-lane diagram Phil's Quick Lube (Damelio, 2011)

Flowchart

A flowchart is a step deeper into the processes than the swim-lane diagram. It represents a sequence of activities that produces a specific unique output. An activity of a swim-lane diagram can be used as subject of a flowchart.
Within a flowchart more different symbols than in a swim-lane diagram will be used. Typical flowchart symbols are shown in figure 5.21.

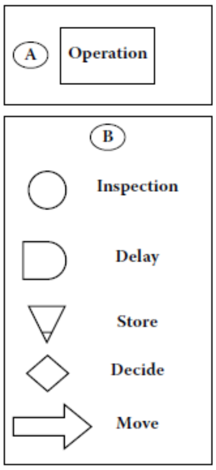


Figure 5.21: Typical flowchart symbols (Damelio, 2011)

Activity 2 from figure 5.20 has been used as the subject of the work-flow diagram in figure 5.22. The boxes 'Page 2' and 'A' refer to other pages of this workflow diagram which are not shown here. This figure shows that a work-flow diagram represents the micro level of a process.

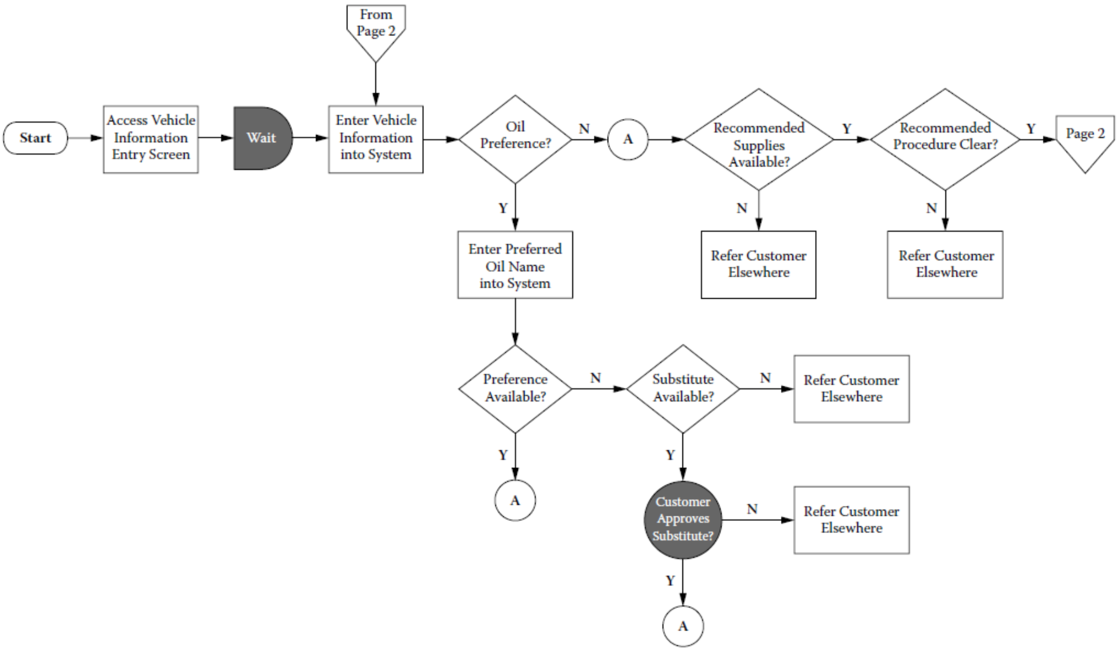


Figure 5.22: Activity 2 work flow diagram (Damelio, 2011)

5.1.3 Delft Systems Approach [3]

The Delft Systems Approach (Veeke, 2008) is another method to map processes. The book focuses mostly on industrial systems.
Although it is believed that by using the definitions and terms given by Veeke will help in understanding the process and there role of its elements within it.
Therefore the system concepts that are used within the Delft Systems Approach (DSA) will be explained in this section.

[3]This section is based on the book by (Veeke, 2008)

System

A system is a collection of elements and there is interaction between these elements. The definition given by (Veeke, 2008) is: *"A system is, depending on the researcher's goal, a collection of element that is discernible within the total reality. These discernible elements have mutual relationships and (eventually) relationships with other elements form the total reality.* Within this definition some key-words have been used, these and other concepts will be explained further.

Elements These parts are the smallest parts of a system. They are also called objects, components, entities. When talking about living elements there are not called objects but subjects. That is why the term element is used, since this can account for both explanations. An element can also be material or non-material. If the elements are material, such as the parts of a machine, then the system is concrete. A system is called abstract if the elements are non-material, such as a system of services.

Content This is the sum of the collection of elements of the system. One could also call this a 'parts list'.

Attributes These are the properties of the element. For example the length and/or character of a person.

Relationships Between elements certain relationships exist. These relationships represent an interaction or multiple interactions that occur between elements.

Structure The list of all the relationships is called the structure of the system. The content is the parts list of the drawing and the structure is provided by the actual drawing.

Universe This is the total reality, all the elements and relationships, known and unknown. Not all the elements in the total reality have a relationship with one of the elements in the system under consideration. That is why the environment is also distinguished.

Environment The environment of a system is all the elements of the universe that influence or are influenced by the elements of the system. It may prove difficult to discern all the elements of the environment. It is sometimes not clear if an element outside the systems has an influence on the system or not.

Emergence This concept means that groups or elements display characteristics that are only there when assigned to the whole and cannot be reduced to the single elements.

Subsystems and Aspect-systems

It has proven useful to split the system into subsystems and aspect-systems. A total system consists of elements and relationships, therefore two methods can be used to split partial systems: subsystems and aspect-systems.

Subsystem *"A subsystem is a partial collection of the elements in the system whereby all the original relationships between these elements remain unchanged."*
The original system forms an important part of the environment of a subsystem. For example, the starting motor of a car engine. The engine is a subsystem of the car, the car is the environment of the engine. And the starting motor is a subsystem of the engine, the

engine the environment of the starting motor.
Subsystems should be chosen such that they are a more or less independent part of or they fulfil a function in the whole.

Aspect-system *"An aspect-system is a partial collection of the relationships in the system whereby all the original elements remain unchanged."* The relationships of an aspect-system are usually on the same type. In a motor these are two of the many aspect-systems:

- The thermodynamic aspect-system, the conversion of chemical into kinetic energy for example
- The kinematics aspect-system, movements parts of the motor make in relation with another.

Between aspect-systems relationships also exist, these are called inter-relations. And social aspect-systems are relationships between people that are part of the system.

Summary Subsystems divide groups of elements while keeping the relationships between those elements and aspect-systems divide relationships while keeping the elements.

State, process and behaviour

All the characteristics of the elements have certain value, the elements can influence each other so that values changes. In that case there is a relationship between elements.

State A state of the system is the value of the characteristics of a system at a given time. When the value of the property of an element changes an event has occurred. When one event leads to another event it is an activity. The state of a system is the result of previous activities or events.
Not only can the values of the properties change, but also the nature of the relationships. This is called a changing structure.
Time-dependent systems rely on input from the environment, energy, materials, ideas, etc., to fulfil their functions.

Process *"A process is a series of transformations that occur during throughput which result in a change of the input elements in place, position, form, size, function, property and any other characteristic."*
The activities in a process are usually performed by subsystems. Those subsystems have their own function and corresponding contribution within the process. The goal of the system fulfilling its function in the environment, which it does with the processes. And each element and subsystem helps achieving the system's goal.

Behaviour *"Behaviour is the property of an element that describes the way in which the state of the element together with its input results in output."*
If the output can be predicted from a known input, the behaviour is called completely determined (deterministic). If the output can only be predicted to a certain degree, the behaviour is called stochastic.

Goal, function and task

Table 5.2: Task and function

Task	Function
What the element does	Its purpose
The actual work	The (unintentional) effect of it in the greater whole

The function of an element is the desired contribution of that element to the greater whole. This is also the case for processes and subsystems. The task is what needs to be done to meet the function.

5.1.4 Conclusion

The techniques, methods and conventions used by (Galloway, 1994) and (Damelio, 2011) in their books will be useful when creating a framework and when actually mapping the processes in the Port of Rotterdam.
The steps given by Galloway to define the process will help focus on the important steps and the three different maps explained by Damelio will help to represent the processes clearly. The cross-functional process map will probably be used the most, although for some processes a flowchart will also be needed to clarify some activities.

The Delft Systems Approach by (Veeke, 2008) will be useful in defining certain parts of the processes and to order them into various categories such as subsystems and aspect-systems. Using the terms and definitions given by Veeke will result in a more clear and understandable process map.

6 | Summary

This chapter will summarise the previous chapters regarding the literature part. The goal for this chapter is to create a short overview in which all the literature is combined to give a broad view of the step that are to be taken.
Not all the literature that has been discussed will be part of this summary. Some literature will function as background information, for example the chapter on agent based methodology.

6.1 Actor analysis

As mentioned in chapter 4.1 both the analysis of Koppenjan and Klein (Koppenjan and Klijn, 2004) and the one of Enserink (Enserink, 2010) take roughly four steps:

1. Formulate the problem
2. Determine relevant actors
3. Identify stance and objectives of stakeholders
4. Ascertain position and resources of the actors

Koppenjan and Klein take a look at the interactions within a network as well.

The first two steps are not ones that can be taken actor per actor but need to be done beforehand.
The problem of this research is to discover the processes as they occur, and the reasons why, within the nautical chain of the Port of Rotterdam. The nautical chain consists of the processes starting at the point where a sea-going vessel enters the 12-mile zone until it is berthed at a terminal and the processes from leaving the terminal until leaving the 12-mile zone. Thus the boundaries of this process are clear, only the processes occurring when the vessel is sailing are relevant for this research.

This also helps with determining the relevant actors. There are six actors who perform actions within the nautical chain relevant to the safe and efficient passage of a sea-going vessel in the Port of Rotterdam. Those actors are a vessel, the Port Authority, the pilot organisation, a towage company, the boatmen organisation and a terminal. Other process occurring to a vessel in port, such as control by customs or bunkering fuel, usually take place when a vessel is berthed and is thus not relevant for this research.

That covers the first two steps, the other two steps and the network analysis have to be taken per actor. The research for these two steps will overlap. First, the (in)formal relations between the actors need to be investigated, as discussed in section 4.1.2.
Then an inventory of the problem perception must be taken, as well as the interests and objectives of the actors. This is described in sections 4.1.2 and 4.1.3.
Finally, the dependency relations between actors and networks of power are analysed. This

has been discussed in sections 4.1.2 and 4.1.3.
Koppenjan and Klijn (Koppenjan and Klijn, 2004) also suggest a method for a network analysis, closely relation to the (in)formal relations mentioned before.

Following these methods will result in a sound actor analysis that can be used as a basis to investigate the business models and processes.

6.1.1 Business models

With the help of the actor analysis and some further investigation. The Business Model Canvas of Osterwalder proved to be a good way to analyse a business model.
The Business Model Canvas consists of nine different building blocks that have been discussed in section 4.2.1. With the help of these building blocks a concise business model can be constructed for each service provider. Not all the building blocks will be relevant for this research and for some it may prove difficult to obtain the right information.

The important building blocks are: Value Propositions (4.2.1), Channels (4.2.1), Key Resources (4.2.1), Key Activities (4.2.1) and Key Partnerships (4.2.1). Of lesser importance are: Customer Segments (4.2.1) and Customer Relationships (4.2.1). This is because all the service providers essentially service one customer, which is a vessel. The two building blocks that refer directly to money, Revenue Streams (4.2.1) and Cost Structure (4.2.1), will be difficult to analyse. This is because the service providers will probably prefer to keep this information to themselves and there is no added value in knowing these things for this particular research.

The resulting concise business model will provide an even better insight into the various service providers. And will help explain certain relations and reasons for processes.

6.2 Mapping techniques

This is the main part of this master thesis. Mapping the process of the service providers in the Port of Rotterdam. The books and methods discussed in chapter 5.1 will be used to map the process in as much detail as needed and as is possible.
The level of detail can be determined when working on the processes and obtaining information. The theories from chapter 3.2 will help with that as well.

Part II

Actor Analysis & Business Models

7 Introduction

In this part two types of analysis of the actors in the nautical chain of the Port of Rotterdam will be performed, an actor analysis and a business model analysis.

This part does not discuss the operational processes and capacities of the actors in the nautical chain, those are discussed in part III.

7.1 Actor analysis

Firstly, in chapter 8, an actor analysis will be performed with the methods of Enserink, and Koppenjan and Klijn (Enserink, 2010; Koppenjan and Klijn, 2004). These were discussed in part I.

This chapter starts with a recap of the methods, after that the actors will be discussed one by one. This includes an introduction to the actors, their relations, interests and objectives and inter-dependencies.

7.2 Business models

Chapter 9 will discuss the business models of the actors involved. This analysis is based on the business model canvas of Osterwalder (Osterwalder et al., 2010), it will not be followed to the letter since the canvas focusses mainly on commercial private ventures. The actors of this research are both private and public companies. The analysis will look at different aspect of the companies such as customer segments, key partnerships and activities.

7.3 Actors

The actors in this research are the Harbour Master, the pilot-organisation, the tugboat-companies, boatmen-organisation, terminal-operators and the vessel.
The Harbour Master is a compound actor of the Port of Rotterdam Authority. He is responsible for the safe and smooth traffic in the port and to this end performs public tasks.
Maritime pilots guide vessels longer than 75 meters into and out of the port in order to achieve a safe and smooth traffic in the port.
Tugboats help manoeuvre vessels in the port and its harbours. Without tug-assistance many vessels would have trouble manoeuvring in the harbours which would cause delays and possibly dangerous situations.
Boatmen are tasked with the (un)mooring of sea-going vessels. Vessels larger than 75 meters are obliged to employ the services of the boatmen.
Often a terminal is the destination of a vessel calling at a port, here their cargo is unloaded

and new cargo is loaded.
The activities of the nautical service providers are dispatched to vessels. The visiting of vessels to the Port of Rotterdam is very important to the nautical service providers.

8 | Actor analysis

This chapter shows the relations between the various actors of this research and their interdependencies.
It shows that all the actors have different responsibilities within the nautical chain and with that responsibilities different kind of rules and regulations apply.
Interests and objectives within the nautical chain also vary, but all relate to performing the activities in the nautical chain and servicing the vessel.
An essential part of this chapter is to determine whether actors are invaluable to the nautical chain or if they can be replaced.

First a short recap of the methods presented in chapter 4 will be given.

Opportunity This research presents an opportunity rather than a problem. The goal is to map the nautical chain as it is now. This map can then be used to help the search for efficiency improvements. The methods presented in chapter 4 will be used to analyse the actors of the nautical chain.
Enserink (Enserink, 2010) as well as Koppenjan and Klijn (Koppenjan and Klijn, 2004) have the same first two steps: Formulation of a problem and inventory of actors involved. The formulation of a problem serves as a working hypothesis, to give the analyst a starting point. Also in formulating the problem, a perspective can be chosen. Either the analyst regards himself as the problem owner or as the person doing the analysis. In this case the analyst regards himself not as the problem owner but as the person doing the analysis.

Inventory of actors The second step is the inventory of actors involved. In the case of this research this has already been done. The main nautical service providers (NSP) of the Port of Rotterdam are regarded as the actors. These are the Harbour Master, the pilot-organisation, the tugboat-companies, the boatmen-organization and the terminal-operators. The vessel is not a nautical service provider but essential for the nautical chain, since she is the recipient of services . The vessel is thus the sixth actor.

Since this thesis represents an opportunity rather than a problem and the actors have already been identified, the actor analysis will not include the first two steps of the actor analysis methods of Enserink and Koppenjan and Klijn.
As was described in Enserink's stakeholder analysis (Enserink, 2010), formal relations can be described in three ways:

Formal relations One by one the actors will be analysed following the techniques presented in the literature part of this research.
This will start with mapping the formal relations.As was described in Enserink's stakeholder analysis (Enserink, 2010), formal relations can be described in three ways:

1. By describing the formal positions and the tasks and responsibilities of the actors

2. Specifying formal relations between actors
3. Describing in short the most important laws, legislation, procedures and authorities

These steps will be used to map the formal relations in the nautical chain of the Port of Rotterdam to the extent where the documentation and information will allow it.

Interests and objectives Following the formal relations, the interest and objectives of the actors will be determined. This will be done using the methods of Enserink, and Koppenjan and Klijn (Enserink, 2010; Koppenjan and Klijn, 2004) as was discussed earlier. However, in their methods they also include the problem perception of the actors, since as explained before this research focusses on an opportunity rather than a problem, this will not be included.

Inter-dependencies As a last step the inter-dependencies will be analysed. This step has three parts, first it will be determined what the most important resources of each actor are. These resources, as distinguished by Kok (Kok, 1981), are:

- Information
- Knowledge (and skills)
- Manpower
- Money
- Authority/formal power
- Position in network: support from or access to other actors
- Legitimacy
- Organisation (ability to mobilise and use resources effectively and efficiently)

The next step uses table 8.1 to determine the resource dependency of actors. The dependency on a certain resource of an actor depends on the resource's importance and the available options to replace it.
For example, pilots use their knowledge to guide vessels into the Port of Rotterdam. As of now there is no way of replacing this knowledge. This means the knowledge-resource of the pilots has a high dependency.

Table 8.1: Resource dependency (Hanf, 1978)

	Limited importance	**Great importance**
Limited options to replace	Medium dependency	High dependency
Can easily be replaced	Limited dependency	Medium dependency

Table 8.1 looks at resources in a positive way, the dependency of the resource in relation to supporting activities rather than blocking them.
However, actors may also want to hinder activities. Actors that have this kind of blocking power or the resources to realize certain activities are called critical actors. These are actors vital to the activities performed and cannot be ignored.
To go back to the example of the maritime pilots mentioned above, if the pilots would no longer perform their activities the nautical chain would miss an essential link and it would stop functioning. To that effect the pilot-organisation is a critical actor.

The dedication of parties also plays a part in their dependency. Dedication of actors is determined by which extent their core interests are affected by the problem. For example, if an actor is affected by costs or benefits this will usually mean the actor is dedicated.
The dedication of an actor in this research will be determined based on its interests and objectives in the nautical chain. It is to be expected that all the actors of this research

can be classified as dedicated actors.
Back to the example of the pilot-organisation, they perform all their activities in the nautical chain, their interest in the nautical chain is high. They can thus be classified as a dedicated actor.
Table 8.2 can then be used to categorize actors based on their criticality, dedication and whether their interests are beneficial to the nautical chain or not.

Table 8.2: Overview table for classification of inter-dependencies (Enserink, 2010)

	Dedicated actors		**Non-dedicated actors**	
	Critical actors	Non-critical actors	Critical actors	Non-critical actors
Similar/ supportive interest and objectives	Actors that will probably participate and are potentially strong allies	Actors that will probably participate and are potentially weak allies	Indispensable potential allies that are hard to activate	Actors that do not have to be involved initially
Conflicting interests and objectives	Potential blockers of certain changes (biting dogs)	Potential critics of certain changes (barking dogs)	Potential blockers that will not act immediately (sleeping dogs)	Actors that need little attention initially (stray dogs)

8.1 Harbour Master

The Port Authority, also called Port of Rotterdam Authority, is a land-lord port, meaning that it owns the ground of the Port of Rotterdam and leases this to other entities such as terminals. Thus, the Port of Rotterdam does not operate the terminals and such, it maintains and develops the port area. As Port Authority it is also responsible for maintaining a safe and smooth handling of all shipping, this is the primary responsibility of the Harbour Master. The Port of Rotterdam is an unlisted public limited company with 70% of the shares owned by the municipality of Rotterdam and the other 30% by the Dutch government.

Within the nautical chain it is the Harbour Master that takes part in the process, The Harbour Master is a compound actor of the Port Authority. Since the Harbour Master is the division involved in the nautical chain this analysis will focus on the Harbour Master and not the Port Authority as a whole, so this actor will be known as the Harbour Master.

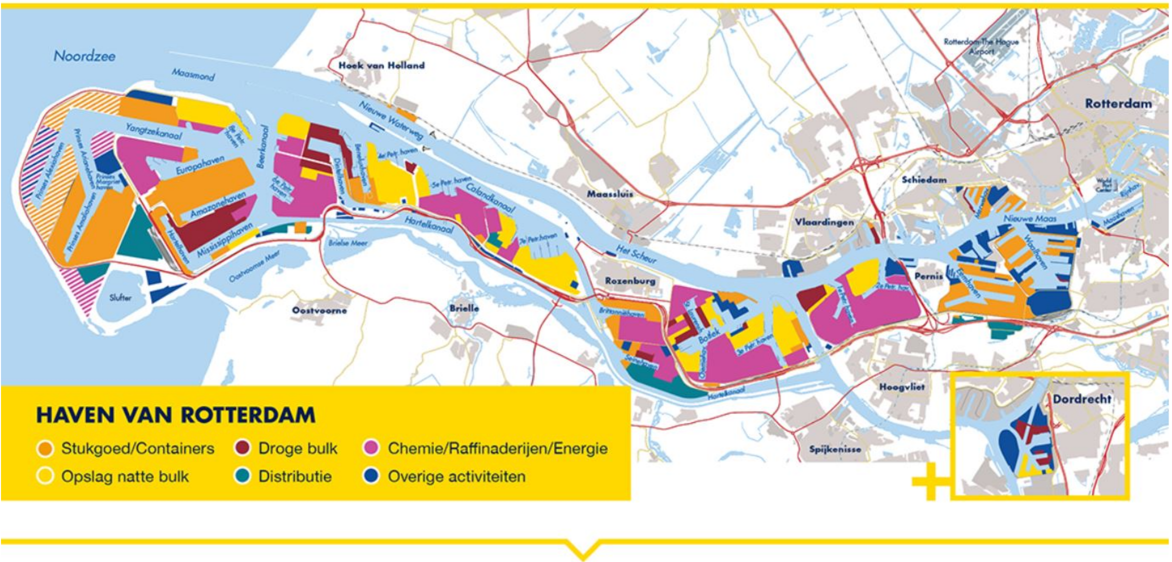


Figure 8.1: Port of Rotterdam (Havenbedrijf Rotterdam, 2016)

8.1.1 Mapping formal relations

The Harbour Master is a special division within the Port of Rotterdam Authority, which can also been seen in figure 8.2. It is not accountable to the executive board of the Port of Rotterdam for its policies but to the competent authorities[1].

In the context of the public interest the Harbour Master is responsible for a safe, efficient and sustainable handling of the shipping traffic. To be able to perform this duty the Harbour Master has been given the mandate to perform certain public-law tasks. The powers relating to these tasks have been delegated to the Harbour Master by the central government and the municipalities of Rotterdam, Schiedam, Vlaardingen, Dordrecht, Zwijndrecht and Papendrecht (*Havenmeester-convenant Rotterdam* 2004).

As Port Security Officer the Harbour Master is also responsible for enforcing the security rules set in the International Ship and Port facility Security Code (ISPS).

[1]Mainly the municipality of Rotterdam and the Dutch government

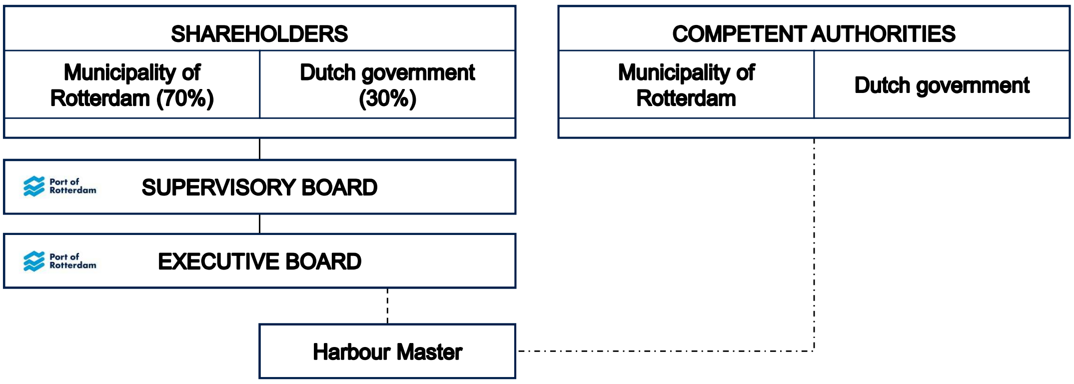


Figure 8.2: Organisational chart Port of Rotterdam

Another responsibility is the admissions of vessels to the port. The Harbour Master is the Reporting Authority, to which vessels have to make their intentions clear to the Harbour Master. Based on this information the Harbour Master will decide on administrative clearance.
Next to this the Harbour Master is also the VTS authority, in this capacity the Harbour Master deals with the operational clearance of vessels and vessel traffic services.

In this research it are especially the Harbour Coordination Centre (HCC) and the Vessel Traffic Service (VTS) departments of the Harbour Master that take part in the nautical chain.
The HCC deals with the administrative clearance and the VTS with the operational clearance and vessel traffic services.

The most important rules and regulations regarding the Harbour Master are firstly that sea-going vessels with a gross tonnage of 300 or more and carrying certain chemicals have a duty of notification to the Harbour Master (Staatcourant, 2015). And secondly, that the Harbour Master is the enforcing authority regarding international, national and local rules and regulations.

8.1.2 Determining the interest and objectives

The Harbour Master is responsible for, and thus has as a main interest, the safe and smooth flow of ship-traffic in the Port of Rotterdam.
More specifically its five main interests are: safety, efficiency, environment protection, security and health in the Port of Rotterdam. In this research only safety and efficiency are relevant.

The objective is to maintain the safety and efficiency. The Harbour Master wants to keep improving efficiency (Port of Rotterdam, 2017a) while maintaining a safe shipping environment. This requires cooperation between all the parties involved in the maritime chain to keep the risk off shipping-delays to a minimum.

8.1.3 Analyse inter-dependencies

The Port Authority receives a lot of information on the port and the vessels that want to enter the port. Much of this information is also distributed to other actors.
The Harbour Master has formal powers given to him by the central government and the municipalities within the Port of Rotterdam.
Thus, the most important resources of the Harbour Master are its formal power and information.

Vessels that want to enter the Port of Rotterdam are legally obliged to provide the Harbour Master with certain information, this is discussed in chapter 13. This formal power cannot be transferred to another party or actor. This formal power is also essential for keeping the Port of Rotterdam safe and efficient, it has a high dependency.
Based on the power the Harbour Master has and its essential role in the nautical chain, it is a critical actor.

Since the Harbour Master has as objective to maintain the safety and efficiency of the Port of Rotterdam, in which the nautical chain plays a vital part, it can be considered as a dedicated actor who is in favour of the nautical chain.

Table 8.3: Actor analysis - Harbour Master

Harbour Master	
Interests	Safe and smooth shipping
Desired situation/obj.	Maintaining safety/efficiency, cooperation
Important resources	Formal power, information
Replaceable	No
Dependency	High
Critical actors	Yes

8.2 Pilot-organisation

A registered maritime pilot, in this research also called (maritime) pilot, guides a vessel into and out of the port and its harbours. Vessels longer than 75 meters are obliged to take a pilot on-board if they want to sail in the Port of Rotterdam.

Figure 8.3: Pilot on board a vessel

The pilot boards a vessel before it enters the port and will from that moment on guide the vessel to her berth in a safe and efficient way. To accomplish this, the pilot cooperates with the tugs, boatmen and the Harbour Master. The pilot coordinates the tugboats and boatmen to make sure the vessel reaches or leaves its berth safely without being a hindrance to other shipping-traffic.

Pilots have various degrees of qualifications regarding the vessel-type and -size they may to pilot. Depending on the weather-conditions and the vessel-type and -size pilots will embark via a helicopter or a tender, considering an incoming vessel. When the weather-conditions do not allow pilots to be brought to the vessel, smaller vessels can be piloted from shore (Shore-based Pilotage) by a specially trained pilot from the Traffic Centre in Hoek van Holland.

The pilots that are the actors in this research are pilots from the region Rotterdam-Rijnmond. In The Netherlands there are four regions: North, Amsterdam-IJmond, Rotterdam-Rijnmond and River Scheldt. Of these four, Rotterdam-Rijnmond is the largest and busiest region with the most pilots.

In 1988 Dutch Pilotage was privatized. Before, it was part of Rijkswaterstaat[2]. Since then the pilots have operated through two organisations, the Dutch Maritime Pilot's Association and the Dutch Pilotage Services.
All the pilots are independent contractors registered with the Dutch Maritime Pilot's Association and shareholders in the Dutch Pilotage Services. The association provides training and education. The Dutch Pilotage Service is focused on supporting registered pilots in their tasks. This includes administrative tasks, transporting pilots to the vessels, maintaining the fleet and IT-support.

This research focuses on the work of a pilot when he or she is on-board a vessel and the steps taken in the planning phase.

8.2.1 Mapping formal relations

The main task of a registered maritime pilot is to pilot vessels that are obliged to pilotage, for this contributes to a safe and smooth handling of the shipping traffic. Sea-going vessels of 75 meters and larger are obliged to pilotage.
The Pilotage Act states that the registered pilot has the task to provide pilotage services. Furthermore, according to the Pilotage Act the independent pilots are solely authorized in The Netherlands to pilot ships(*Loodsenwet* 2017).

[2]The Department of Waterways and Public Works

8.2.2 Determining the interest and objectives

Just as the Harbour Master the main interest of the pilots is to serve the public interest. The pilots want to ensure a safe and smooth passage of the vessels they pilot. They also want to deliver a high quality service and maintain a good relationship with their clients.

Their objective is to deliver quality services in every operation.

8.2.3 Analyse inter-dependencies

The most important resource of the pilot-organisation is their knowledge. Pilots are specially trained to pilot vessels in the harbours of the Port of Rotterdam. Captains of the visiting vessels and other parties do not have the knowledge to perform these tasks [3].
Vessels larger than 75 metres are obliged to pilotage, this formal power is an important resource.
Thus, the knowledge and formal power that the maritime registered pilots possess are their most important resources.

As mentioned above, pilots are obligatory for vessels larger than 75 meters. This formal power cannot be transferred to another actor, not only because it is against the law but also because no other actor possesses the necessary knowledge.
If for some reason the pilot-organisation would no longer perform their tasks, the nautical chain would no longer be able to function. This blocking power results in the pilot-organisation being a critical actor.

The pilots operate within the nautical chain, they are involved in the chain from almost the beginning to the very end. The services they deliver depend on visiting vessels and the existence of the nautical chain. They are interested in the nautical chain and efficient functioning of the nautical chain and are thus, dedicated actors.

Table 8.4: Actor analysis - Pilot-organisation

Pilot-organisation	
Interests	Safe and smooth shipping
Desired situation/obj.	Quality of operations
Important resources	Knowledge on port, formal power
Replaceable	No
Dependency	High
Critical actors	Yes

[3] It is possible to obtain a Pilot Exemption Certificate (PEC) for certain combinations of vessel, captain and port but this is not common.

8.3 Tugboat-companies

Tugboats assist a vessel with manoeuvring by either pushing or towing it. The precise manoeuvring required in a harbour can often not be safely performed by a vessel herself thus a tugboat has to assist with this.
Tugboats are not obligatory for vessels, like the pilots and boatmen are, unless - in specific circumstances - ordered by the Harbour Master.

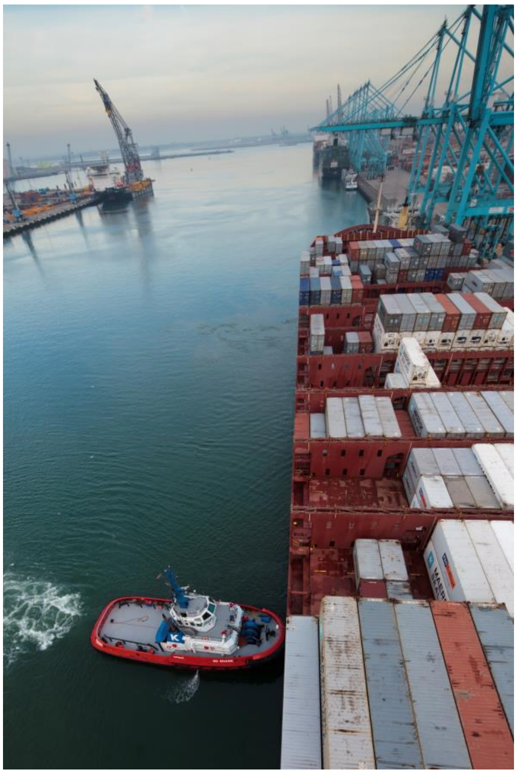


Figure 8.4: Tugboat pushing container vessel

When a vessel enters the Port of Rotterdam and the pilot has embarked, it sails towards the entrance of the harbour. The tugs usually meet the vessel near the entrance of the destined harbour, there they connect to the vessel and manoeuvre the ship towards the berth. This is done in coordination with the pilot on the bridge. When the vessel has berthed and is securely connected to the shore the tugs will move on to their next assignment.
When a vessel is leaving the port, the tugs will assist in unmooring the vessel and sailing it out of the harbour before disconnecting.

Within the Port of Rotterdam the two largest tug-companies that are operational are Kotug Smit Towage and Fairplay Towage. A short introduction to these two companies will be given next. For the remainder of this research the tugboat-companies are viewed as a single actor, since procedures, objectives and interests of the separate companies align.

Kotug Smit Towage

In April 2016, the towage department of Kotug International and Smit merged to form Kotug Smit Towage. SMIT was established in 1842 in the Port of Rotterdam by Fop Smit and became a member of Royal Boskalis Westminster in 2010 (Kotug Smit, 2017).
The origins of Kotug International can also be found in Rotterdam, in 1934 the company 'Towage Company Adriaan Kooren BV' was registered in Rotterdam. Later in 1987 Adriaan Koorens' son established Kotug International B.V.
Kotug Smit Towage is active in twelve ports in Europe, in Belgium, Germany, The Netherlands and the United Kingdom. They operate a total of 64 vessels in all those ports.

Fairplay Towage

Fairplay Towage Rotterdam is part of the Fairplay group based out of Hamburg. Their towage department operates in seven ports throughout Europe, in Belgium, Germany, Poland and The Netherlands. They operate a total of 36 tugs in all seven ports, of those 36, 8 are stationed in Rotterdam/Antwerp (Fairplay Towage, 2017).

8.3.1 Mapping formal relations

As mentioned above, vessels are not obliged to employ the services of a tug in the Port of Rotterdam. Practice shows that without tug-assistance many vessels are not able to manoeuvre safely in the port in the same time span. Vessel would be able to make the manoeuvres without tug-assistance but that would take much more time resulting in a longer time spent in the port for the vessel and a queue of other vessels.

Shipping companies calling at the Port of Rotterdam usually have a contract with one of the tugboat-companies to provide services every time one of their ships requires it.
A certain amount of tugs are ordered based on, among others, previous visits. But it is possible that due to certain conditions, such as the weather or a defect bow-thruster, the pilot requires more tugs than were ordered.
Tugboat-companies make their planning based on the ordered amount of tugs and if a last minute change is made by the pilot this could cause capacity problems. Thus, the tugboat-companies are somewhat dependent on the pilots.

8.3.2 Determining the interest and objectives

The tugboat-companies are commercial parties. They do not have, like the Harbour Master and the pilots, a legal obligation to provide certain services, or the obligation of other parties to enlist their services.
However, they are bounded by contract to deliver their services.

The mission that Kotug Smit has set for itself is to deliver high quality services to their customers and they have the vision to become the largest European harbour towage company (Kotug Smit, 2017). To achieve this, their objective is to have a flexible and efficient organisation. Fairplay also wants to deliver a consistent quality of services (Fairplay Towage, 2017).

So, the interest of the tugboat-company is to deliver quality services and obtain growth by having an efficient and flexible organisation.

8.3.3 Analyse inter-dependencies

The tugboat-companies in the port are the companies with the knowledge and experience to tow large vessels. However, contrary to the pilots, there are other companies in comparable ports that have the same knowledge and experience. For example, the company Bugsier in Hamburg (Bugsier, 2017).
Their position in the network is an important resource. Although the use of tugs is not mandatory in the Port of Rotterdam, without them large vessels spent a long time manoeuvring. Also in case of bad weather or other circumstances the Harbour Master can obligate vessel to use tug-assistance.

The above also means that the tugboat-company is a critical actor. Some large vessels such as cruise liners that operate azimuth thruster do not need tug assistance, but most of the other large vessels do. There is thus a high dependency and there are limited options to replace tugs.
It needs to be noted that the tugboat-company as a whole is a critical actor but that the individual companies are less critical since they can replace each other.

A large portion of the work tugboat-companies perform takes place in the nautical chain, namely their harbour-towage activities. Without it they would lose a significant amount of work, thus the tugboat-company is a dedicated actor.

Table 8.5: Actor analysis - Tugboat-company

Tugboat-company	
Interests	Quality & growth
Desired situation/obj.	Efficient & flexible
Important resources	Position in network
Replaceable	No
Dependency	High
Critical actors	Yes

8.4 Boatmen-organisation

The main activity of the boatmen-organisation is the (un)mooring of vessels. This is done 24/7, in all weather conditions, throughout the port.

The boatmen sail to the vessel in a mooring boat, there they collect the ropes of the vessel which are brought to the quay, buoys or jetty. When mooring at a quay the ropes are given to fellow boatmen who attaches the ropes at the bollards, sometimes with the help of a truck equipped with a towing winch.
Boatmen also assist shifting vessels, these are vessels that move location within the port or shift at the quay. This involves first unmooring the vessel at one location and then mooring it at the next. The boatmen-organisation also assists in the transport of pilots. They use fast vessels and taxis for that purpose.

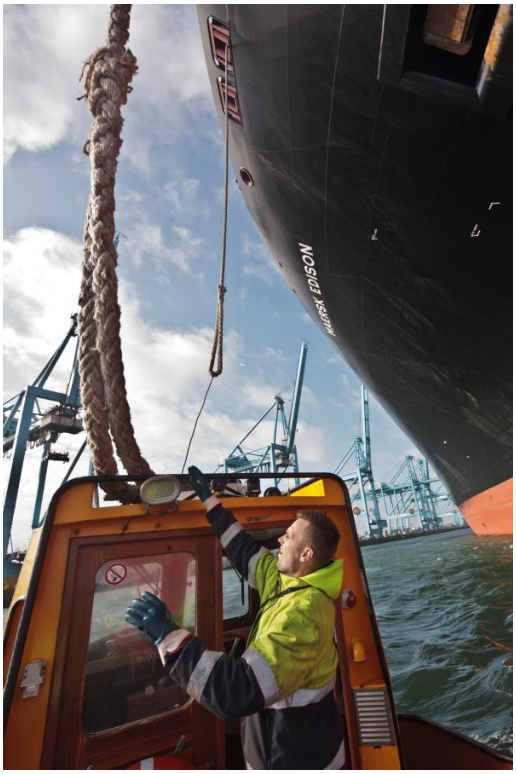


Figure 8.5: Linesman at work

The boatmen-organisation in the Port of Rotterdam is the Koninklijke Roeiers Vereeniging Eendracht (KRVE). This organisation was established in 1895 and back then rowboats were used to collect the ropes. That is why the Dutch name for boatmen is still *roeiers* (rowers), nowadays the KRVE has about 60 modern vessels to perform their duties.

8.4.1 Mapping formal relations

The boatmen perform the mooring and unmooring of seagoing vessels. Vessel of 75 meters or larger are obliged to use the services of the boatmen in the Port of Rotterdam. Vessels smaller than 75 meters but which contain dangerous cargo need to be (un)moored by qualified boatmen. Exemptions can be made for certain vessels under strict conditions, for example the Ro-Ro vessels that frequently (once every 48 hours) visit a dedicated berth (Port of Rotterdam, 2010).

8.4.2 Determining the interest and objectives

The main interest of the boatmen-organisation is business continuity and serving their customers (vessels) to the best of their ability. They want to deliver high quality services to their customers.
There is no competition of other boatmen-organisations within the Port of Rotterdam and to keep it that way the KRVE aims to deliver high quality services for competitive tariffs, as to leave no room for competitors.
To achieve continuity and competitive quality their objective is to keep improving the quality of their services by innovations such as the ShoreTension (KRVE, 2015).

8.4.3 Analyse inter-dependencies

Since vessels are obliged to employ the services of the boatmen when larger than 75 meters, the most important resource of the boatmen is their formal power.
They also have a vast amount of knowledge regarding the (un)mooring of vessels, but this knowledge is not exclusive to the Port of Rotterdam, as is the case with the pilots. In other ports the same knowledge is available.
Although if external boatmen want to perform their services in the Port of Rotterdam they need to have completed an accredited boatmen education or have at least four years of experience in a comparable port.

Since there is only one boatmen-organisation within the current nautical chain they are irreplaceable. This, combined with the fact that most vessels are obliged to use the boatmen, means that the boatmen-organisation is a critical actor.

The primary activity the boatmen perform is part of the nautical chain, the (un)mooring of vessels. A good functioning nautical chain is essential to their work, they are thus a dedicated actor.

Table 8.6: Actor analysis - Boatmen-organisation

Boatmen-organisation	
Interests	Continuity
Desired situation/obj.	Keep improving quality, innovation
Important resources	Formal power
Replaceable	No
Dependency	High
Critical actors	Yes

8.5 Terminal

A terminal is the place where cargo is transshipped. A terminal is operated by a terminal-operator. At the terminal the cargo that needs to be unloaded at that specific terminal is taken of the vessel. Also cargo that will be shipped from that terminal is loaded onto the vessel. Cargo taken off the ship will be transported from the terminal to another port via sea-going vessels or to the hinterland via trains, trucks or inland shipping.
These processes are not part of this research, the scope ends at the moment the vessel is berthed at the quay. The terminal is a start- and an end-point of the nautical chain, which among other things means that the designated berth needs to be free and available.
This partly concerns the planning at the terminal and whether or not this planning is on schedule.

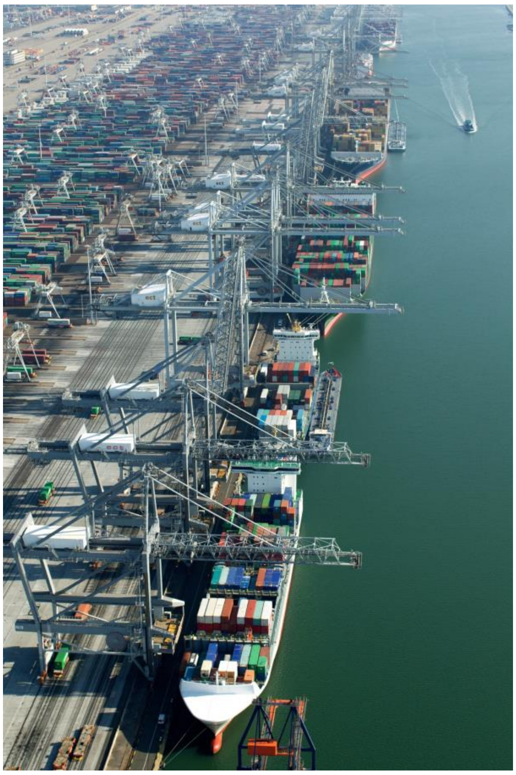


Figure 8.6: ECT Delta terminal

8.5.1 Mapping formal relations

The land the terminal-operator operates his terminal is rented form the Port of Rotterdam Authority. With that land a certain part of the harbour, an amount of meters outside the quay-wall, is also rented. The terminal has an agreement with the Port of Rotterdam about the depth of that harbour and the Port of Rotterdam will make sure that this depth is maintained. This is a task of the Port Authority and not of the Harbour Master.

The terminal is not allowed to accept or invite vessels that are forbidden to come to their harbour, due to safety or size issues. The terminal must also ensure the safety and security of the rented land.

Terminals have contracts with shipping companies regarding the visit of vessels. Container vessels for example sail in line-services, this means that they visit a port on regular intervals. A terminal has a contract with a shipping company, or a shipping alliance, to service this vessels.
At the ECT Delta terminal, for example, one of the quays is reserved for the Mediterranean Shipping Company (MSC) and its alliance partners (personal communication, August 8, 2017).

8.5.2 Determining the interest and objectives

There are many terminals-operators which, within the same market segment, compete with each other, both within and outside of the Port of Rotterdam. Terminals-operators in the Port of Rotterdam are commercial ventures, who's main interest is to service their customers as good as possible. Since there is competition each operator wants to be the best in order to be attractive to shipping companies.

Vessels want to have as little non-sailing time as possible. That means that the terminal has as an objective to (un)load the vessel as fast as possible and sent it on her way again. The (un)loading of the vessel is not part of the nautical chain and falls outside of the scope of this research.
To make sure that the vessel can berth as soon as it has arrived at the port, the terminal has to make sure that the vessel's designated berth is free. And it has to signal the relevant parties in time about the expected departure of the vessel.

8.5.3 Analyse inter-dependencies

The main resource of the terminal is its position in the network, since almost all the vessels going to the Port of Rotterdam will use a terminal. Most vessels need a terminal to be able to (un)load their cargo, this is of great importance and thus has a high dependency.

The nautical chain cannot start if a terminal cannot or will not allow a vessel to visit. A condition for a vessel to enter the Port of Rotterdam is that her berth is free. This blocking power and power of realization makes the terminal a critical actor.

In order for the terminal to (un)load goods and in that way earn money it is necessary for a vessel to come to the terminal. Guiding vessels on their voyage (to the terminal) is the nautical chain, a terminal can thus not exist without the nautical chain, and it is a dedicated actor.

Table 8.7: Actor-analysis - Terminal

Terminal	
Interests	Quality
Desired situation/obj.	(Un)loading as fast as possible
Important resources	Position in network
Replaceable	No
Dependency	High
Critical actors	Yes

8.6 Vessel

Vessels are the reason that the port and the nautical chain exist. All the other actors in this research exist to serve the interest a vessel-call represents.

Figure 8.7: Tanker at sea

In the context of this study, vessels sail to a port, and consequently take part in the nautical chain, to (un)load cargo.

In the port a shipping agent is the representative of a vessel. The agent makes sure that services such as pilots, tugs, bunkering and waste-disposal are ordered. The agents make sure that all the necessary information relating to the voyage is provided to the relevant parties, such as the Harbour Master. This information contains, among other things, the Estimated Time of Arrival and if any nautical service providers are needed.

In this research the vessel and the agent are seen as one actor, namely the party requesting and receiving the services. Ultimately the master of the vessel is responsible for providing all the information and the well-being of the vessel and not the shipping agent.

8.6.1 Mapping formal relations

A vessel needs to notify the Harbour Master and other authorities before arriving or leaving the port. This notification is required by law (*Regeling meldingen en communicatie scheepvaart* 2016).
Examples of an arrival notification are the Estimated Time of Arrival (ETA) which needs to be reported 24 hours before arrival. The Estimated Time of Departure (ETD) needs to be reported two hours before the departure. For more information regarding the subjects that need to be reported are discussed in chapter 13.

Also, as mentioned before, vessels longer than 75 meters are obliged to employ the service of the pilots and boatmen.

8.6.2 Determining the interest and objectives

The vessel is employed or operated by a shipping company. The interest of a shipping company is to make a profit, which means as little time spent in a port as possible.
This can be achieved by shortening the time spent at the terminal while (un)loading and by arriving at the terminal as fast as possible. This second part happens within the nautical chain.
So the objective of the vessels is to spend as short a time in the port as possible.

8.6.3 Analyse inter-dependencies

It should be clear that without a vessel there can be no nautical chain. The nautical service providers would not be able to perform their activities. The position in the network is thus the main resource of the vessel. Obviously this resource cannot be replaced and has a high dependency.

Also the fact that the main activities of the nautical services providers focus on vessel makes the vessel a critical actor.

The vessel is also highly dependent on the nautical chain, due to regulations and operational limitations the vessel can normally not reach the terminal without the nautical chain. The vessel is thus a dedicated actor.

Table 8.8: Actor analysis - Vessel

Vessel	
Interests	Profit
Desired situation/obj.	Short time in port
Important resources	Position in network
Replaceable	No
Dependency	High
Critical actors	Yes

8.7 Views on the project

As discussed in section 3.1.1 the consortium of the SwarmPort project consists of various parties.
The Harbour Master and a terminal are part of the consortium, the pilot-organisation, the tugboat-companies and the boatmen-organisation are not.
Those actors play a key role in the nautical chain, although accurate information on their processes would contribute to the value of the agent based model.

As of now the companies representing those actors have not fully committed to sharing information for the benefit of the SwarmPort project and subsequently this master thesis. The author has observed the following regarding the commitment of the actors.

The pilot-organisation is careful in sharing business information. The pilot-organisation is under active supervision of the ACM (Authority for Consumers and Markets) as a precautionary measure to ascertain that the pilot-organisation does not abuse its monopoly position.
Because of this supervision the pilot-organisation is very careful in sharing their business information with anyone.
Influence of the ACM may result in less flexibility of the pilot-organisation when the ACM believes processes could be organised more efficiently.

The tugboat-companies do not have a monopoly in the Port of Rotterdam. There are two companies that provide the main part of the tug-services in the port. They are reluctant to make their business information transparent because they do not want that information to be obtained by their competitors.
This does not only relate to the competitors currently operating in the Port of Rotterdam but also to tugboat-companies that are not operating in the Port of Rotterdam. They do not want an extra competitor in this port.

Also, both these actors want to limit the influence the Harbour Master has on their activities as much as possible.

However, the nautical service providers see a chance for added value from this project, but as of now they choose to wait and see.

These parties should have been invited to join the consortium during the initial phase of the SwarmPort project, and subsequent steps in the project should involve the nautical service providers.

It is possible to map the operational processes of these parties without their business information and for now this is the way to proceed. But it should be noted that information on their business processes would further benefit the model.

8.8 Chapter conclusion

In this chapter the actors' relations, interests and objectives, and inter-dependencies have been analysed. As well as their views on the SwarmPort project.

Mapping formal relations It has become clear that there are multiple formal relations between actors in the nautical chain. Mainly between the vessel and the other actors, for example: vessels have to provide certain information to the Harbour Master.
The Harbour Master, pilot-organisation and boatmen organisation are also obliged by law to provide their services to vessels.

Analysing the formal relations shows that there is no central command of the nautical chain. There is not one actor that has the formal power to control the activities in the nautical chain. Although the pilot-organisation has a large influence on the activities in the nautical chain, since they take part in many of the activities.

The relationship between the terminal-operator and the vessel is arranged in the business domain, the relationship between the Harbour Master and the vessel is arranged in the public domain. Consequently, the relationship between the terminal-operator and the Harbour Master is not determined ambiguously.

Determining interest and objectives The interests and objectives of the different actors in the nautical chain do not always align and sometimes may even oppose each other.
However, all actors in the nautical chain benefit from an efficient process of high quality.
To this end, more cooperation and keeping in mind each other's interests could lead to benefits for all the actors in the chain.

Analyse inter-dependencies All actors collaborate in the nautical chain, their services are complementarity to each other. Next, often their services are dependent on each other. For the optimal performance of the nautical chain, these dependencies need to be managed. Thus, agreements need to be made to benefit the performance of the chain.
Furthermore, there are limited to no options to replace actors, by for example with a smart information system. Based on the evidence in the Port of Rotterdam, there is no intention to replace one of the actors in the nautical chain. At this moment, replacement would cause dis-functioning of the chain.

Views on the project The companies that represent the actors who play a key role in the nautical chain have not fully committed to the SwarmPort project and thus, in lesser extent, to this master thesis.

The lack of commitment is due to multiple reasons. The pilot-organisation is careful to share information due to the surveillance on their monopoly position.
The tugboat-companies are reluctant to share information because they do not want their business information to fall in the hands of their competitors.
Both the companies want to limit the influence the Harbour Master has on their processes.

Although they see a chance for added value from the project, it is not enough to fully commit them, and this may result in less added value of the project.

9 Business models

The goal of this chapter is to show that there are different kinds of businesses operating in the nautical chain. These businesses both represent public and private interests but all focus their key activities on vessels. The activities are different and contribute to the nautical chain.
This chapter shows that the nautical service providers and the vessel are dependent on each other.
It also indicates that the revenue the actors obtain flows from the activities they perform in the nautical chain.

Business model canvas For the analysis of the business models of the actors in the nautical chain the business model canvas of Osterwalder (Osterwalder et al., 2010) is used as a basis. This canvas has been explained in part I.

The canvas consists of nine building blocks:

1. **Customer Segments** An organisation serves one or several customer segments
2. **Value Propositions** It seeks to solve customer problems and satisfy customer needs with value propositions
3. **Channels** Value propositions are delivered to customers through communication, distribution and sales channels
4. **Customer Relationships** Customer relationships are established and maintained with each customer segment
5. **Revenue Streams** Revenue streams result from value propositions successfully offered to customers
6. **Key Resources** Key resources are the assets required to offer and deliver the previously described elements...
7. **Key Activities** ... by performing a number of key activities
8. **Key Partnerships** Some activities are outsourced and some resources are required outside the enterprise
9. **Cost Structure** The business model elements result in the cost structure

The business model canvas of Osterwalder focusses on commercial private enterprises. The nautical chain in the port of Rotterdam consists of both commercial/private companies, parties that serve the public interest and some that are a combination of both.
That needs to be kept in mind when analysing the business model, there is a mixture of public and private interests in the same (operational) domain.

9.1 Harbour Master

The Harbour Master is a separate division of the Port of Rotterdam Authority. Its main interests, in the scope of this research, are a safe and efficient port.
Its main 'customers' are the vessels, for which it provides a safe and efficient port. This is achieved through the VTS and HCC services.
Revenue is obtain via port dues, but is not directly relevant to the Harbour Master, and its key resources are information and formal power.

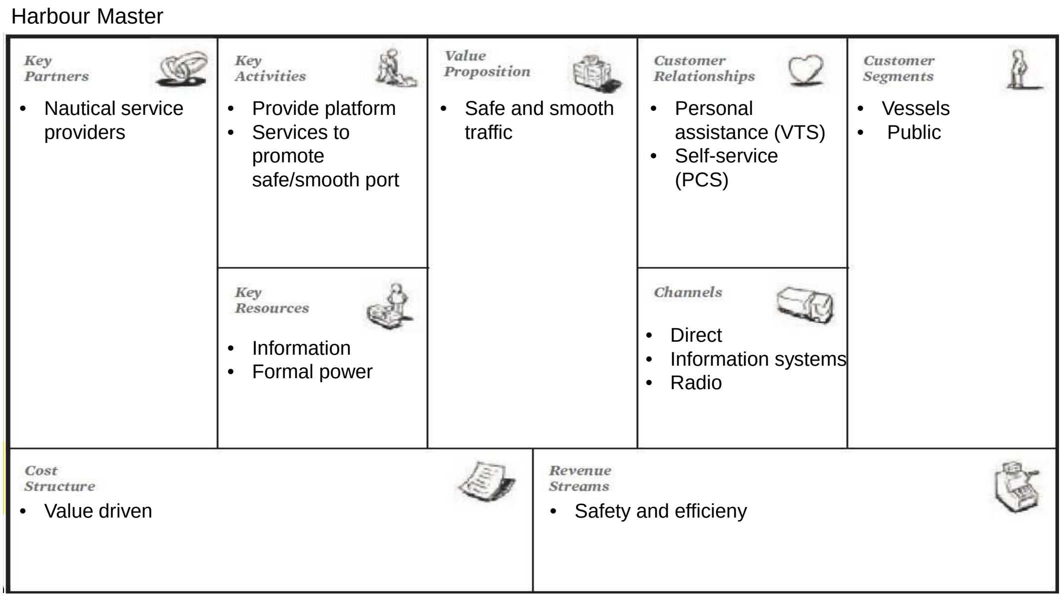


Figure 9.1: Business model of the Harbour Master

Customer segments Vessels visiting the Port of Rotterdam are the 'customers' of the Harbour Master. Both the HCC and VTS provide services to vessels. Servicing these customers in a correct way will ensure a safe and efficient flow of traffic, the main interest of the Harbour Master.
This interest is shared with the Harbour Masters other customers, the public. The shareholders (the government and the municipality) demand a safe and efficient port, so in a way they are customers.

Value propositions Within the Port of Rotterdam vessels have to report to the Harbour Master, but the reason vessels choose the Port of Rotterdam in the first place is not under the sole influence of the Harbour Master. The Port Authority as a whole also plays a role, just as the other nautical service providers.

The value that the Harbour Master delivers is safe and efficient traffic handling in the port. This is achieved by providing certain services (HCC and VTS) and making sure those services sustain a high level of quality. Also the Harbour Master creates and maintains a framework in which the other nautical service providers can and will provide quality services that bring value to the port as a whole.

Channels The channels through which the Port Authority has contact with its customers are direct. They do not use third parties through which they deliver their services. Contact is established through information systems, such as HaMIS, by phone, email or via the radio for the VTS-services.

Customer relationships The Harbour Master has various categories of customer relationships. They have personal assistance, for example the VTS-operators who speak directly to the vessels. There is also a form of self-service, in which the vessels supply information via information systems and not directly to the Harbour Master.

Revenue streams The revenue that the Harbour Master obtains from its services to vessels is not capital but it is safety. The Harbour Master wants to maintain a safe and efficient port partly by providing the VTS and HCC services. In return of those services the Harbour Master receives a safe and efficient port.

Key resources Information and formal power are the most important resources, as was mentioned in section 8.1.
The information the Harbour Master receives from the vessels is crucial for the processes in the port and of the nautical service providers. The formal power of the Harbour Master enables providing for a safe and smooth flow of traffic.

Key activities The Harbour Master provides a platform, the port, where the vessels and nautical service providers can do their jobs. This platform is continuously maintained and improved, making it as safe and efficient as possible.
The HCC and VTS-services are vital to providing this platform. They make sure the port and its traffic are safe and efficient. Every journey of a vessel is unique and guiding this vessel safely to the harbour is part of this platform.

Key partnerships The Harbour Master has partnerships with other actors in the nautical chain. These partnerships are strategic alliances. There is no competitor within the port and these alliances are needed to service vessels qualitatively.

Cost structure The Harbour Master is value driven, it want to provide safe and smooth operations in the Port of Rotterdam. The goal is not to earn money but to provide high valued services.

9.2 Pilot-organisation

Pilots guide vessels into and out of the Port of Rotterdam. Individual pilots go to a vessel and provide a customised service, ensuring a safe and efficient voyage. Vessels have to pay for the service, the fee depending on her size and destination.

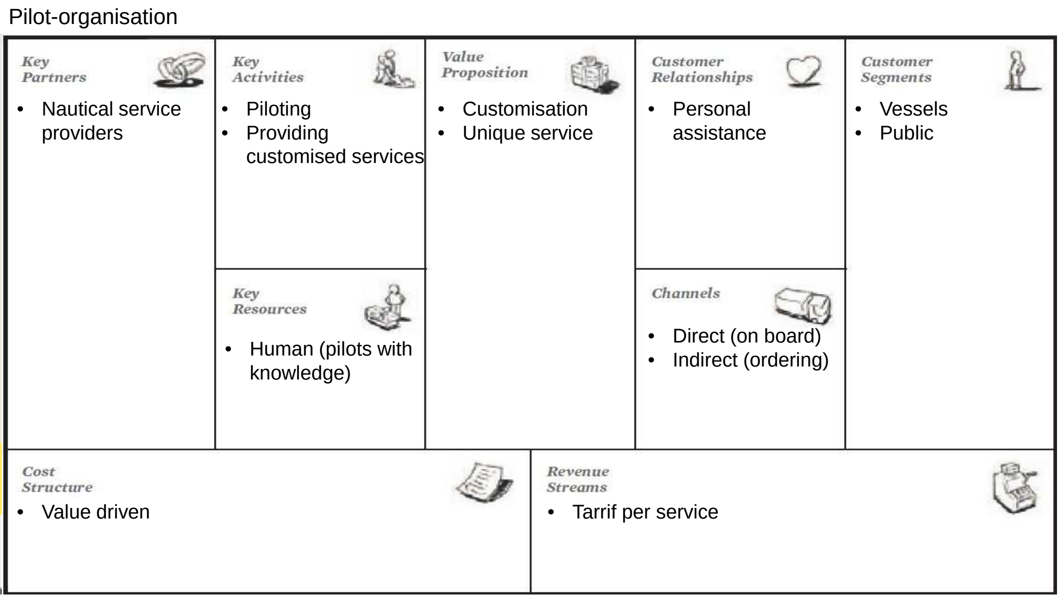


Figure 9.2: Business model of the Pilot-organisation

Customer segments The pilot-organisation has one main customer that is the vessel. This is a niche market, focused on a specialised type of customer segment. Within this segment there are various types of vessels that have to be serviced by various types of pilots.

The public is also, just as with the Harbour Master, a customer. The pilot-organisation contributes to the safe and smooth shipping traffic in the Port of Rotterdam.

Value propositions Customised safe passage into the port is the value that the pilots bring to the vessels. They deliver a unique service to every vessel, the service in itself is not unique, and they perform a pilotage multiple times every day. But every pilot-journey is unique, it is a different vessel, there are different conditions, etc.

Channels Communication between pilots and vessels is conducted directly or via a third party. On-board the pilot communicates directly with the master of the vessel. Whilst in ordering the pilot or supplying preliminary information, the vessel communicates indirectly, via the HCC

Customer relationships The relationship can be defined as personal assistance. One pilot is allocated to a vessel and services that vessel until she is safely moored. The next time a vessel calls the Port of Rotterdam it may be another pilot, that is why it is not dedicated personal assistance.

Revenue streams The pilots have certain tariffs depending on the vessel type, draught and destination (Nederlands Loodswezen, 2017b). Frequency discounts are given and additional fees may be added.

Key resources For the pilot organisation the key resource is the pilots and their knowledge. The pilots are trained for a long time and they constitute the service that the pilot organisation offers.

Key activities The key activity of the pilot organisation is piloting vessels. They deliver a customised service for every trip, it is a form of problem solving.

Key partnerships The partnership that the pilots have is the same as the Harbour Master's, a strategic alliance with the other actors in the nautical chain to service a vessel. Together with the tugs and the linesmen the pilot services a vessel.

Cost structure Just as the Port Authority, the pilot-organisation is value driven. They do have commercial interests, but focus on the quality of their services.
Since the pilot-organisation has a monopoly and want to make a profit, the Authority for Consumers and Markets (ACM), the Dutch competition authority, monitors the tariffs of the pilots.

9.3 Tugboat-companies

Vessels may be assisted by tugboats to manoeuvre in the port. This is not obligatory but many vessels cannot manoeuvre without tug-assistance. Shipping companies have a contract with a certain tugboat company in the port to provide those services to their vessels. Contract prices are based on the size and destination of the vessel.

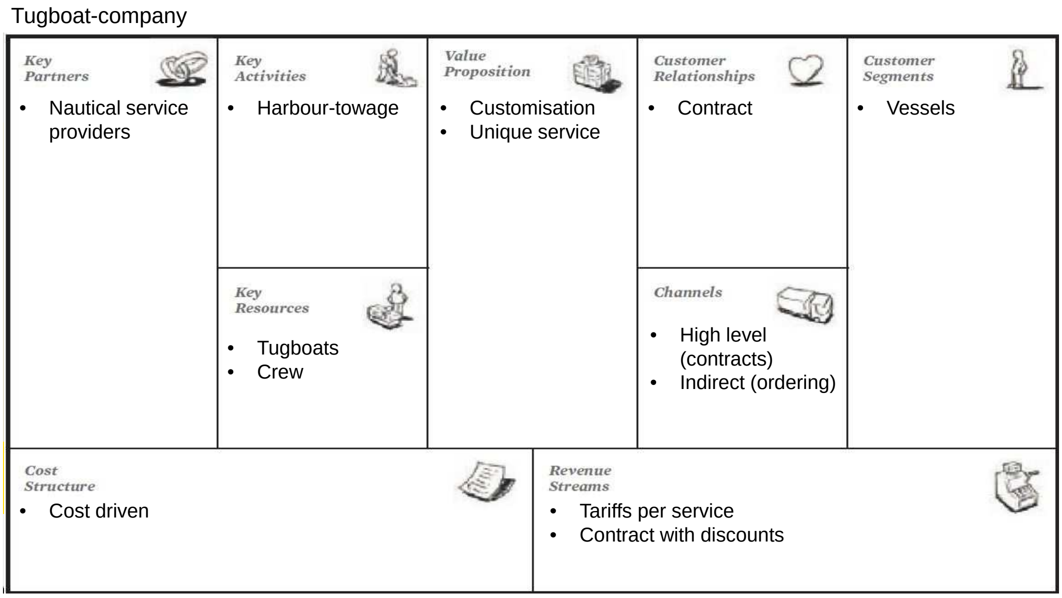


Figure 9.3: Business model of the tugboat-companies

Customer segments Tugboat-companies service vessels. The main purpose of tugboats is to tug or tow vessels in the port. Nowadays other services are also provide, such as salvage and sea-towage.
Within the scope of this research the focus is on harbour-towage. The customers of harbour-towage are sea-going vessels, which is a niche market.

Value propositions The tugboat-companies offer the same value proposition as the pilots, namely customisation. The tugs offer a unique service for every vessel. Depending on weather conditions, preferences of the pilot, destination and other variables every tug-operation is different.
The choice of a vessel between the two tugboat-companies in the Port of Rotterdam is dependent on contracts between the shipping companies and the tug-boat companies.

Channels Big shipping companies usually have a contract with a certain tug-boat company in a port, which states that if their vessels call the port they will be serviced by the tugs of that company. That kind of communication is direct and will happen on a high level by a dedicated account manager.
On a lower level, actually ordering a tug will go via the agent and the HCC. When a tug arrives at a vessel to start the operation the contact will go via the pilot.

Customer relationships Clients that receive tugs from the same tugboat-companies every time they call port, will likely have a dedicated account manager.

When the tug arrives at the vessel, the contact there will be direct, between the tugboat and either the captain or the pilot.

Revenue streams The cost of hiring tug-services depends on the length and destination of the vessel (Port of Rotterdam, 2016b). If the tugs have to wait or bunker prices rise there will be extra surcharges. Between the various companies some small variance can be found in the pricing.
As said before, shipping companies usually have a contract with a certain tugboat-company, these contracts often involve discounts on the tariffs.

Key resources Tugboats and their crew are the key resource for tugboat-companies, without these boats they cannot perform their services.

Key activities Harbour-towage is the key activity for tugboat-companies. In essence their operations are the same in general but unique individually , because vessels vary in size and weight, weather conditions change and the traffic is different every time. So just as with pilotage, it falls in the category of problem solving.

Key partnerships As mentioned in the section 9.2, the nautical service providers have a partnership to service a vessel.

Cost structure In section 8.3 it is made clear that the tugboat-companies want to make a profit. They are cost driven, they want to minimize the costs by deploying their capacity as efficient as possible.

9.4 Boatmen-organisation

The use of boatmen in the Port of Rotterdam is obligatory for vessel larger than 75 meters. The boatmen provide (un)mooring services, these services are priced based on the length of the vessel. The boatmen-organisation also provides taxi-services for the pilots next to their key activity of (un)mooring.

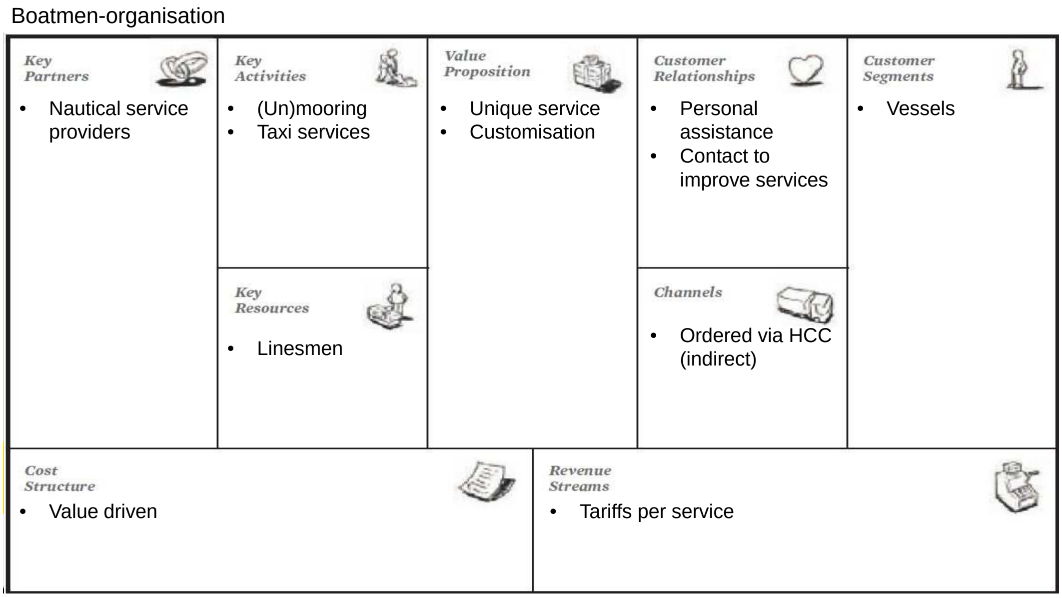


Figure 9.4: Business model of the Boatmen-organisation

Customer segments The customer segment of the boatmen is a niche market, just as the other actors in the port. The main customers of the boatmen are the vessels calling the Port of Rotterdam. Most vessels are obliged to employ their services. Those services are (un)mooring and the shifting of sea-vessels (KRVE, 2017). The boatmen also provide services to the pilots, they transport the pilots around the port with the help of vessels and taxis.
It is also possible to rent vessels, cranes and pontoon from the boatmen organisation.

Value propositions The boatmen make sure that every vessel is moored correctly, no matter the circumstances. This requires a unique service for every operation. Thus, the value proposition of the boatmen is based on customisation.

Channels Vessels larger than 75 meters are obliged to use the service of the boatmen to moor their vessel. Since there is only one boatmen-organisation they do not need to promote their services.
Just as the pilots and the tugboats the boatmen are ordered via the HCC.
To improve the quality of their services they have regular contact with their customers, the shipping companies.

Customer relationships As mentioned above, they keep in contact with their clients, the shipping companies. This is not done to sell their product but to improve it.
During the operations they provide personal assistance, although they do not have direct contact with the vessel, this contact goes via the pilot.

Revenue streams The cost for (un)mooring or shifting a vessel depends on the length of the vessel. Some surcharges may apply for special circumstances or locations (Port of Rotterdam, 2016b).

Key resources The boatmen are the most important resource for the boatmen organisation. Their experience and training is invaluable for the operations. They are supported by mooring boats and winch trucks.

Key activities The most important activity is the (un)mooring and shifting of vessels. This is an unique service for every operation and falls in the category of problem solving. Next to this they provide taxi services for the pilot-organisation.

Key partnerships Cooperation with the other nautical service providers is essential for the operations of the boatmen to take place.

Cost structure The boatmen-organisation is value driven. This has been briefly mentioned before, in section 8.4, the boatmen want to keep improving their service in order to make it more difficult for other parties to enter the market.

9.5 Terminals

At a terminal a vessel can (un)load its cargo. This (un)loading and subsequent storing of the cargo is provided by the terminal-operator. Pricing is usually based on the volume of the cargo.

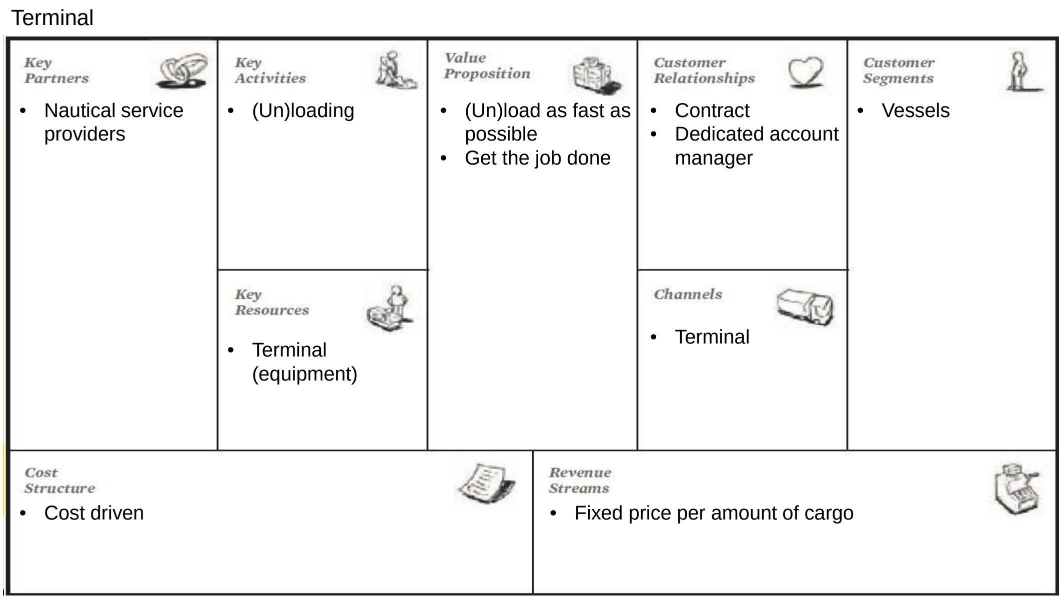


Figure 9.5: Business model of the terminal

Customer segments The terminals (un)load vessels, the goods that are taken off a ship are transported from a terminal to the hinterland via trucks or inland-shipping. Within the scope of this research the only customer of the terminal are the vessels that come to (un)load goods.
This is a very specific market, each terminal has their own specialisation. There are container-terminals, bulk-terminals, oil-terminals and many others. Thus, the terminals operate in a niche market.

Value propositions Terminals and the vessels strive to (un)load the vessel as fast as possible. Usually there is not a lot of customisation involved but it just needs to be done. So the value proposition can be placed in the category "getting the job done".

Channels The services provided by the terminal-operator are provided by their own terminal, there is no third-party involved.

Customer relationships Shipping companies have a contract with a terminal to (un)load their vessel. Contact between the terminal and the shipping company will happen via a dedicated account manager.

Revenue streams Terminals mostly work via a fixed pricing mechanism. For example a container-terminal: the shipping-company pays per container, prices vary depending on things as the container being empty or full, whether it is a transshipment, import or export and the type of container. Additional charges may also apply depending on variables such as the vessel size and the time of the week. (McKinsey&Company, 2015; EUROGATE Hamburg, 2014; Steveco, 2017)

Key resources The most important resources for a terminal-operator, is the terminal itself. Especially the cranes and other equipment, such as automated guided vehicles (AGVs) and straddle carriers. Employees are becoming less and less important due to automatization.

Key activities In the scope of this research the key activity of the terminal is the (un)loading of goods. Next to this they also store the goods, repack them and provide for subsequent transport.

Key partnerships The key partners of the terminal-operator are the nautical service providers, without out them the vessels would not be able to (un)moor at the terminal.

Cost structure Terminals are cost driven, as mentioned before they want to move the goods on and off the vessels as quickly as possible to lower costs and service more vessels.

9.6 Vessel

Vessels come to the Port of Rotterdam mainly to (un)load cargo. A vessel, or its shipping company, has a contract with that terminal to deliver goods.

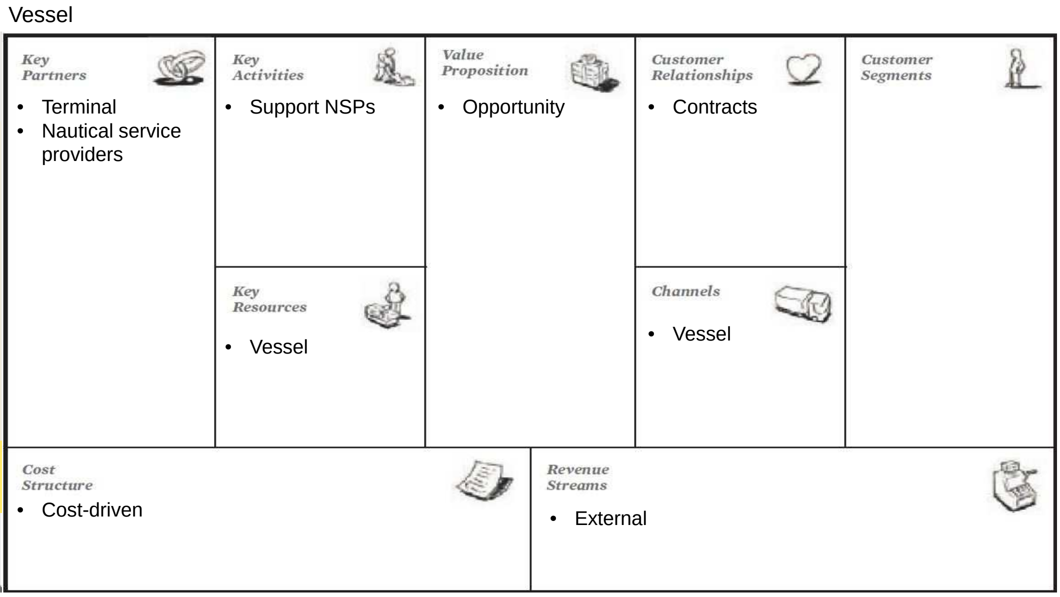


Figure 9.6: Business model of the vessel

Customer segments When a vessel comes to the port it wants to arrive safely at the terminal to (un)load cargo. When arriving at the terminal the terminal-operator provides a service to the vessel, namely (un)loading cargo, the vessel is thus a customer of the terminal. Regarding the other actors, the vessel is also the customer of the other nautical service providers.
In the scope of this research the vessel has no customer but is the most important customer of all the other actors.

Value propositions The value proposition that the vessel delivers to the terminal is that without the vessel coming to the terminal the terminal does not have work. The terminal is dependent on the vessel for work and other way around. The value proposition is work.
As has been mentioned before, the vessel is the main customer of the other actors in this research. A vessel comes to the port which creates the opportunity for the other actors to provide their services.
The value that vessel bring to the nautical chain is opportunity.

Channels The value proposition is delivered through the vessel itself. The vessel is the opportunity.

Customer relationships A vessel, or her shipping company, has contracts with a tugboat-company and terminals for them to provide their services to the vessel. For example, every-time a vessel needs tug-assistance this will be delivered by the same tugboat-company.

Revenue streams Within the nautical chain there is no revenue for the shipping companies or vessel. They have to pay the service providers but do not earn money in return. The port is the way to deliver goods to their end-customers who pay for the transportation of those goods.

Key resources The key resource of the vessel is the vessel itself, she is used to transport the goods. The captain and the crew are also important to this process but they are much more easily replaced.

Key activities Vessels are mainly used to transport and deliver cargo, but within the nautical chain this is not relevant. The definition of the nautical chain as used in this research assumes the vessel has already made the decision to enter the port.
So, the key activity of the vessel within the nautical chain is to support the nautical service providers in providing their services to the vessel. This also includes the vessel functioning properly, with for example lines that meet the safety requirements, a working engine, sufficient fuel and qualified personnel.

Key partnerships Within in the nautical chain the key partnership the vessel has is with the terminal, that partnership is the reason the vessel comes to the port. But also the other actors in the nautical chain are essential in the vessels visit to the port.

Cost structure For the vessel, or shipping company, the cost structure is to make a profit. This is a cost-driven structure, the vessel wants to minimize cost.

9.7 Chapter conclusion

In the chapter the business models of the actors in the nautical chain have been analysed.

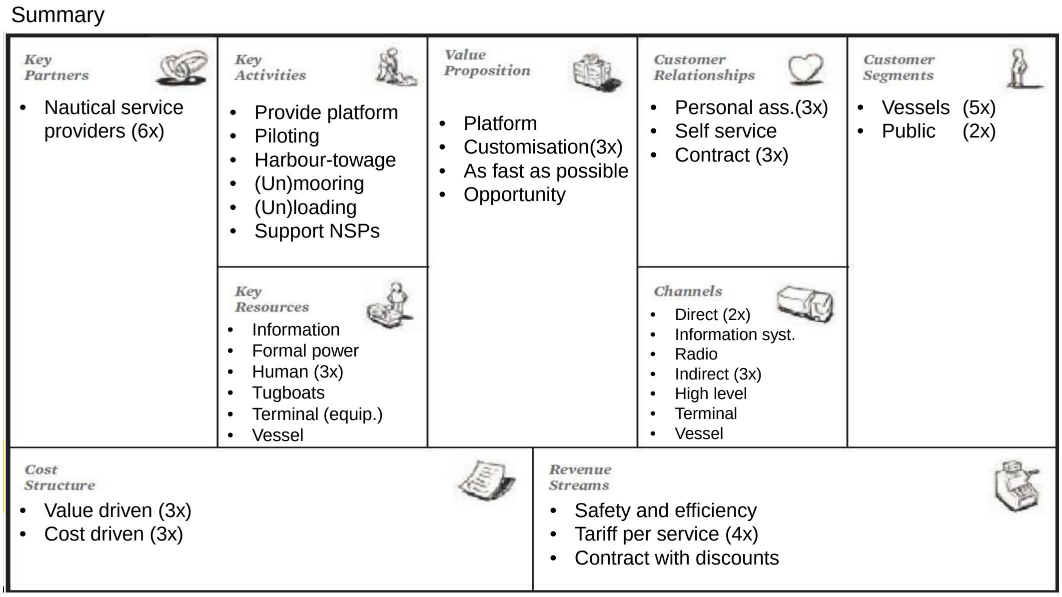


Figure 9.7: Summary of the business models

Figure 9.7 shows that there are many different business models in the nautical chain. In fact, none of the actors have the same business model.

The figure shows all actors are each other's key partners, meaning that the actors need each other to provide their services. This was already made clear in the actor analysis. The actors, except for the vessel, have as a main-customer the vessel.
This shows that the actors need each other to service one particular customer. Good co-operation in the nautical chain would thus benefit the chain and its participants.

Part III

Process analysis

10 | Introduction

In this part of the master thesis the actual operations of the nautical service providers will be described. With this description it should be possible to construct an agent based model of the nautical chain in the Port of Rotterdam[1].

Thus, the goal of this part is to provide a consistent framework that can be modelled into an agent based model. This framework consists of process maps, relevant data and recommendations on the functioning of the model.

Figure 10.1 shows the general architecture of the framework that will provide the information to construct the agent based model. As can be seen in the figure, there are three different 'building-blocks': the environment of the nautical chain, the actors and information.
The first two blocks were already introduced in chapter 1.1, the information block has been added separately because information is a key part of the functioning of the nautical chain.
From the classes developed by Nilesh Anand(Anand et al., 2012) the activities and resources have been added to provide a complete image of the processes in the nautical chain.

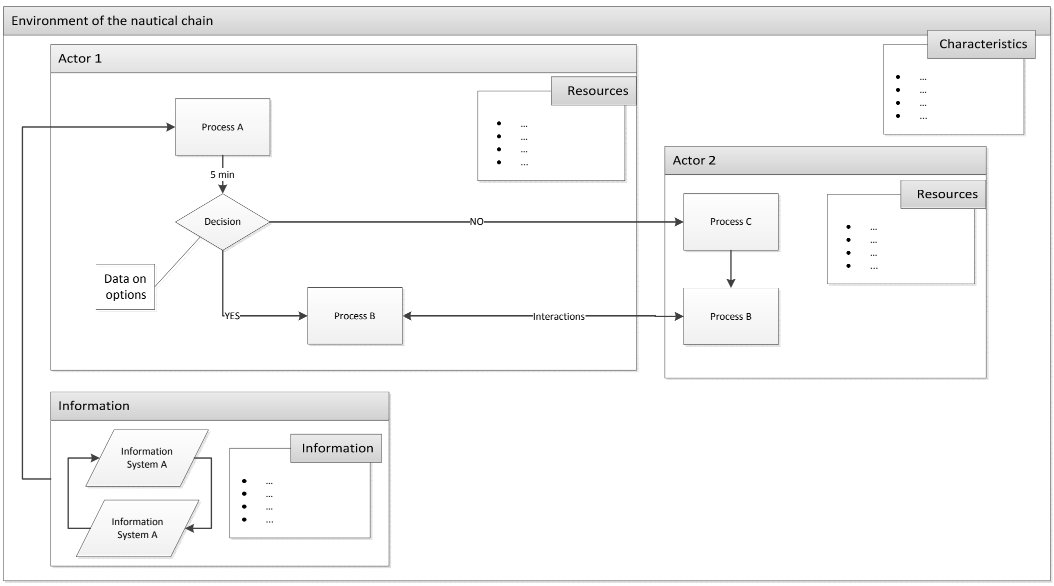


Figure 10.1: General architecture of the framework

[1]This description relates to the day to day business of the nautical chain. It does encompass big incidents or events that occur rarely, for example a vessel sinking on the waterway

10.1 Environment

All the processes of the actors take place in a environment, this environment is the Port of Rotterdam. This environment is described to be able to explain and model the processes in the port.
The port is divided into certain sections. These sections have a certain length, speed and rules. The rules vary depending on the vessel in the section. Therefore, seven classes of vessels are defined that vary in length and draft.
The ship-movements in the port, whether arriving, departing or shifting are also described. To every movement one or more locations and a vessel-class are connected.

These characteristics will form the environment in which the actors can perform their processes, which are described in chapter 11

10.2 Actors

Each actors has its own processes, characteristics and resources.
The resources and characteristics of each actor will be detailed to such an extent necessary to design and built the model. For example, the capacity of an actor or the locations an actor begins or ends a process.
All actors perform key activities or processes, these are represented by square blocks in figure 10.1. Decisions, following a process, are represented by a diamond and will, if possible, contain data on the possible options.
The connections between the processes show the sequence of the processes and may include information on variables such as duration, distance and destination.
Between the actors interactions occur, these interactions can be physical events in the operational domain or, prior to the physical events, information that is shared in the tactical domain. Both these kind of interactions will be represented.

The actors are described in chapter 12. Each section will discuss one of the relevant actors. The sections start with a general explanation of the processes of the actor and include a process map of the general overview of those processes. After which each process is explained in more detail.

10.3 Information

The information that is shared in the tactical domain will be defined. This includes the various information systems used by the actors and the way those systems interact with each other.
This is described in chapter 13.

11 | Environment

In this chapter the Port of Rotterdam is described as the environment, upon which the simulation can be based.

The port is divided into sections and traffic-rules are assigned to these sections. The sections and their rules are discussed first. After that, information is provided on the vessel-voyages that occur in the environment.

11.1 Port network and rules[1]

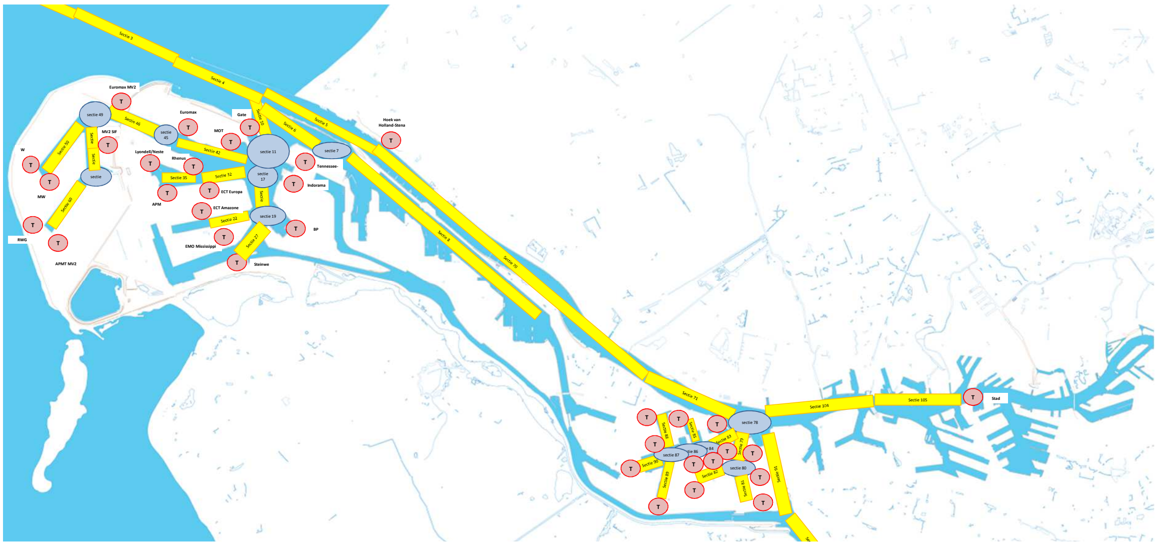


Figure 11.1: Network overview (TBA, 2017)

11.1.1 Network

Figure 11.1[2] shows the Port of Rotterdam and the sections it has been divided into for this research. The sections are numbered and are designated for manoeuvring or sailing. The length, designation and sequence of these sections can be found in table A.2, a snippet is shown in table 11.1.
To make the model more accurate it is recommended to split up some of the sections, for example section 8.

[1]The information in this section has been obtained from a study done by TBA and the PoR (TBA, 2017).

[2]A larger figure is provide in the Appendix

Table 11.1: Section lengths (TBA, 2017)

Section	Sailing (S) /Manoeuvre(M)	Length [nm]	Follows after Section
32	S	0,65	49
35	S	0,6	55
42	S	1,1	59
45	M	0,01	11
46	S	1,35	17
49	M	0,3	32

11.1.2 Vessel classes

For the purpose of the research, the vessels that sail in the Port of Rotterdam are classified into seven different classes, as shown in table 11.2. These classes are in accordance with the classes used in the admittance policy of the Harbour Master.

Table 11.2: Vessel classes (TBA, 2017)

Class	L [m]	T[m]
1	<120	
2	120-200	
3a	200-300	<14.3
3b	200-300	>14.3
4	>300	<14.3
5	>300	14.3-17.4
6	>300	>17.4

11.1.3 Section rules

In each section traffic rules regarding overtaking and encountering apply to the various vessel classes. Two examples are shown in table 11.3 and 11.4.
These rules have been drawn up by the Harbour Master and the Pilot Organisation in support of traffic modelling.
The row shows the overtaking vessel, the column the vessel to be overtaken. A '1' means it is allowed for the vessel-class in the row to overtake or encounter the vessel-class in the column. A '0' means that this is not allowed and '-1' shows that this vessel-class does not occur in that section.

Table 11.3: Overtaking rules - Section 4

Section 4	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	0	0	0	0	0
Class 3b	1	1	0	0	0	0	0
Class 4	1	1	0	0	0	0	0
Class 5	1	1	0	0	0	0	0
Class 6	1	1	0	0	0	0	0

Table 11.4: Encounter rules - Section 70

Section 70	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

For example, in section 4 a class 5 vessel is allowed to overtake class 1 and class 2 vessels but none of the other classes. And in section 70 a class 4 vessel is allowed to encounter all other classes that she meets there.
The encountering and overtaking rules for all sections are found in the Appendix in tables A.3 to A.14.

11.1.4 Separation times

Each section has a certain separation time for each vessel-class. The separation time is the time interval that a vessel should keep at a minimum between her and the vessel she is not allowed to overtake.
The time intervals are given in table A.15 in minutes[3].
A small snippet of table A.15 is shown below.

Table 11.5: Section separation times [min] (TBA, 2017)

Section	Class 1	2	3a	3b	4	5	6
4	0,1	0,1	2,8	2,8	3,5	3,7	45
5	0,1	1,7	2,8	2,8	3,5		
6	1,1	1,8	3,5	3,5	4,6	4,9	45
7	1,1	1,8	3,5	3,5	4,6	4,9	45
8	1,2	1,9	3,5	3,5	5,1	5,4	45

Continuing the previous example, in section 4, a class 5 vessel has to keep a time interval between her and the vessel in front of her of 3.7 minutes. Unless they are class 1 or 2 vessel, then she is allowed to overtake in section 4.

11.1.5 Section speeds

In the environment each vessel-class has a minimum and a maximum speed in each section. These speeds are found in table A.16, and in the small snippet in the table below.

Table 11.6: Section speeds [kn] (TBA, 2017)

Section	Class 1		2		3a		3b		4		5	6
	Min.[kn]	Max.[kn]										
83	4	6	3	4	3	4	3	4	3	3		
84	4	6	3	4	3	4	3	4	3	3		
85	4	6	3	3	3	3	3	3	3	3		
86	4	6	3	4	3	4	3	4		3		

This shows that a class 1 vessel sailing in section 84 should sail with a minimum speed of 4 knots and with a maximum speed of 6 knots. In that same section class 5 and 6 vessels do not occur, thus there is no minimum and maximum speed presented.

11.1.6 Swing-table

Before arriving or after leaving the terminal the vessel may have to swing in order to have the bow facing the correct direction.

[3]The time interval of 0,1 has been added for certain class-section combinations to keep the simulated vessels from sailing 'on top of each other'

The time it takes to perform these manoeuvres for the various classes in various sections are shown in table A.17, a part of this table is shown in table 11.7. It is also indicated whether this manoeuvre has to be performed at arrival (A) or when departing (D).
The swing manoeuvres only have to be performed when the destination- or departing-terminal is bordering the manoeuvring-section.
The column 'Small block.' shows the smallest class of vessel that will be hindered by this manoeuvre.

Table 11.7: Swing-table(TBA, 2017)

		Class 1			2	3a	3b	4	5	6
Terminal	Section	Arr/ Dep	Dur. [min]	Small block.						
MV1 - MOT	11									A 30 1
MV1 - APMT Rotterdam	17								D 25	
MV1 - ECT Delta Europa-haven	17								D 25	
MV1 - ECT Delta Amazone-haven	19					D 30 1	D 30 1	D 30 1	D 30	

The table above shows that when a class 3b vessel departs from the ECT Delta Amazone-haven terminal she needs to make a swinging manoeuvre. This manoeuvre will take 30 minutes and vessels of class 1 to 6 cannot pass the vessel during this manoeuvre.

11.2 Voyages[4]

To determine the amount and type of vessels arriving, departing and shifting in each section data from the period June and July 2017 has been analysed.
A larger period has not been chosen because of the computing power this would require to process the data. To give an indication, the two Excel-sheets containing the data together consist of more than 1,5 million cells. This does not include the processing of the data.

The data consists of port-calls starting in the months June and July 2017. Consequently, all the voyages of a vessel which arrived in July and continued into August are included. Port-calls that ended in June but started in May are not included.

The period of June-July 2017 is representative for the total vessel traffic in the Port of Rotterdam. This is shown in table 11.8.

Table 11.8: Data comparison

			Voyages previous years				Previous years compared			
	June-July 2017	2017	2013	2014	2015	2016	2013	2014	2015	2016
Arrival	4778	28572	28662	28753	28849	28734	100%	101%	101%	101%
Departure	4763	28483	28347	28664	28767	28668	100%	101%	101%	101%
Shift	3253	19453	17638	18199	18650	18386	91%	94%	96%	95%
Transit	69	413	560	332	273	295	136%	80%	66%	71%
Total	12863	78165	75207	75948	76539	76083	96%	97%	98%	97%

The amount of voyages in this period is shown in the column *June-July 2017*. This column has been extrapolated to represent an entire year[5], this is shown in the column *2017*. The next set of columns show the total amount of voyages in the years 2013 to 2016. The final set of columns show the percentages of the previous years compared to the extrapolated

[4] The information in this section has been obtained from the Harbour Master Management Information System (HaMIS, 2017).
[5] Column 3 is multiplied by 5,98 to obtain column 3. June and July consist of 61 days, 365/61=5,98

2017.
As can be seen, these percentages lie within a reasonable range and thus the data set of the period June-July 2017 may be considered representative for the entire year.
For the arriving and the departure voyages only voyages that start or end at section 1 have been considered. Adding locations from the hinterland would create extra levels of complexity, since these voyages are not properly logged. Furthermore, those voyages represent a little more than 1% of the total amount.

11.2.1 Voyage types

Tabel 11.9 shows per class how many arriving, departing, shifting and transit voyages occurred in the period June-July 2017.
Transit voyages are not discussed since they represent a small percentage of the voyages. Also vessels on a transit voyage are not serviced by boatmen or tugs and just a small amount by pilots.

The model will be able to use this data to generate vessels with a certain class and voyage type.

Table 11.9: Voyage distribution per class (June-July 2017)

	Class 1	2	3a	3b	4	5	6	**Average**
Arrival	1750	2060	685	89	154	21	19	4778
Departure	1747	2049	684	89	154	21	19	4763
Shift	937	2199	79	19	13	1	5	3253
Transit	69							69
Average	4503	6308	1448	197	321	43	43	12863

11.2.2 Voyage duration

In tables 11.10 to 11.12 the average duration, the standard deviation and the amount of voyages to each section per class are shown. These tables are snippets of the ones found in appendix A.8.

For arriving voyages this duration starts at port entry, at the end of section 4, and ends when the vessel is berthed, the Actual Time of Arrival (ATA).
For the departing voyages the duration starts at the Actual Time of Departure (ATD) and ends when the vessel enters section 4.
The duration of shifting voyages is measured from the ATD of the departing berth until the ATA at the arriving berth.

It should be noted that these durations encompass all the voyages in the period June-July 2017, the voyages with and without pilots. In chapter 12.2 information is split out to the durations with pilot.

Table 11.10: Port entry until ATA - Average duration per section per class (June-July 2017)

Arrival	Class 1			2			3a			3b			4			5			6			Total		
Destination	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
Section 5							0:26	0:09	181	0:21	0:00	2										0:25	0:09	183
8	1:02	0:32	195	1:12	0:26	605	1:21	0:35	195	1:28	0:26	41	2:03	0:33	6	2:28	0:00	1	1:57	0:28	11	1:13	0:30	1054
11	1:15	0:49	4	1:00	0:00	1	1:02	0:15	21	1:04	0:10	13	1:19	0:00	1				1:50	0:49	8	1:12	0:32	48
17				1:44	0:00	1																1:44	0:00	1
19	0:48	0:08	7	0:48	0:12	29	1:12	0:18	6	0:59	0:08	5										0:52	0:14	47
22	0:44	0:07	15	0:48	0:19	111	1:08	0:17	44	1:19	0:19	21	1:09	0:17	48	1:05	0:08	5				0:58	0:21	244
27	0:44	0:10	15	1:01	0:08	2			1	1:24	0:00	1										0:49	0:14	19
32	0:43	0:18	18	0:44	0:17	37	0:49	0:18	86				0:51	0:16	21							0:47	0:18	162
35	1:05	1:10	14	0:54	0:22	55	1:05	0:15	33				1:24	0:37	21			1				1:03	0:36	124
42	0:39	0:29	9	0:52	0:33	74							1:11	0:12	25	2:06	0:58	5				0:58	0:35	113
45			1																					1

Table 11.11: ATD until port exit - Average duration per section per class (June-July 2017)

Departure	Class 1			2			3a			3b			4			5			6			Total		
	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
Section 5							1:15	0:30	181	1:07	0:00	2										1:15	0:30	183
8	2:18	1:15	208	2:07	0:37	599	2:18	1:03	190	3:02	3:04	43	3:30	0:48	6				2:49	0:29	12	2:14	1:05	1058
11	1:40	0:12	4	1:58	0:00	1	2:21	0:17	21	2:19	0:19	10	2:23	0:00	1	2:03	0:00	1	2:36	0:08	6	2:20	0:19	44
17	1:47	0:00	1																			1:47	0:00	1
19	1:45	0:14	6	2:00	0:15	28	2:15	0:18	10	2:29	0:19	6										2:05	0:20	50
22	2:06	1:16	14	1:37	0:18	111	2:09	0:28	42	2:51	0:25	21	2:19	0:15	45	2:23	0:23	5				2:00	0:37	238
27	3:21	5:00	19	1:47	0:01	2	2:36	0:00	1	2:22	0:00	1										3:08	4:34	23
32	3:21	2:50	30	1:35	0:23	35	1:54	0:18	83				2:04	0:25	20							2:08	1:27	168
35	2:03	0:31	22	1:59	0:20	35	2:00	0:42	35	2:03	0:00	1	3:09	3:50	25			1				2:16	1:56	119
42	1:31	0:18	6	2:01	1:58	73							2:28	0:25	25	2:33	0:07	5				2:05	1:41	109
45			1																					1

Table 11.12: Average duration of shifting voyages per sections per class (June-July 2017)

		Class 1			2			3a			3b			4			5			6			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
8	8	0:51	0:37	43	0:49	1:50	115	1:16	0:21	24	1:52	0:23	5	1:51	1:14	5				3:06		1	0:56	1:29	193
	11							1:56	0:09	2	2:37		1				3:21		1	2:23		1	2:27	0:35	5
	19				1:23	0:11	3	2:24	0:21	3	2:13		1	3:08		1							2:05	0:40	8
	22				1:55	0:18	4	0:56		1													1:40	0:33	5
	32	1:10	0:08	3				1:16		1													1:11	0:07	4
	35	1:04	0:16	5	1:42	0:17	7							2:04		1							1:29	0:26	13
	50							2:56	0:24	6	2:57	0:24	2										2:56	0:22	8
	60	1:14		1	1:54		1																1:34	0:28	2
	79				3:18	0:14	2																3:18	0:14	2
	80				3:36		1																3:36		1
	81				2:52	0:26	14																2:52	0:26	14
	82				2:59	0:13	3																2:59	0:13	3
	85	2:11	0:17	3																			2:11	0:17	3
	86	2:14	0:08	2	2:55	0:14	2																2:34	0:25	4
	88				3:45	0:41	2																3:45	0:41	2
	89				2:47	0:43	4																2:47	0:43	4
	104	2:29		1	3:11	0:33	4	5:08		1													3:24	0:59	6
	105	2:41	0:45	20	3:11	0:38	19	4:27	0:02	2													3:01	0:47	41
11	8							2:54	0:08	2	2:19	0:34	4							2:55	0:18	2	2:37	0:30	8
	50																			1:45		1	1:45		1

The model may be able to use these times to determine the duration of a voyage with a certain bandwidth. It is advised not to use a wider bandwidth than one standard deviation (σ), since durations beyond the average $\pm$ σ become unreliable, see table 11.13.

Table 11.13: Duration distribution of selected cases

	Section 8			Section 32			Section 60		
σ	Duration [hrs]	Amount of voyages	Percentage						
-3σ	-0:34	0	0%	-1:00	0	0%	-0:19	0	0%
-2σ	0:02	88	9%	-0:24	0	0%	0:16	10	9%
-σ	0:38	389	42%	0:11	87	64%	0:53	57	49%
Avg.	1:14	928	100%	0:47	137	100%	1:29	117	100%
σ	1:50	354	38%	1:24	40	29%	2:05	40	34%
2σ	2:26	78	8%	2:00	9	7%	2:41	6	5%
3σ	3:02	12	1%	2:36	1	1%	3:17	2	2%

11.2.3 Duration before port entry

In table 11.14 the durations from operational contact until port entry are shown. These times are much larger than the times shown in table 11.10. This is because the vessel may not sail into the port straight away.
She has to obtain operational clearance before she can proceed into the port. She has to wait, for example, for a pilot to come on board or until her designated berth is free. It is also possible that the vessel has arrived ahead of schedule and has to wait at anchorage or that, due to market demand, she is ordered to remain at anchorage by the shipping company.
This is also the case for departing and shifting voyages, although the reasons may vary.

Since the reasons behind these times are widespread and it is not possible to discern the reasons with the available data, it is recommended to further investigate this before implementing these durations in the model. These durations can shed a light on delays in the period before port entry.

Table 11.14: Op. contact until port entry - Average duration per section per class (June-July 2017)

Arrival	Class 1			2			3a			3b			4			5			6			Total		
From	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
5							1:57	0:16	181	2:19	0:06	2										1:57	0:16	183
8	7:18	7:58	195	5:23	7:10	605	7:55	9:47	195	9:54	7:09	41	21:42	5:39	6	3:38	0:00	1	14:00	6:33	11	6:33	8:02	1054
11	6:23	2:59	4	5:39	0:00	1	13:30	11:06	21	13:01	8:49	13	4:02	0:00	1				15:34	6:54	8	12:53	9:33	48
17				6:47	0:00	1																6:47	0:00	1
19	17:23	7:31	7	12:48	11:39	29	19:23	9:09	6	20:07	12:44	5										15:06	11:22	47
22	8:35	8:40	15	8:03	7:28	111	7:09	7:06	44	7:57	5:49	21	6:55	6:29	48	9:02	9:59	5				7:43	7:15	244
27	7:16	10:06	15	20:34	16:47	2			1	4:07	0:00	1										8:44	11:46	19
32	7:30	7:03	18	8:54	10:14	37	8:41	8:55	86				9:01	8:30	21							8:38	9:00	162

Tables A.29 and A.30 in the Appendix show all the data regarding these durations.

The circled area in figure 11.2 corresponds with the duration before port entry.

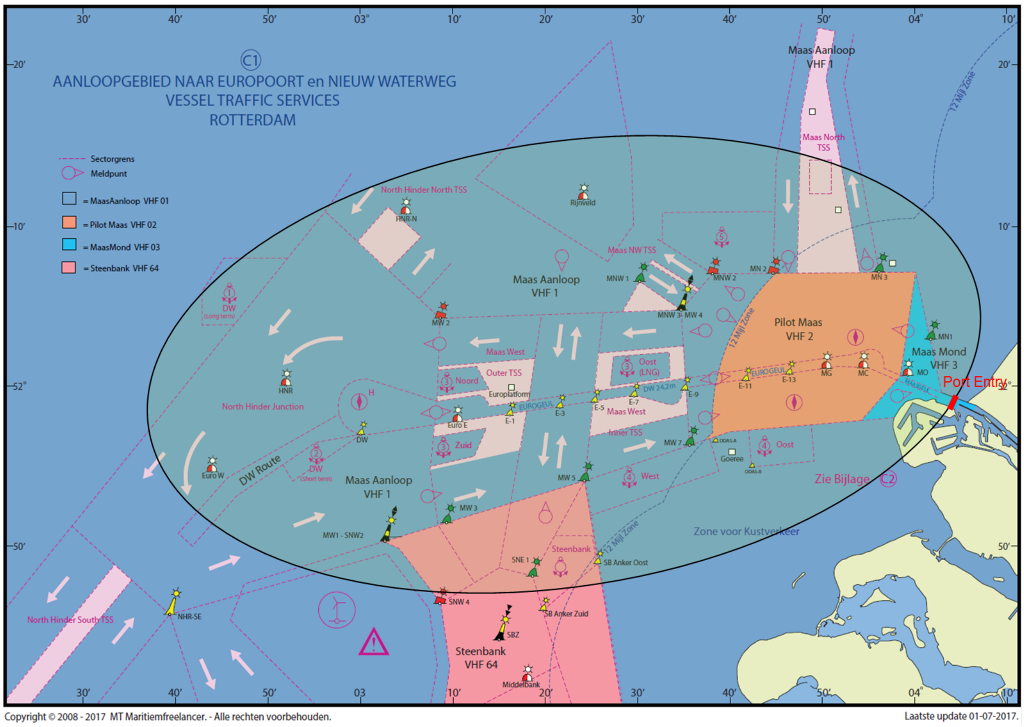
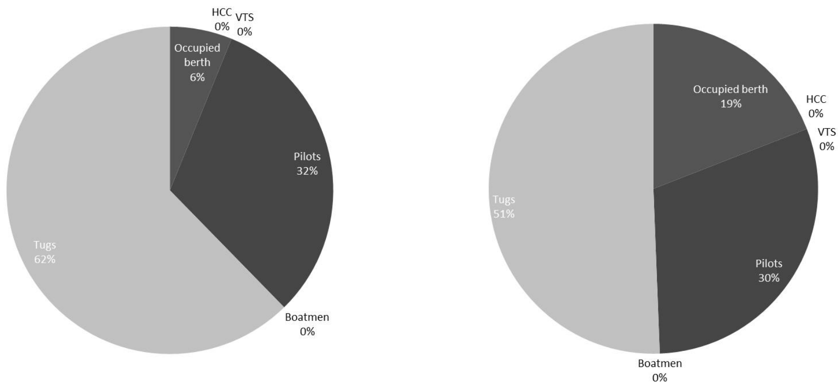


Figure 11.2: Before port entry area

11.2.4 Delays



(a) Percentage per actor

(b) Total time per actor

Figure 11.3: Delays (June-July 2017)

An analysis of the logged delays[6], of the actors in this research shows that in the period of June-July 2017 62% of the delays were caused by tugs, 32% by the pilots and 6% by occupied berths, see the figure 11.3a and table 11.15.
The boatmen, the HCC and VTS, did not cause any of the logged delays.

The distribution of the actual delay time is somewhat different, as seen in figure 11.3. The actual delay time is higher for the occupied berth and lower for the pilot and tugs, compared to the percentage, as shown in table 11.15.

[6]These delays are not logged constantly and consistently by HCC- and VTS-operators, therefore do not provide a complete image.

Table 11.15: Delays (June-July 2017)

	Amount	Percentage of amount	Time [hrs]	Percentage of time	Average delay [hrs]
Occupied berth	9	6	34:00:00	19	3:46:40
Pilots	46	32	53:58:00	30	1:10:23
Tugs	91	62	90:10:00	51	0:59:27
Boatmen	0	0	0	0	0
HCC	0	0	0	0	0
VTS	0	0	0	0	0
Total	146	100	178:08:00	100	1:13:12

These delays do not provide a picture accurate enough to be able to use in the model. This is because the delays are logged sporadically and the responsible actor may not always be the root cause. A tugboat may be late and is made responsible for a delay, but it may be possible that the tugboat was late because during its previous assignment the pilot was late. This is a logistics related delay.

A trade related delay is also possible, for instance an oil tanker that stays at anchorage for the charterer to wait for a better oil price. As with this example, trade-related delays are not caused by an actor in the nautical chain and cannot be solved by the model.

So, these delays need to be reviewed with that in mind. The data however gives an indication on the potential actors that caused the delay. During this research observations were made that support this indication. Tugboats, for example, are often a cause for delay and the boatmen are almost always on time.

To obtain qualitative data on delays, it is recommended that the Harbour Master logs all delays including accurate causes, constantly and consistently.

11.2.5 Weekday distribution

The distribution of these vessels is constant on weekdays and lower in the weekend, as is shown in table 11.16.

Table 11.16: Distribution per day (June-July 2017)

Day	Total Amount	Average Amount	StDev
Monday	2399	262	55
Tuesday	2348	294	45
Wednesday	2150	269	34
Thursday	2606	290	37
Friday	2585	290	33
Saturday	408	46	12
Sunday	369	40	15
Total	12865	1490	82

The model can use this data, if it wants to simulate longer periods of time.

11.3 Chapter conclusion

The sections and the traffic rules are capable to realistic describe the behaviour of simulated vessels. Although, the sections presented in the network do not cover all individual berths in the port, the network is extended and detailed enough to set up the simulation model.

With the tables and information regarding the voyages the model will be able to generate a vessel with a certain class, voyage type and destination/departure section.
The duration of simulated voyages can help determine the time a vessel spends in the port, within a certain bandwidth.

The data available on the first part of the voyage is insufficient to be useful to the model. Incorporating these durations would expand the model. However, the information on the the second part of the voyage, after port entry, can be used in the model.

A conclusion on the causes for delays cannot be drawn with the available data, this would require better logging of the delays.

The environment described in this chapter is suited to serve as a basis for the simulation model.

12 Actors

This chapter will discuss the processes of the actors in the nautical chain. These processes will be discussed in the sections 12.1 to 12.6.
This chapter aims to describe the processes of the nautical service providers in such a way that they can be used in the agent based model. Figure 12.1 shows the overview of the processes for an arriving voyage, figure 12.2 shows the overview for a departing voyage.

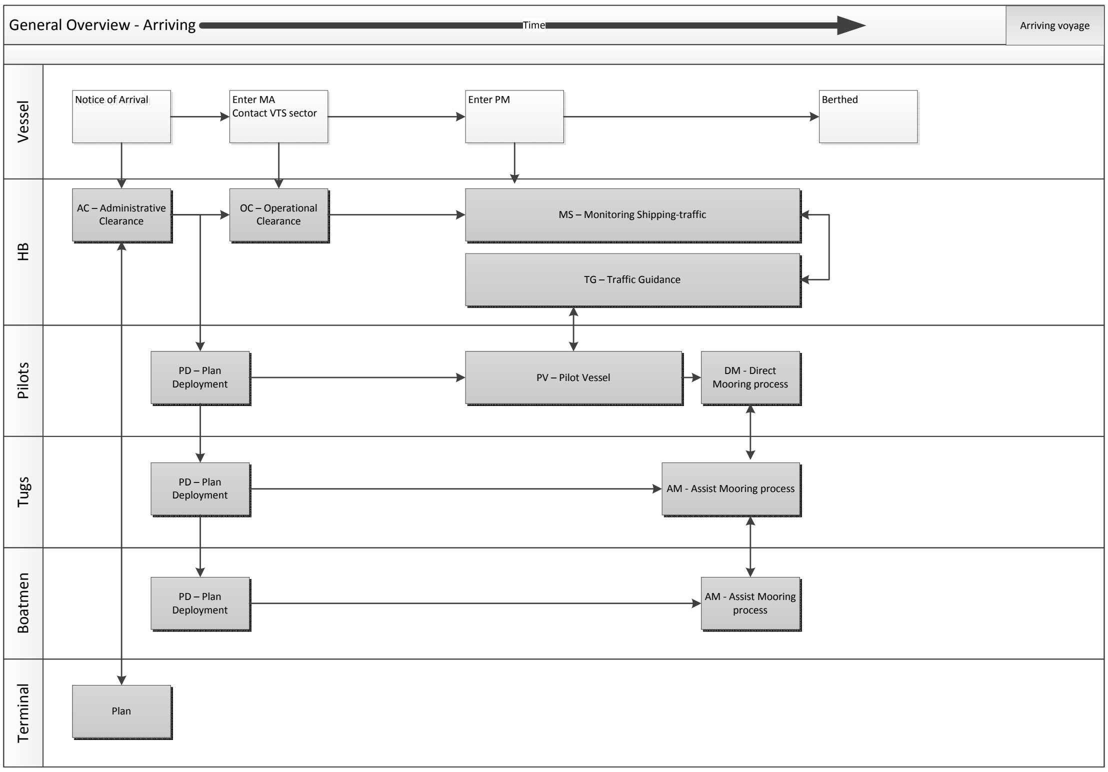


Figure 12.1: General overview of processes in the nautical chain - Arriving voyage

Firstly, the Harbour Master is discussed. The Harbour Master is tasked with maintaining a safe and efficient flow of traffic. This is shown, for instance, in the processes Administrative and Operational Clearance where the journeys of the vessels are checked regarding certain regulations, in order to prevent vessel traffic from becoming unsafe.

After the Harbour Master, the processes of the pilots will be discussed. As well as the data corresponding to the deployment of the pilots. The important processes of the pilots are the planning, piloting the vessel and directing the (un)mooring process.

The processes of the tugs that will be discussed are the planning and the assistance they provided in the (un)mooring process.

Another service that is, just as the pilots, often obligatory for vessels, is that of the boatmen. The processes and accompanying data of the boatmen are discussed in section 12.4. These processes involve planning their deployment and assisting in the (un)mooring of vessels.

Finally, the processes of the terminal and the role of the vessel is discussed in sections 12.5 and 12.6.

The sections are built up in the following manner. Firstly, an introduction to the actor and its processes are given. This introduction contains a figure with the general overview of the processes of the concerning actor.
After the introduction, the processes shown in the general overview are explained. The process maps of the processes are available in the appendix and the activities of the processes are explained in this chapter.

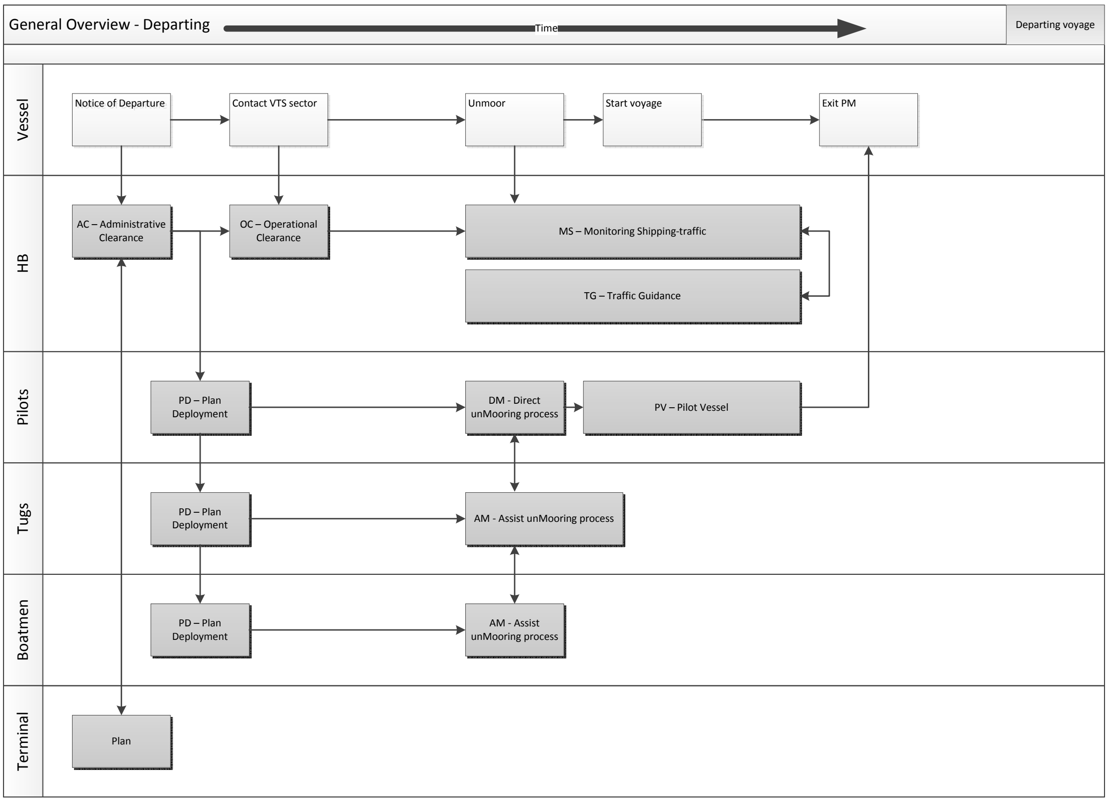


Figure 12.2: General overview of processes in the nautical chain - Departing voyage

12.1 Harbour Master

In this section the processes of the Harbour Master relevant to the nautical chain are described. These processes have been drawn up with the help of internal process descriptions of the Port of Rotterdam, and with the help of interviews.

Each (sub)section describes one of the four relevant processes. Each activity is performed by one or more division of the Harbour Master. This is mentioned in the title of the activity description.

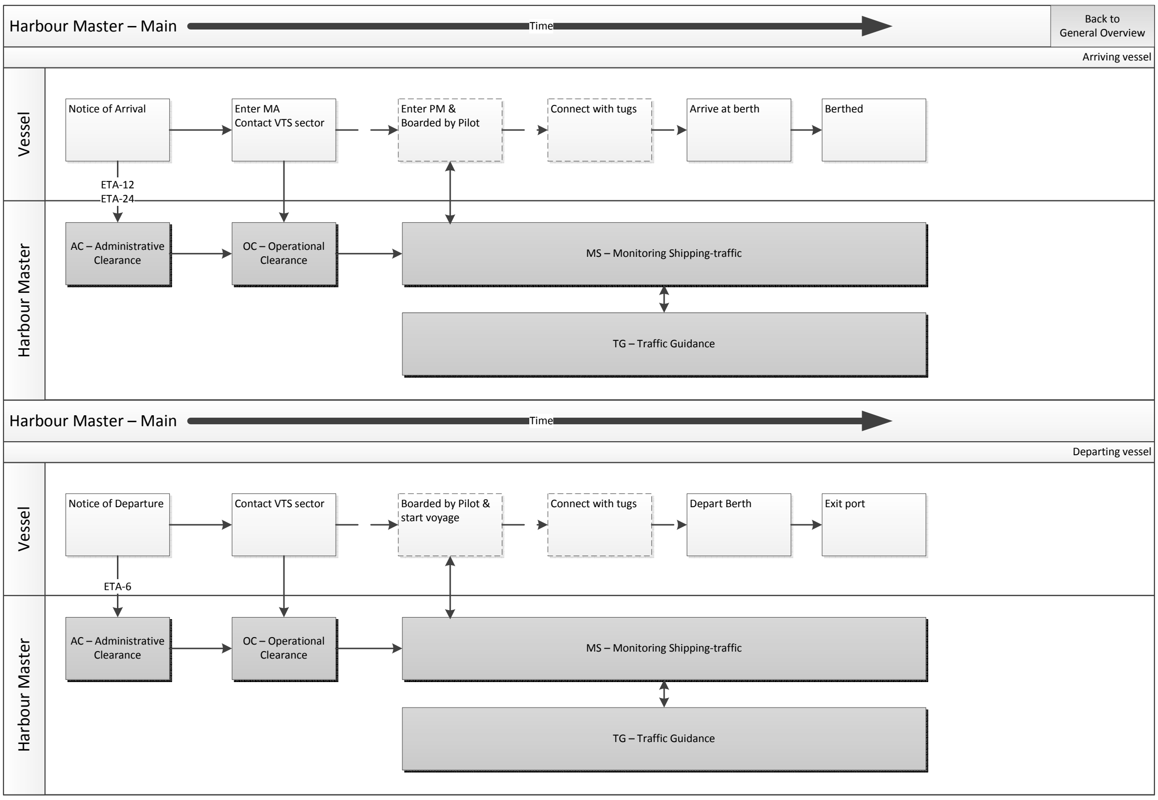


Figure 12.3: Harbour Master - General overview

Processes

The first section describes the administrative clearance process. In this process the information on the port-call that has been provided at least 24 hours before the ETA is assessed. From this assessment it is decided whether the vessel obtains the administrative clearance to enter the Port of Rotterdam.

In section 12.1.2 the operational clearance is discussed. This process starts when there is operational contact with the vessel. It is checked whether the vessel has been granted administrative clearance and whether the information on which this clearance was granted is still up to date. When operational clearance has been granted the vessel can enter the Port of Rotterdam.

The third process in this chapter relates to the monitoring and evaluating the shipping traffic in the port. This process continuously monitors the activities on the waterways and in the harbours and, if necessary, acts accordingly.

A vessel may require guidance, this is described in section 12.1.4. This guidance may be physical or via VHF. With physical guidance a patrol vessel will accompany the vessel during its voyage to provide guidance. Guidance via VHF is done by a VTS-operator from one of the traffic centres.

12.1.1 AC –Administrative Clearance[1]

This process encompasses all the administrative processes executed by the Harbour Master to assess the proposed port-call and relating activities.
The Harbour Master bases the assessment on information provided by the vessel via a Notice of Arrival (NoA) or Notice of Departure (NoD). This so called electronic port-call notification is the moment the vessel notifies the concerning parties that she will call on the port. In this notification information will be provided to the concerning parties by the vessel, the required information is discussed in chapter 13.

Arriving vessels are required to deliver certain information 24 hours before ETA (in case of deep-draught vessels bound for the Euro-Maasgeul; 48 hours before ETA) via an electronic notification. For departing voyages this is 2 and 12 hours before ETD respectively.
The model can simulate the impact of changing these times.
This entire process takes 10 to 20 minutes, if all the information has been provided.

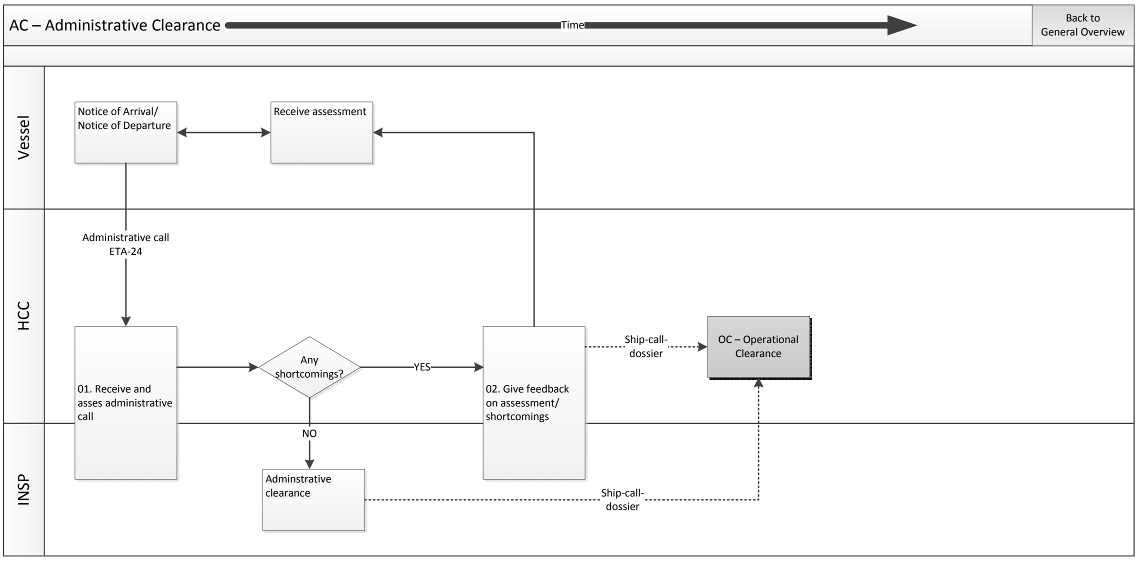


Figure 12.4: Harbour Master - Administrative Clearance

<ins>01. Receiving and assessing administrative call [HCC & INSP]</ins> This process starts when a new or changed port-call notification is made, or when special circumstances (such as obstructions) require a re-evaluation of the port-call.

When the Notice of Arrival (NoA) and other required notifications have been received, the Harbour Coordination Centre (HCC) and the inspection will check the notifications. The

[1]This section is based on internal process information of the Port of Rotterdam (personal communication, June 15, 2017) and a Duty Officer HCC (personal communication, August 9, 2017)

following aspects will be checked: nautical, security, waste, port health and ship activities (incl. transhipment of Hazardous and Dangerous Goods). When the call has shortcomings this will be given as feedback to the reporting party.

The nautical part of the assessment is concerned with whether the entire route of the vessel is accessible for that vessel. Extra attention is paid to the tidal window regarding tidal-bound vessels and deep-draught vessels. Also the planning of special transports will get extra attention.

02. Feedback on assessment [HCC & INSP] Feedback will only be given to the reporting party if the notifications are not complete or are considered incorrect. The reporting party is not notified when the port-call is accepted. In this respect, administrative clearance is always granted, unless the Harbour Master needs additional information or the received information needs to be corrected.

It often happens that the vessel will provide the required information in multiple notifications. This means that the HCC will give feedback on the incomplete notifications that information is missing.
Data on the amount of how often administrative clearance is not granted is not available, to simulate this process better this would be helpful. It is thus recommended to further investigate this.

12.1.2 OC - Operational Clearance[2]

This process relates to the actions taken after the first operational contact with the vessel, before arriving in the port. These actions, taken by VTS and the HCC, check if the vessel can proceed to its designated berth or if there are any constraints (e.g. incident on its route).
This process is also applicable to berth changes (shifting) and departures.

This process checks whether the port-call has administrative clearance and if the data whereupon that administrative clearance was based, is still up to date.

The process starts when the master of the vessel contacts the sector Maas Approach (VHF 1), reports from the hinterland to the port (for incoming or passing voyages) or when the master reports ready for departure on VHF-channel 11. Figure B.1 and B.2 in the Appendix show the sectors in the port.

The process ends when the Harbour Master observes no (more) constraints for the port-call and grants operational clearance.
Just as the previous process this is a relatively short process that takes 10 to 20 minutes if all the information is correct.

[2]This section is based on internal process information of the Port of Rotterdam (personal communication, June 15, 2017) and a Duty Officer HCC (personal communication, August 9, 2017)

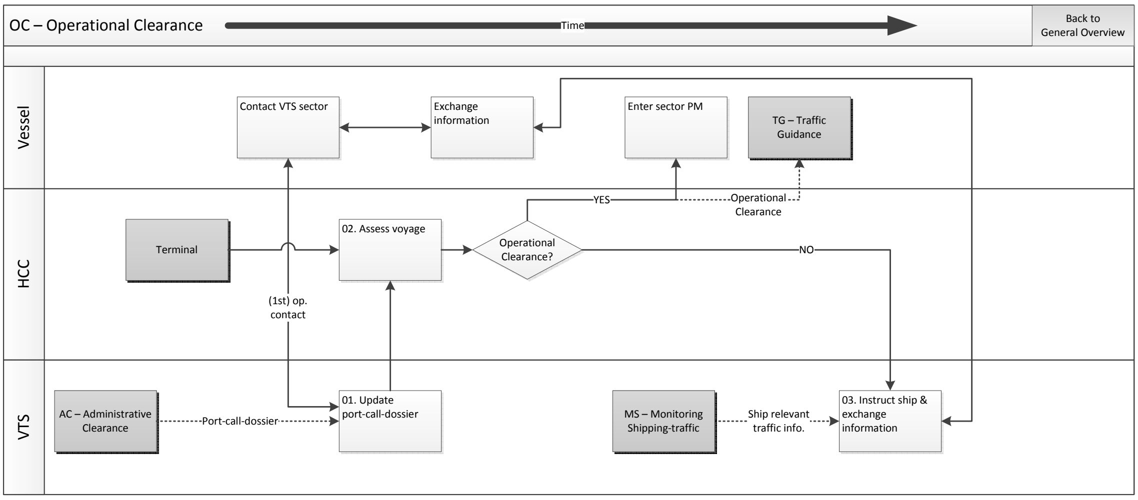


Figure 12.5: Harbour Master - Operational Clearance

<u>01. Update port-call dossier [VTS]</u> At first contact with the vessel the VTS-operator will ask the master of the vessel to provide the actual draught of the vessel, its destination, ETA/ETD and if there is anything that requires extra attention. If necessary, the received data will be used to update the port-call dossier.
If there are significant[3] changes in the data the VTS-operator will contact the HCC.

<u>02. Assess voyage [HCC]</u> After operational contact by VTS, the HCC-coordinator will check the voyage again. The HCC will give special attention to vessels that have not yet fulfilled their registration regarding security (ISPS).

The HCC-coordinator will or will not approve operational clearance. When administrative clearance has been granted, the actual data of the vessel is in accordance with the administrative clearance and the ETA/ETD is in accordance with the planning, the HCC-coordinator will grant operational clearance.
Furthermore, the HCC will check whether, if applicable, the destination berth is free. There needs to be at least a two hour window between the arriving vessel and the vessel leaving the berth (Planner ECT, personal communication, August 8, 2017). This is so that there are no unwanted encounters when manoeuvring in the harbour.

If the vessel requires one or more of the nautical service providers (NSP) the HCC will check if the deployment of the concerning NSP has been planned. The planning of the deployment of NSP is done by the NSP. This will be discussed in the sections on the processes of the NSP.

If operational clearance has been granted this will not be explicitly told to the master. Only when the clearance has not been granted.

As was discussed in the previous chapter, the duration between operational contact and port entry varies greatly and qualitative data on these durations is missing. During this time the operational clearance is also granted, but it is not registered how often operational clearance is denied before it is granted. So as was mentioned in the previous chapter, more

[3]Significant is important enough to inform HCC or the nautical service providers (e.g. limited propulsion, defect bow thruster, lost anchor, etc.)

investigation must be done into the time before port entry to be able to assist the model.

03. Instruct ship & exchange of information [VTS] This process is applicable if operational clearance has not been granted.

In the case of incoming and passing vessels, the VTS-operator informs the vessel that the operational clearance has not been granted and discusses the further course of action with the master. During that time the VTS-operator and master exchange information about the vessel and the up to date traffic image.
When a vessel does not obtain operational clearance, it can choose to drop anchor in an anchor-area outside the port, in anticipation of operational clearance.

If this process relates to leaving vessels and quay-change operations, the VTS-operator informs the vessel that the operational clearance has not been granted. The ship has to stay at its current quay/anchorage and request operational clearance again at a later time.

12.1.3 MS – Monitoring Ship traffic[4]

In this process the shipping traffic is monitored and evaluated. In general, the process consists of gathering particularities on individual ships, creating the actual traffic image, evaluating this image and signalling any potential dangerous situations. If a situations requires guidance this is done in the Traffic Guidance process (section 12.1.4). All the activities deal with real-time events.
The MS process is a continuous process that does not have any trigger event.

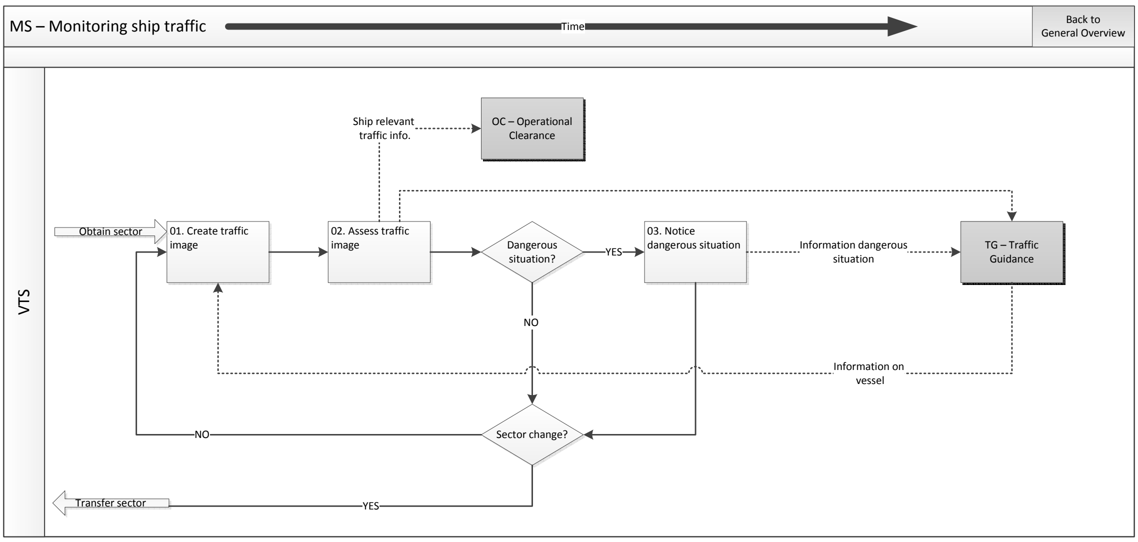


Figure 12.6: Harbour Master - Monitoring Ship traffic

01. Create traffic image [VTS] The VTS-operator creates a mental image of the actual traffic situation in his/her sector. This image is derived from feedback of the VTS-operator he/she replaces, from ARAMIS[5] visuals and from HaMIS data.

[4]This section is based on internal process information of the Port of Rotterdam (personal communication, June 15, 2017) and a Duty Officer HCC (personal communication, August 8, 2017)
[5]Advanced Radar Monitor and Information System, provides radar information to the VTS-operator

02. Assess traffic image [VTS] The VTS-operator assesses the real-time traffic image in the sector of his/her responsibility, keeping in mind the up-to-date hydro- and meteo-circumstances. Also, he or she is alert on any potential dangerous situations that could occur. The VTS-operator will also monitor the short-term planning to make sure no congestion or any potential dangerous situations will occur.
If necessary the VTS-operator will inform the shipping traffic on the traffic image, this is part of the Traffic Guidance process (section 12.1.4).

03. Notice potential dangerous situation [VTS] In case of a potential dangerous situation or an incident the VTS-operator is expected to notice this. The information regarding this situation is communicated to the vessels and sectors concerned, this is part of the Traffic Guidance process. The potential dangerous situation and possible incidents need to be reported to the VTS supervisor.

After having the responsibility of a specific VTS area for one hour, the VTS operator will change to another VTS area.

12.1.4 TG – Traffic Guidance[6]

In this process the Harbour Master guides the sea-going vessel on its voyage within the VTS area. This is done remotely via the VTS Centre or on the spot with the assistance of a patrol vessel. The second will only occur in special circumstances.

This process starts when there has been operational contact. For incoming vessels and vessels passing through this is the instance that the master contacts the first sector within the VTS area. In the case of berth changes and leaving vessel, it is the instance when the master reports that he is ready to leave.
The process ends when a vessel has left the VTS area (leaving and passing through) or when the vessel has moored (incoming vessel and berth changes), meaning the vessel no longer is part of the traffic on the waterway.

During this process the VTS-operator has regular contact with the vessel. In this description the person with whom there is contact will be called the master, being the person in command of the vessel. This does not have to be the captain it can also be another officer or a maritime pilot.

[6] This section is based on internal process information of the Port of Rotterdam (personal communication, June 15, 2017) and a Duty Officer HCC (personal communication, August 8, 2017)

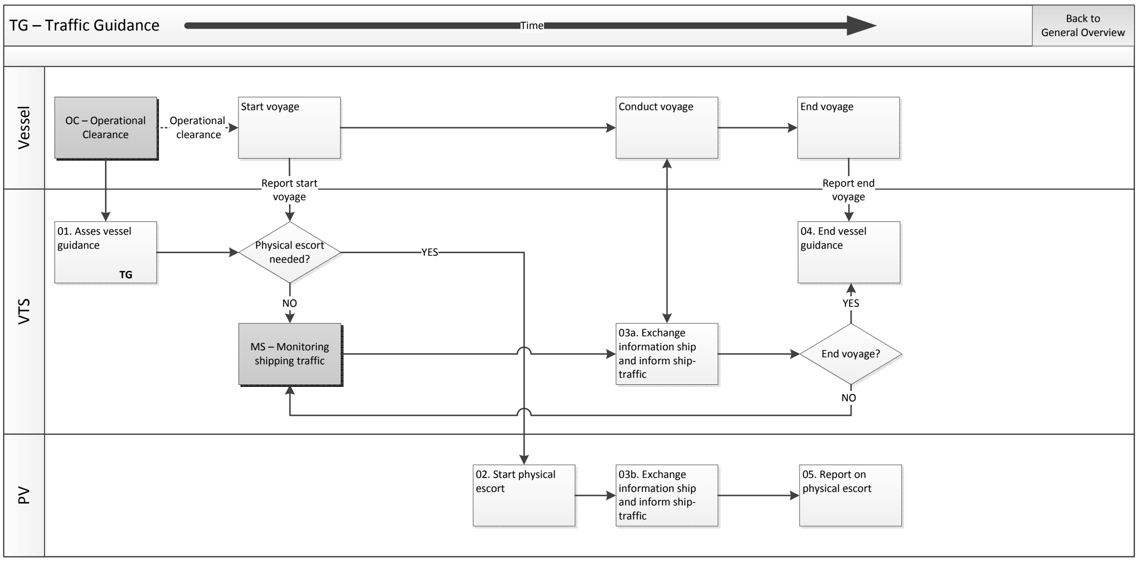


Figure 12.7: Harbour Master - Traffic Guidance

01. Asses vessel guidance [VTS] The VTS supervisor prioritises in HaMIS which vessels need physical escort based on potential and special circumstances. For departing vessels this prioritisation is done when the vessel has requested the pilot and for incoming vessels when there is operational contact. The VTS supervisor can choose between three priorities: urgent, high and medium.
A special transport[7] gets prioritised as urgent by HaMIS automatically. The VTS supervisor needs to decide whether this priority is maintained or needs to be scaled down.

The traffic guidance of the voyage starts when the master indicates that he wants to start the voyage within the VTS area. In the case of incoming vessels or vessels passing through these are the sectors ME, MB or OM (see figure 12.8 or B.1: Maas Entrance, Maasbruggen and Oude Maas). In case of leaving vessels this is the instance that the master reports that he is ready to depart.

When the vessel is designated for physical escort, this will be communicated with the patrol vessel. When the vessel has no need for physical escort the VTS-operator will continue with the process Monitoring Ship traffic (section 12.1.3). If, from that process, it shows that a vessel needs extra guidance the VTS-operator will offer this.

02. Start physical escort [PV] The crew of the patrol-vessel will go to the vessel, which needs physical escort, at the designated time. When arriving at the vessel the patrol-vessel will report via the sector-channel that it is at the location and will start the physical escort.

The VTS-operator will monitor the current traffic image and provide information regarding the traffic to the patrol-vessel. During the physical escort the crew of the patrol-vessel will continuously listen to the sector-channel. And will report on the situation to the VTS-operator.

03a. Exchange information ship and inform ship traffic [VTS] This process occurs when there is no physical escort, but from the process Monitoring Ship traffic it shows that

[7] A special transport is for instance a vessel without propulsion or the transport of a FPSO on a semi-submersible vessel

the vessel needs guidance. The VTS-operator and the master of the vessel exchange information regarding the vessel and the current traffic image, until that time guidance is no longer necessary.

<u>03b. Exchange information ship and inform ship traffic [PV]</u> This process occurs when there is physical escort.
The VTS-operator will direct this process. The crew of the patrol-vessel will report on the situation to the VTS-operator.

<u>04. End vessel guidance [VTS]</u> The guidance of the vessel ends when the vessel is no longer taking part in the waterway traffic.

In the case of arriving vessels and berth changes the vessel is no longer taking part when the master reports that the vessel is moored. The VTS-operator registers this as the Actual Time of Arrival (ATA). In the case of vessels passing through and vessels leaving the VTS area, the VTS-operator will notice this on ARAMIS. The voyage is registered as ended in HaMIS automatically, except for the exit point Oude Maas and Maasbruggen, where registrations are made manually.

<u>05. Report on physical escort [PV]</u> The crew of the patrol-vessel decides that physical escort is no longer needed and reports that the physical transport has ended. This information will also be made available to the VTS-operators.

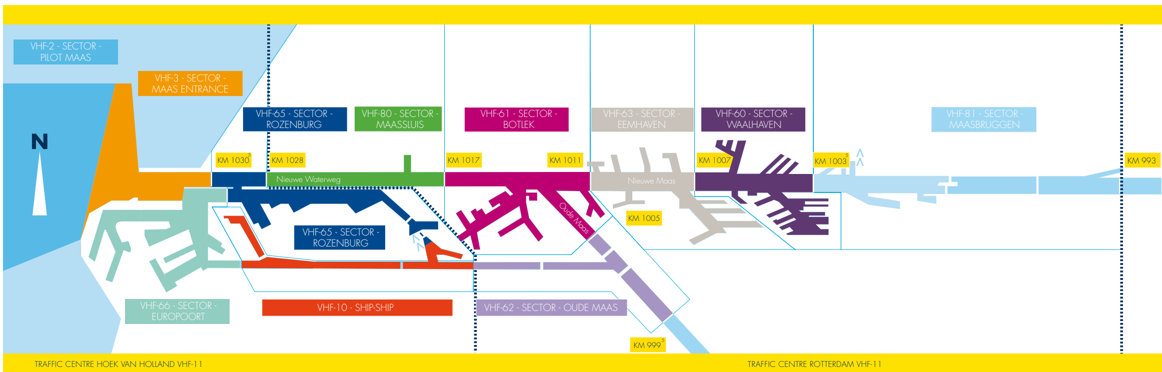


Figure 12.8: VTS area's (Port of Rotterdam, 2017b)

12.1.5 Conclusion

The administrative clearance starts when a vessel makes the notification regarding her voyage. Depending on the voyage type and vessel class the vessel has to make this notification at a certain time. The model may be able to show what the effect is of changing these times.

Obtaining more information on the amount of rejected administrative clearances can also be beneficial to the model.

Just as the administrative clearance the operational clearance takes 10 to 20 minutes is all the information provided is correct. It is not logged how often operational clearance is denied before it is granted thus as of now cannot be beneficial to the model.

12.2 Pilot-organisation

This section covers the processes of the maritime pilots and the pilot organisation relevant to the nautical chain. The processes have been drawn up on the basis of an interview with an experienced pilot during a pilot journey (departing and arriving) and interviews with employees of the Port of Rotterdam Authority[8].

Each (sub)section describes one of the three relevant processes of the pilot organisation. The overview of the processes of the pilots is shown in figure 12.9. In Appendix H this process and the other processes are shown in a larger format.

The process maps of the pilot-organisation have been split up into arriving and departing journeys. A shifting voyage is regarded as a combination of a departing and an arriving voyage.

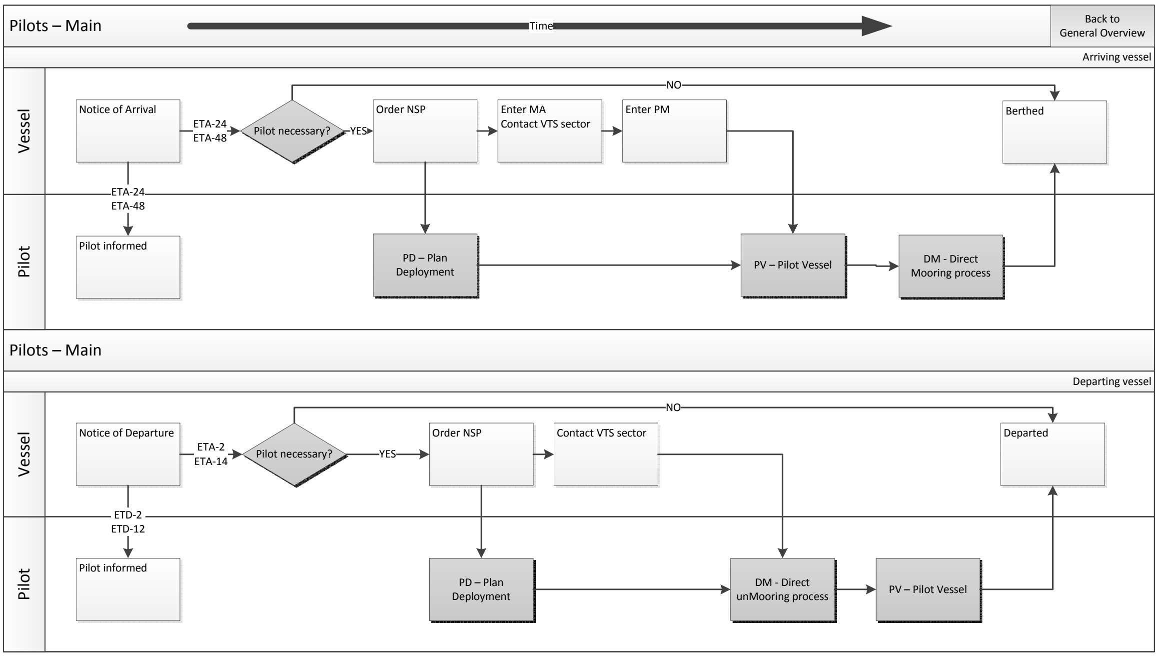


Figure 12.9: Pilot Organisation - General overview

Processes

The relevant processes of the pilot-organisation are the planning incl. pilot boarding (12.2.1), the actual piloting of the vessel (12.2.2) and the directing of the (un)mooring process (12.2.3).

The first process deals with the planning of the deployment of pilots. When a vessel has indicated that she needs a pilot, the pilot-organisation will determine which pilot needs to go to the vessel, how and where the pilots will board the vessel.

Concerning an incoming vessel, the second process will explain the actual piloting of the vessel until the moment when the designated berth has been reached. When the berth has

[8]The pilot journey provided a first-hand experience which is a reliable source for mapping the processes, information provided by employees of the PoR is second hand although the interviewees are experienced.

been reached the third process will describe the mooring process.

When a departing vessel is concerned, the second process explains the piloting of the vessel from the berth to the disembarkation station of the maritime pilot.

Table 12.1: Pilots per class per voyage type (June-July 2017)

	Arrival		Departure		Shift		Transit		Total
	No pilot	Pilot							
Class 1	552	1198	587	1160	384	553	34	35	4503
2	659	1401	676	1373	463	1736			6308
3a	258	427	259	425	2	77			1448
3b	2	87	2	87		19			197
4		154		154		13			321
5		21		21		1			43
6		19		19		5			43
Total	1471	3307	1524	3239	849	2404	34	35	12863

Table 12.1 shows whether a pilot was used per class per voyage type. For class 6 vessels two pilots are used, due to the long duration of the voyage. All other classes only require one pilot.
This data can be used in the model to determine how pilots may be distributed among the vessels.

12.2.1 PD - Plan Deployment

In this sub-process the pilots are planned in order to get the proper pilot to the vessel at the right time.

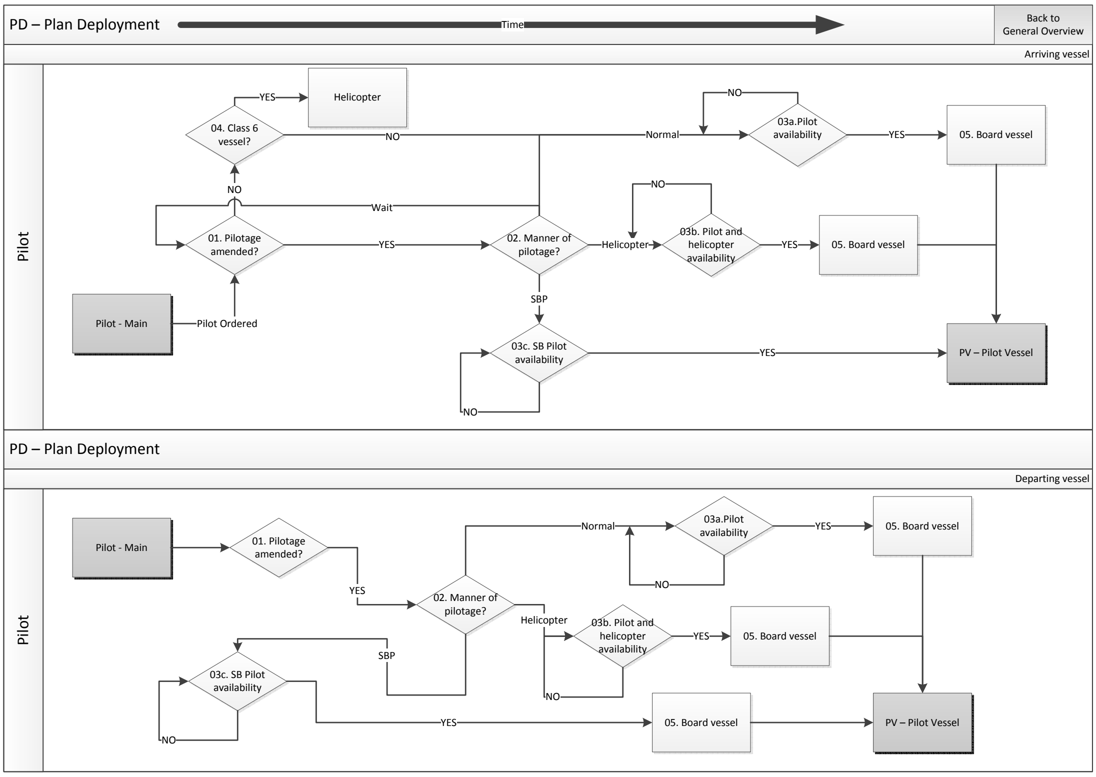


Figure 12.10: Pilot Organisation - Plan Deployment

01. Pilotage amended Pilotage is amended for small shipping[9] when there is a wave height of 2.4 metres and pilotage is completely amended in the case of a wave height greater than 3.2 metres (Port of Rotterdam, 2016a). Likewise for disembarkation via the tender for departing voyages. Thus, pilotage is amended when boarding by the tender is no longer possible.

In the period June-July 2017 pilotage was amended two times, once for small shipping and once completely. This is considered low due to the summer weather. Table 12.2 shows the amended pilotage for this period, in table 12.3 information can be found on amended pilotage in the period Jan. 2013 to October 2017 (HaMIS, 2017).

The model can use this data to determine to which extent and how long pilotage is amended. It has to be noted that when pilotage is completely amended it is automatically amended for small shipping, also in the registration of the durations.

Table 12.2: Amended pilotage (June-July 2017)

Type of amendment	Amount	Average duration [hrs]
Small	1	42:11
Completely	1	31:28

[9]There is not fixed length that defines what is small shipping, this is decided by the HCC at that time. For the model it is advised to limit this to class 1 vessels, since in reality most vessels fall in this class.

Table 12.3: Amended pilotage per month (Jan. 2013 - Oct. 2017)

	Amended for small shipping			Completely amended		
Months	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#
January	16:48	13:52	25	23:23	18:10	16
February	13:22	15:34	24	16:27	7:45	10
March	7:05	6:02	9	13:29	13:22	5
April	16:05	16:49	3	8:52	0:00	1
May	4:34	4:53	8	13:07	7:59	4
June	18:54	14:25	5	17:35	10:19	3
July	4:11	4:07	5	16:15	0:23	2
August	12:46	11:26	5	6:28	2:50	2
September	12:11	8:59	10	11:44	5:20	6
October	15:09	15:07	17	22:36	11:38	9
November	8:05	4:47	22	22:47	18:00	10
December	9:55	10:50	32	16:09	10:01	11
Total	11:47	12:22	165	18:35	13:45	79

02. Manner of pilotage If pilotage is amended, there are four options with regards to the manner of pilotage. This can be either 1) delivery of the pilot by helicopter, 2) Shore Based Pilotage (SBP), 3) pilotage is only amended for small shipping or 4) the vessel has to wait until pilotage is no longer amended.

Table 12.4 shows how many times the helicopter was deployed per vessel class in the period June-July 2017 when pilotage was amended. This is only for arriving voyages, since other voyages types did not require a helicopter[10]. Table 12.5 shows the amount of times a helicopter was deployed during the entire period June-July 2017 when pilotage was not amended.
This shows that a helicopter is also deployed when pilotage is not amended, to vessels that need to be piloted further out to sea due to their draft or dangerous cargo.

Table 12.4: Helicopter pilotage during amended pilotage (June-July 2017)

Arrival	Amount
Class 1	1
2	11
3a	3
3b	1
4	0
5	0
6	0
Total	16

Table 12.5: Helicopter pilotage when pilotage not amended (June-July 2017)

Arrival	Amount
Class 1	4
2	12
3a	10
3b	25
4	3
5	0
6	19
Total	73

Shore Based Pilotage will be provided when pilotage is amended and delivering a pilot via helicopter is not possible. Upon entry, the vessel is guided via VHF into the breakwaters of the port where a pilot will board the vessel. Upon exit, a pilot will guide the vessel until the breakwaters where he or she will disembark.
Not all vessels are eligible for SBP, whether or not a vessel can receive SBP is decided by

[10]In specific situations the pilot stays on board until the next port of call, and returns by public transport. This is not part of the data.

the HCC and the maritime pilot[11].
Table 12.6 shows which classes made use of SBP during the amended pilotage in the period June-July 2017. The model can use this to assign SBP to a generated vessel when pilotage is amended.
The information on shore based pilotage and helicopter delivery in case of amended pilotage is only relevant for the period June-July 2017, since this period had a relative low amount of amended pilotage it is recommended to observe this for a greater period.

The (dis)embarkation location, in case of SBP, of the maritime pilot depends on the destination or origin of the vessel[12]. See table 12.7 and figure 12.11.

Table 12.6: SBP during amended (June-July 2017)

	Arrival	Departure	Total
Class 1	22	15	37
2	9	5	14
Total	31	20	51

Table 12.7: (Dis)embarkation location in case of SBP

Destination	Arrival	Departing
Europoort	Buoy Maas 5 (1)	Buoy CA6 (2)
Nieuwe Waterweg	Buoy NW7 (3)	Buoy NW6 (4)

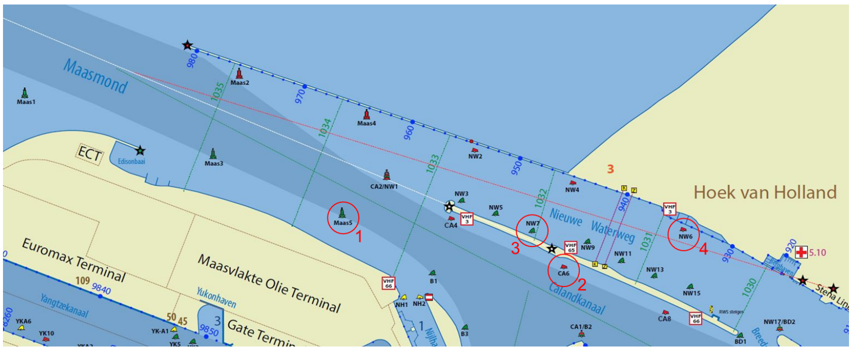


Figure 12.11: Section Maas Entrance

When pilotage is amended for small shipping and the vessel is not regarded to be part of 'small shipping' she can be piloted by a tender.

If both pilotage via a helicopter and SBP is not possible, the vessel will have to wait until normal pilotage is resumed. Qualitative data on this is not available, but it is recommended to investigate this further.

03a. Pilot availability When pilotage is not amended and the vessel is not a class 6 vessel. It is necessary to check whether the right pilot is available. A maritime pilot may not pilot

[11] In general, vessel with a draught of more than 14.3 metres and a length more than 125 meters are excluded from SBP. Detailed information is found in the Port Information Guide (Port of Rotterdam, 2016a)
[12] In reality these locations may vary, but for the model such predestined locations are needed.

every ship, as pilots may have different qualifications.
The total capacity of the pilot-organisation in the Port of Rotterdam is 220 maritime pilots (Nederlands Loodswezen, 2017a). The qualifications of the various pilots is not available at the moment, it is recommended to further investigate this to better model the capacity of the pilot-organisation.

03b. Pilot & helicopter availability The pilot-organisation in the Port of Rotterdam has one helicopter available to deliver pilots to vessel.

03c. SB pilot availability Two shore based pilots guide vessels into the port or out to sea, one in sector PM (Pilot Maas) and one in sector ME (Maas Entrance). Each pilot can handle a maximum of seven vessels at one time.

04. Class 6 vessel Class 6 vessels are boarded by 2 pilots via the helicopter. Two pilots are necessary because of the long duration of these pilot-journeys. Due to their draught these types of vessels have to approach and leave the port via the Eurogeul.
The pilot will (dis)embark the vessel at the beginning of the Eurogeul, near 51°59.0'N, 003 °00.0'E.

05. Board vessel Depending on the way the vessel will be piloted and boarded, the maritime pilot will go to the correct pilot station to board the vessel. Table 12.8 shows the locations depending on the vessel class, figure B.2 shows the locations of the buoys. The numbers correspond to the map shown in Appendix C.1

Table 12.8: Pilot boarding stations

	Arriving	Departing
Class 1-4		
Tender	E13 buoy (1)	MO buoy (4)
Helicopter North	Advised by VTS	MO buoy (4)
Helicopter West	Eastbound lane of TSS Maas West Inner/Outer (2)	MO buoy (4)
Class 5	North of buoy DW (3)	MNW3-MW4 buoy (5)
Class 6	North of buoy DW (3)	Euro E buoy (6)

12.2.2 PV - Pilot Vessel

In this process the pilot will direct the vessel towards her berth. This starts with the Pilot-Master exchange when the pilot comes on board the vessel. The pilot will then act on possible deviations and register the ETA. The pilot will subsequently assist the vessel towards her destination.

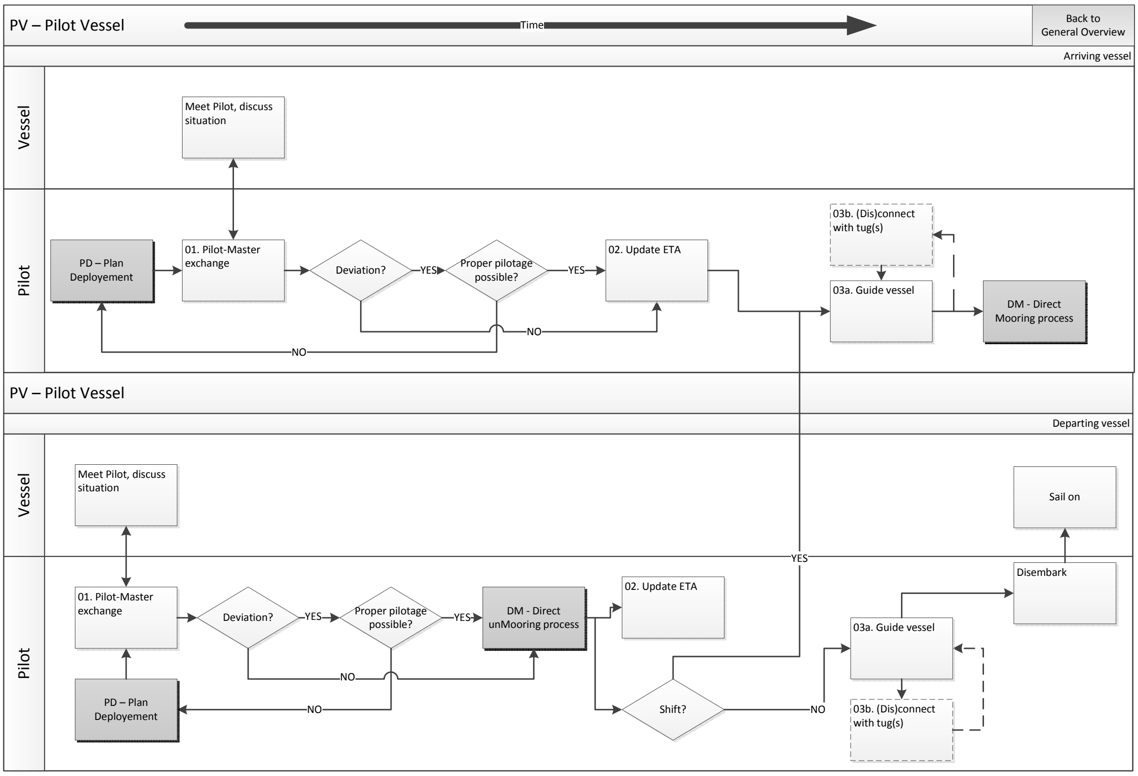


Figure 12.12: Pilot Organisation - Pilot Vessel

01. Pilot-Master exchange When the pilot has come on board the Pilot-Master exchange takes place. In this exchange the pilot presents his plan for the voyage to the master and the master compares this with his plan. Together they decide on the best plan of action. The pilot also asks the master if there are any issues that he/she should be aware of. For example, if the bow-thruster is not working properly or the engine can only perform on half power. If so, the pilot will react on this, for example by ordering extra tugs.
The pilot may also decide, after assessing the situation, not to provide pilotage to this vessel because he/she believes the vessel is not fit for port entry. Then the vessel will be piloted to an anchorage outside the breakwaters, until the issues are resolved and the vessel is fit for port entry.

Data on how often these situations occur is not available, this would however benefit the model, it is thus recommended to further investigate this.

02. Update ETA When the vessel is under way the pilot will update, via an application on his phone, the ETA. This updated ETA is communicated to the tugs and boatmen.
For arriving vessels this is the ETA at the tug-meeting point and when the vessel is completely moored at her berth and the nautical chain has ended, called gangway down.
For departing vessels the ETA at the sector Pilot Maas is updated. This is the location where the pilot will disembark the vessel.

If the voyage does not go as expected, the pilot will update the times so that all the parties are aware of the new ETA's.

03a. Pilot vessel This is one of the key activities of the pilot. The pilot will support the master in sailing the vessel to its designated berth or out of the port towards sector Pilot Maas [13].

03b. (Dis)connect with tug(s) If the vessel has ordered tugs for her incoming voyage the pilot will direct the vessel towards the meeting point with the tugs. These meetings points depend on the destination of the vessel and will be discussed in section 12.3. At this meeting point the tugs will connect to the vessel and together sail towards the berth.
Is the voyage a departing one then the tugs will already connect before the vessel leaves the berth, discussed in the process *Direct (un)Mooring*. When the vessel has unmoored and no longer needs tug-assistance, the tugs will disconnect, the pilot will thank them for their services and the tugs will continue to their next assignment.

Duration

The table below shows the average duration, deviation and amount of the arriving pilot voyages depending on the destination and vessel class. It is a snippet of the table available in the Appendix, there information on departing and shifting voyages is also available.
This is the duration from the moment the pilot embarks the vessel until the pilot has disembarked the vessel.

With this data the model can determine the average duration of pilotage. In this respect, as with the duration mentioned in section 12, it is advised to follow the analysis in section 12 on standard deviation.

Table 12.9: Arrival - Pilot per section per class (June-July 2017)

Arrival	Class 1			2			3a			3b			4			5			6			Total
Destination	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	Amount
Section 8	2:10	0:41	162	2:24	0:36	297	3:09	0:31	117	4:25	1:11	41	4:15	0:42	6	3:50	0:00	1	7:15	0:43	11	635
11				2:28	0:00	1	3:12	0:42	20	3:27	0:35	13	4:49	0:00	1				7:04	0:17	8	43
17				2:22	0:00	1																1
19	2:03	0:09	7	2:16	0:27	29	2:44	0:24	6	3:01	0:12	5										47
22	1:34	0:07	13	1:43	0:22	98	2:32	0:27	43	4:56	1:28	21	2:45	0:49	42	2:42	0:10	5				222
27	1:53	0:14	11	2:24	0:00	2	2:55	0:00	1	3:01	0:00	1										15
32	1:50	0:15	17	1:58	0:34	34	1:59	0:23	76				2:09	0:21	17							144
35	1:55	0:13	10	1:58	0:21	46	2:20	0:24	21				2:43	0:25	19							96
42	1:44	0:23	3	1:41	0:20	61							2:42	0:19	21	3:13	0:20	4				89
46	2:36	0:19	2																			2
50				2:42	0:04	3	3:24	0:16	6	3:48	0:09	5										14
55	3:14	0:56	4	3:10	0:38	5																9
60	2:35	0:39	3	2:06	0:30	53	2:47	0:28	28	3:25	0:00	1	3:16	0:24	17	3:31	0:27	8				110

12.2.3 DM - Direct (un)Mooring

This process starts at the moment when the vessel arrives at the berth or the vessel is ready to depart from the berth.
In collaboration with the other NSP the pilot will either moor or unmoor the vessel.

[13] In the Port of Rotterdam, actually the maritime pilot takes control of the vessel. The master remains in command.

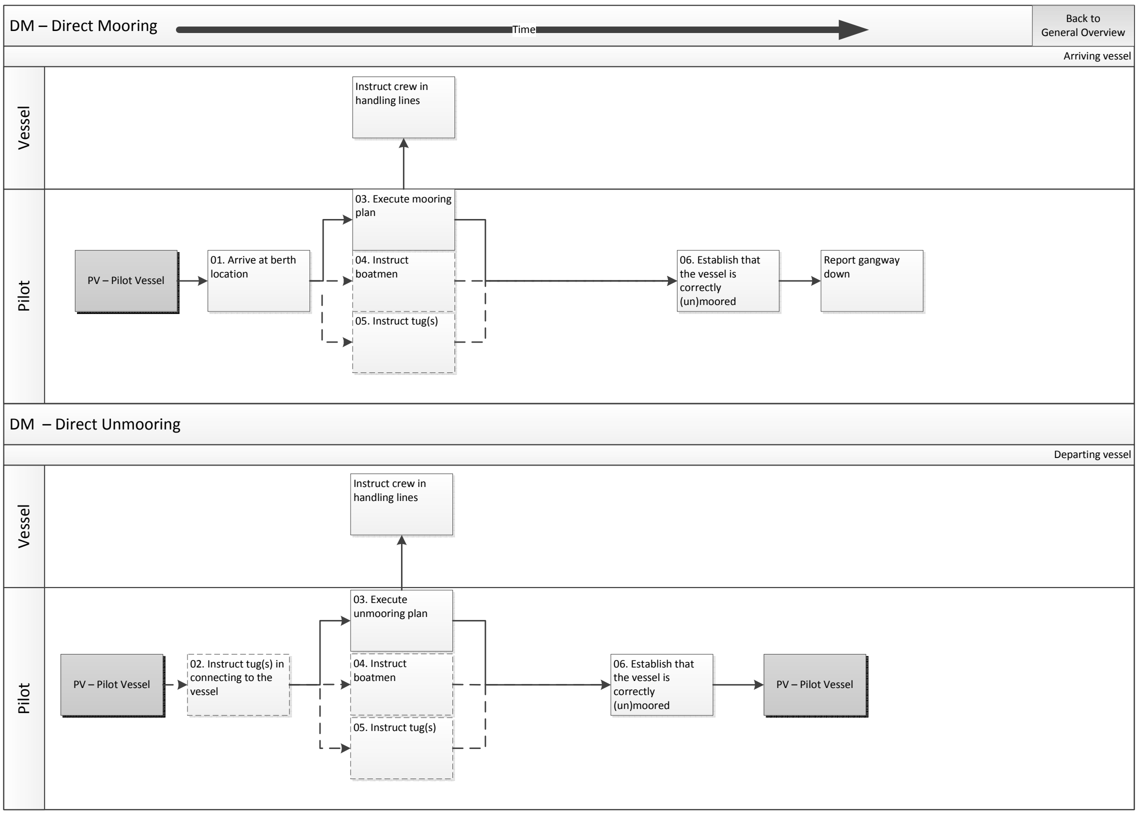


Figure 12.13: Pilot Organisation - Direct (un)Mooring

01. Arrive at berth location If the vessel is on an incoming or shifting voyage she will arrive at the berth location with or without tug-assistance. If the boatmen have been ordered, they will also be at the berth. On the quay and/or on the water.
The pilot will position the vessel in such a way that the berthing can commence.

02. Instruct tug(s) in connecting to the vessel If it is concerning a voyage departing from the berth and tugs have been ordered, the pilot will instruct the tugboat-captains where and in what manner the tugs need to be connected to the vessel. The pilot will also inform the captain of the unmooring plan.

03a. Execute (un)mooring plan The mooring lines are provided to the boatmen, if applicable, and are tightened with the winches on the vessel. This is done by the vessel crew. The crew is not instructed by the pilot but by the master, thus the pilot needs to instruct the master to instruct the vessel crew.

04a. Instruct boatmen For arriving vessel the boatmen collect the lines and fasten them at the berth.
This is directed by the pilot. The pilot has the overview of the situation and communicates with the master of the vessel and the tugboats, when present.

05a. Instruct tug(s) For arriving vessels the tugs are connected before arriving at the berth. The tugs will assist the vessel in her manoeuvres towards the berth. At the berth the pilot will instruct the master or helmsman and the tugs in bringing the vessel towards the berth safely. This means that the tugs push and pull the vessel in such a way that it slowly reaches the berth. When it is close enough the boatmen can fasten the mooring lines. While the mooring lines are connected the tugs will keep the vessel steady. When the mooring lines are connected the vessel is brought towards the berth slowly with the help of these lines and the tugs.

03b. Execute (un)mooring plan For departing voyages the lines are gradually loosened with the winches and collected by the vessel crew when they are free from the boulders.

04b. Instruct boatmen In the case of departing vessels, the boatmen loosen the lines and remove them from the boulders.

05b. Instruct tug(s) When departing, the tugs will keep the vessel in her place so that the mooring lines can be loosened. When the lines are loose and taken on board the tugs will assist the vessel in leaving the berth and harbour.

06. Establish that the vessel is correctly (un)moored When the sub-processes explained above are finished the vessel is (un)moored. This moment is called the gangway down and is established by the maritime pilot.
The duration of the mooring process is greatly dependent on the vessel class and berth location. Also the duration is not logged by the Harbour Master. For the model the duration of (un)mooring will be helpful and it is recommended to try and establish durations for this process. This can for example be done by analysing AIS-data.

12.2.4 Conclusion

In this section the processes of the pilot organisation have been described and data is provided which can benefit the model.

Table 12.1 shows the distribution of pilots among the various vessel classes for all voyage types. The model can use this to determine the distribution of the pilots.

In the Plan Deployment process (section 12.2.1) the deployment of a pilot is planned. First of all table 12.3 can be used to determine the likelihood of amended pilotage and the subsequent duration.
Tables 12.4 and 12.6 give an indication as to the deployment of shore based pilots and helicopters, but it is advised to investigate this further for a greater period of time. This should also include information on how often vessel have to wait at anchorage until pilotage is no longer amended.

Every pilot has a certain amount of qualifications regarding the vessels he or she can pilot. Exact information on the qualifications of the pilots in the Port of Rotterdam is not available in this research. It is recommended that this information is retrieved to be able to better model the pilot capacity in the Port of Rotterdam.

It may occur that a pilot comes on board and notices issues that require, for instance, extra tugboats or make it impossible to pilot the vessel. These situations cause delays in the nautical chain and it is recommended to further investigate this since current information on this is too limited.

Table 12.9 shows the average duration of a pilot voyage and its standard deviation. This data can be used to determine the duration of a generated pilot voyage in the port. It is recommended to follow the analysis in section 12 on standard deviation.
Section 12.2.3 shows the process regarding (un)mooring a vessel. Durations of this process per section and vessel class are not available. It is recommended to analyse these duration

from AIS data.

The data provided in this section provides a good basis to model the processes of the pilot-organisation in the Port of Rotterdam and more data will help to further refine the model.

12.3 Tug-companies

This section covers the data and processes of the tugs. The activities of the tugs have been split up into two processes, the Plan Deployment process and the Assist (un)Mooring process.
The figure below shows the general overview of these processes. In Appendix H this process and the other processes are shown in a larger format.

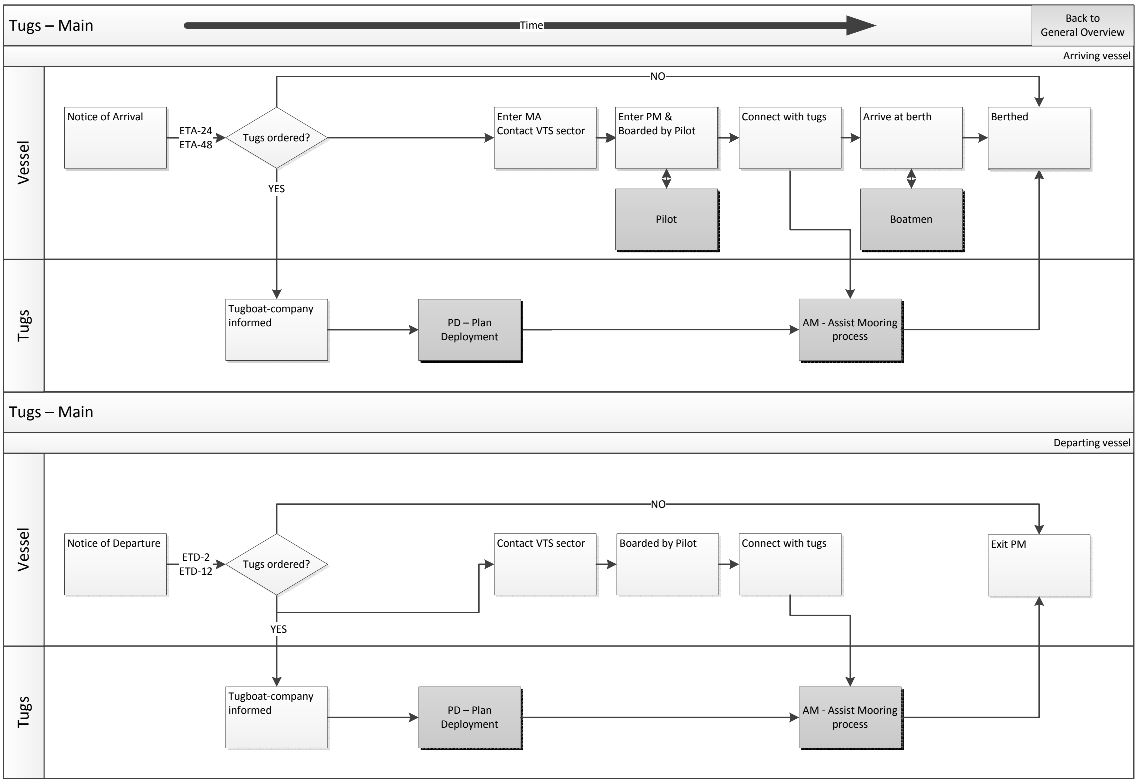


Figure 12.14: General overview of the processes of the tugs

Processes

In Planning Deployment the availability of the tugs will be checked and subsequently committed to an assignment.

In the Assist (un)Mooring process the tugs will sail towards the rendezvous location and connect with the vessel. Then, in the case of arriving vessel, the tug(s) will assist the vessel towards her berth and assist in the mooring process. In the case of departing vessels the tug(s) will assist with unmooring and then assist the vessel in sailing out of the harbour. This process is directed by a maritime pilot.

12.3.1 PD - Plan Deployment

After the tugs have been ordered by the vessel they will be planned and deployed. That is described in this process.
This includes checking if there are tugs available and if they are available near the rendezvous location. And what will happen if no tugs are available.

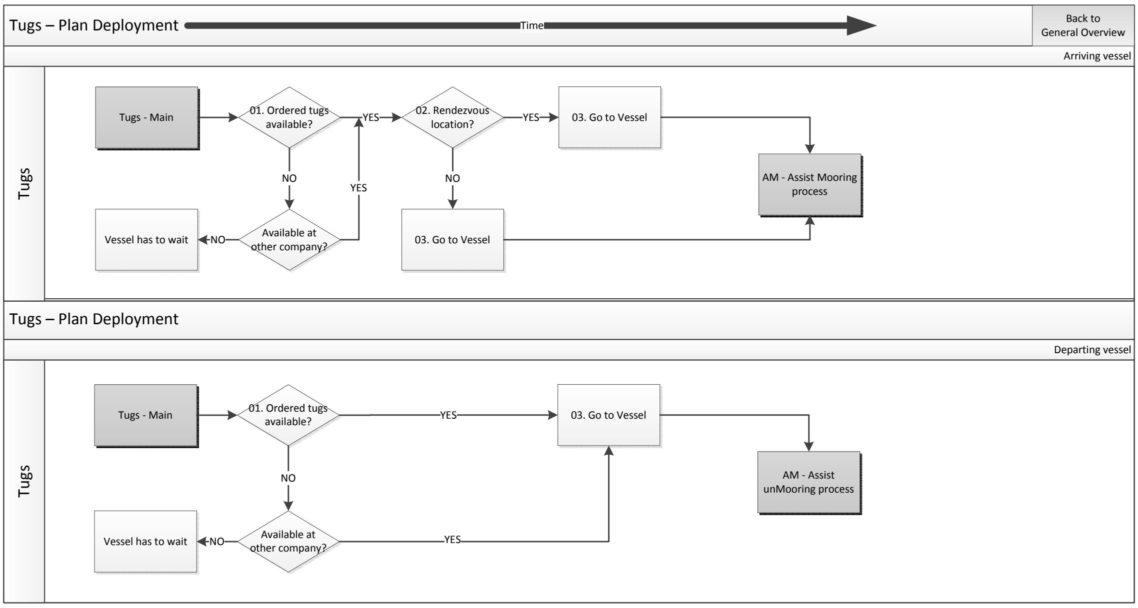


Figure 12.15: Tugboats - Plan Deployment

01. Ordered tugs available First it is determined whether the ordered tugs are available. In table 12.10 the tugboat capacity in the Port of Rotterdam is shown. This is based on the average number throughout the year. It is recommended to investigate the average number of tugboats per tugboat company.

Table 12.10: Tug capacity (Port of Rotterdam, 2016a)

Bollard pull [ton]	Capacity
28-45	13
50-65	15
70-80	5
Total	33

As shown in the table there are different types of tug-boats. As of now it is unclear which types are used to service which vessel classes. No historical data was available to determine this. To be able to better model the tugboat capacity it is recommended that this is further investigated.
However, there is available data on the absolute amount of tugs per vessel class per section. This data for arriving voyages is shown in table 12.11. In the appendix (table D.1 to D.8) it is also shown for departing and shifting voyages. In the period June-July 2017 none of the transit voyages had to use tug-assistance.

If a tugboat-company does not have a tugboat available they will consult the other tugboat-companies in the port to see if they have a tugboat available.
If there is no other tugboat available in time the vessel cannot enter the port and has to wait until the required amount of tugs are available. This causes delays in the nautical chain. Data on how often this occurs is not available and it is recommended to further investigate this.

Table 12.11: Number of tugs per class per section - Arrival (June-July 2017)

Arrival	Class 1				2					3a					3b					4					5			6		Total
Destination	0 tugs	1	2	3	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	2	3	3	4	
Section 5										173	8				2															183
8	177	16	2		448	49	107		1	78	3	111	3				15	26				1	5				1	2	9	1054
11	4					1				1		16		4		1	7	5						1					8	48
17					1																									1
19	2		5		15	7	7					6					2	3												47
22	15				98	12	1			1	5	38					2	18	1	5		40	3			4	1			244
27	15				1		1					1					1													19
32	18				16	16	5			10	50	26								4	8	9								162
35	14				37	6	12			11	3	19								2	1	16	2		1					124
42	9				67	6	1													3		21	1		1	4				113
45	1																													1
46	1	1																												2
50						1	2				1	4	1			1	4													14
55	2		3		3		1		1																					10
60	4				52	12	2			15	10	19					1			13		12	6		1	5	3			155
71	1					2	1				1	1																		6
78	6				2	1	4						2																	15
79	39	2	2		12	5	13																							73
80	22				3	6	3																							34
81	26	3			15	4	6						1																	55
82	17				8	7	8																							40
83	1																													1
84	3						1																							4
85	23				7	4	7					3	1																	45
86	20	2			4	5	5																							36
87	8					1	3																							12
88	50				8	2	17					2	1																	80
89	49	4	1		4	10	8																							76
90	13	1			2		7						1																	24
92	8	1			3	1	1																							14
104	160	6	3		225	22	45			2	3	3	1																	470
105	944	34	11	1	402	68	108	1		21	9	14	2									1								1616
Total	1652	70	27	1	1433	248	376	1	2	312	93	263	13	4	2	2	32	52	1	27	9	100	17	1	3	13	5	2	17	4778

The data in the table above can be used in the model to determine whether a generated vessel with a certain destination which requires tugboat assistance, and show the impact on the tugboat capacity.

<u>02.Rendezvous location</u> Depending on the destination of the vessel the tug(s) will meet her at a certain location. These locations are shown in table 12.12 and figures 12.16 and 12.17, larger figures are shown in the Appendix.

Table 12.12: Tug rendezvous locations (Port of Rotterdam, 2016a)

	Destination section	Rendezvous section (approximate)
1	11 17 18 19 22 27 32 35 42 45 46 49 50 55 58 59 60	10
2	7	6
3	8	8
4	71 78 79 80 81 82 83 84 85 86 87 88 89 90	71
5	104 105	78

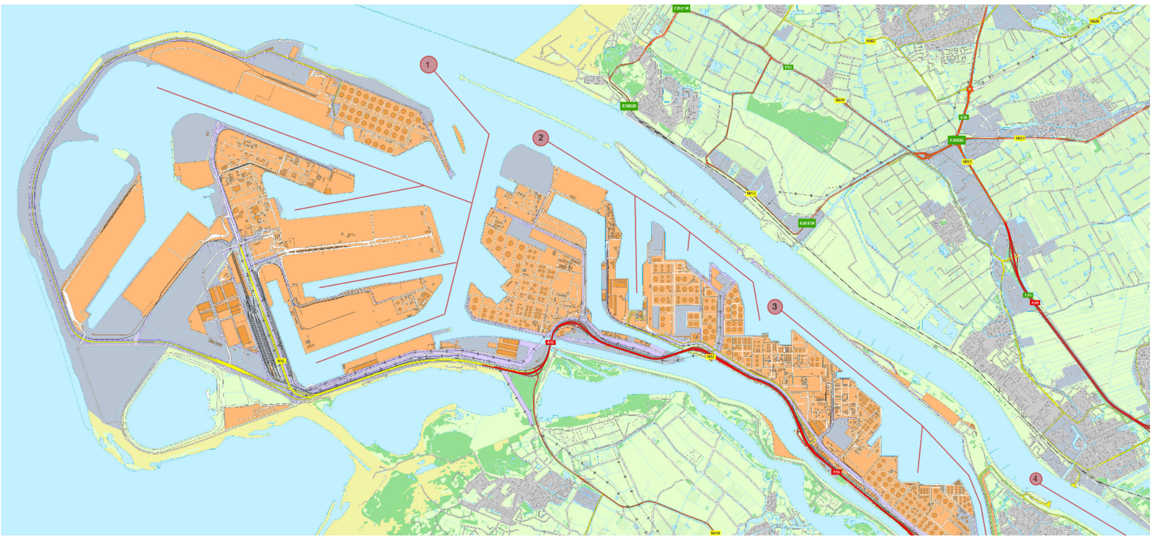


Figure 12.16: Tugboat Rendezvous points - (Port of Rotterdam, 2016a)

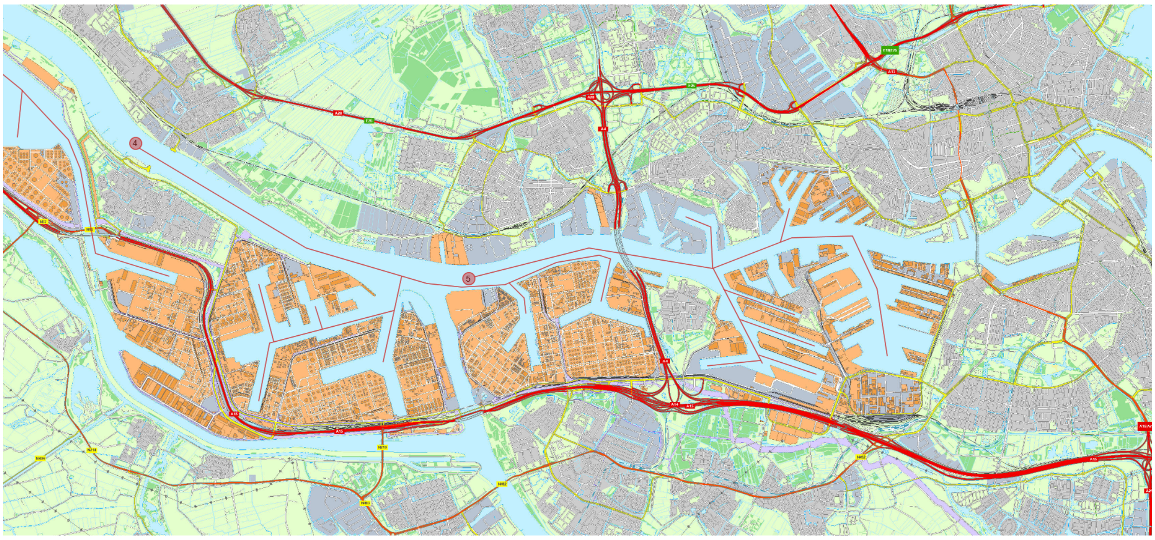


Figure 12.17: Tugboat Rendezvous points - East (Port of Rotterdam, 2016a)

<u>03. Go to Vessel</u> The tugboats also have certain location where they can go between assignments, these are shown in table 12.13. During the planning it will be determined which available tugboats are the closest to the rendezvous point, either at a waiting location or on the waterway. It may occur that the only available tug is far away, in that case sailing to the rendezvous location will cost time.

The model can determine the most optimal distribution of tugboats along the waiting locations, or perhaps find more optimal locations.

Table 12.13: Tugboat waiting locations

Name	Section
Scheurhaven	8
4e PET	8
Tennessee-haven	11
Wilhelmina-haven	105
Merwe-haven	105

12.3.2 AM - Assist (un)Mooring

In this sub-process the tugs assists the vessel in the final part of her arriving voyage or the start of her departing voyage.
This consists of arriving at the vessel, the subsequent connecting to the vessel and finally assisting in the mooring or unmooring of the vessel.

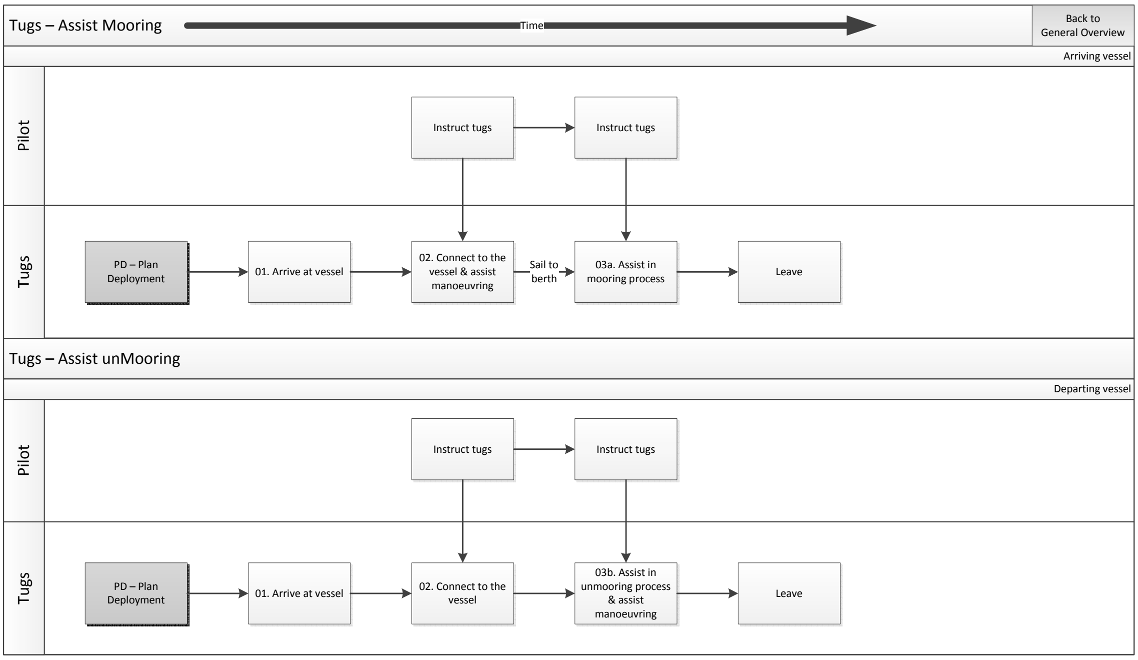


Figure 12.18: Tugboats - Assist (un)Mooring

<u>01. Arrive at vessel</u> From the previous process (Plan Deployment) the tug(s) will either arrive at the meeting point (incoming voyage) or at the berth (departing voyage). Here they will make contact with the pilot, who will further instruct them.

<u>02. Connect to the vessel & assist manoeuvring</u> Under instruction of the pilot the tug(s) will connect to the vessel and assist in manoeuvring. The tug will give its lines to the crew of the vessel, who will securely connect them to the vessel. During the connecting of the lines an arriving vessel will reduce speed to enable safe alignment.
In the case of arriving vessels the tug(s) will then assist the vessel in reaching her berth.

<u>03a. Assist in mooring process</u> When the vessel has reached her berth she needs to be moored. Mooring is directed by the pilot, and tugs, boatmen and the crew of the vessel support this process.

The role of the tug is to control the movements of the vessel and gradually guide it towards the berth while the crew and the boatmen moor the vessel.
When the vessel is safely moored and the tugs are no longer needed they are relieved to go to their next assignment.

03b. Assist in unmooring process & assist manoeuvring During the unmooring the tugs assist the vessel in leaving the berth. This start by pushing the vessel against the berth, while the mooring lines are disconnected at the berth. By doing this the vessel remains in position when the lines are disconnected.
When all the lines are disconnected and safely retrieved on board the tug assists the vessel by leaving the berth in a controlled manner and the subsequent manoeuvring needed in the harbour.
When the vessel is completely unmoored and tug-assistance is no longer needed the pilot will thank the tugs for their assistance and the tugs will continue to their next assignment.

Duration

As was mentioned in the section on the pilots, the duration of (un)mooring varies depending on vessel class and the berth location. With the help of AIS-data it will be possible to analyse these durations. It is recommended to do this, since this will benefit the model.

12.3.3 Conclusion

In section 12.3.1 the tug capacity in the Port of Rotterdam and the distribution in the period June-July 2017 are discussed. With this data the model will be able to assign a certain amount of tugs to a vessel based on the vessel class and destination or departure berth.
To further improve the model it is recommended to analyse the type of tugboats used for each vessel class.

With table 12.12 the model can decide where the tug should meet the vessel based on its destination. If the vessel is on a departing voyage the tug will meet the vessel at her berth. A tug will go to the meeting point either from one of the waiting locations (table 12.13) or from a previous assignment. The model can determine the most optimal distribution of the tugs along the waiting locations, or perhaps find more optimal locations.

The duration of the (un)mooring depends on the vessel class, amount of tugs and the berth location. In this research there is not information on the duration of the (un)mooring, it is recommended that, with the help of AIS-data, these durations are analysed to further benefit the model.

12.4 Boatmen-organisation

The processes of the boatmen relating to the nautical chain will be illustrated in this section. This are the processes regarding planning and executing their main task, assisting in the (un)mooring of vessels.
Figure 12.19 shows the general of the processes of the boatmen organisation. In Appendix H this process and the other processes are shown in a larger format.

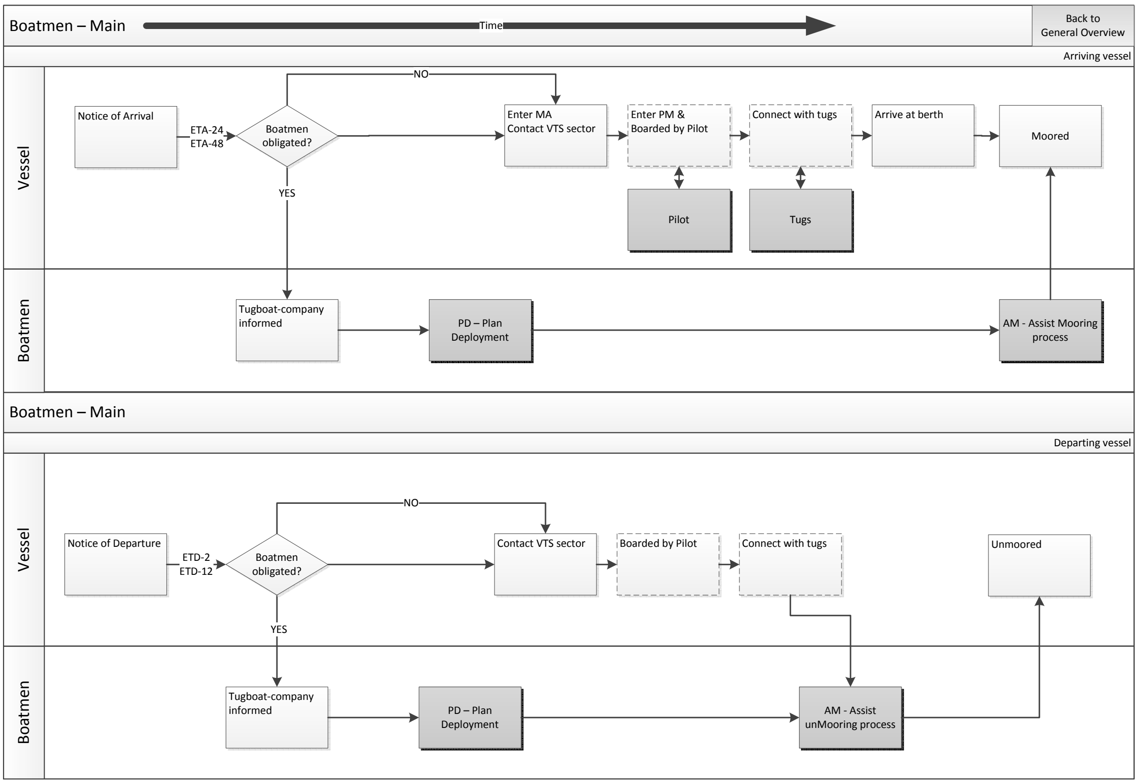


Figure 12.19: General overview of the processes of the boatmen-organisation

Processes

The relevant processes for the boatmen teams in the nautical chain are shown in figure 12.19 and will be explained in this section.

Their main processes are the planning of the deployment and assisting in the (un)mooring of vessels.
When a boatmen team is present at the vessel location they will assist the vessel in mooring or unmooring together with the pilot and the optional tugboats.
Vessels longer than 75 metres and tankers are obligated to use the services of the boatmen[14].
Data on the use of the boatmen-teams per class per section for arriving vessels is shown in the table 12.14. This table is also found in Appendix E together with the distributions for departing and shifting voyages.
The table shows that most vessels require the services of the boatmen.

[14]There are however exemptions, when a vessel is shifting along the same pier without letting go of all the lines she is exempt from using the boatmen (Port of Rotterdam, 2016a). Some terminals are allowed to perform their own mooring services, these are terminals with high frequent visits such as the ferry terminal in Hoek van Holland.

Table 12.14: Boatmen-team distribution per class per section - Arrival(June-July 2017)

Arrival	Class 1		2		3a		3b		4		5		6		Total
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	
Section 5					181		2								183
8	23	185	172	427	76	114		43		6				12	1058
11	3	1		1		21		10		1		1		6	44
17		1													1
19		6		28		10	1	5							50
22	1	13	1	110		42		21		45		5			238
27	5	14		2		1		1							23
32	3	27		35		83				20					168
35	2	20		35		35		1		25		1			119
42		6	1	72						25		5			109
45	1														1
46		2													2
50				1		5		4						1	11
55	4	4	3	2											13
60	2	3	2	73		49				31		9			169
71		2		3		2									7
78	1	3		8		4									16
79		42		25											67
80		15		12											27
81		26		32		1		1							60
82		18		29											47
83		1													1
84		7		1											8
85		21	1	20		4									46
86	1	21		12											34
87		9		6											15
88	10	46		29		3									88
89	2	50		16											68
90		12		8		1									21
92		8		4											12
104	53	130	161	115	5	1									465
105	296	647	92	510		46				1					1592
Total	407	1340	433	1616	262	422	3	86		154		21		19	4763

The model can use this data to determine whether a generated vessel with a certain locations requires the services of the boatmen-organisation.

12.4.1 PD - Plan Deployment

In this process the deployment of the boatmen is planned. The capacity of the boatmen is large, 280 boatmen, and it almost never occurs that the boatmen cannot provide mooring assistance due to capacity problems. The boatmen work in teams of about 4 to 6, the size depending on the vessel and berthing location. More study into the size of the teams is recommended to best model the capacity of the boatmen.
The boatmen can also deploy 60 mooring boats to assist them in (un)mooring vessels.

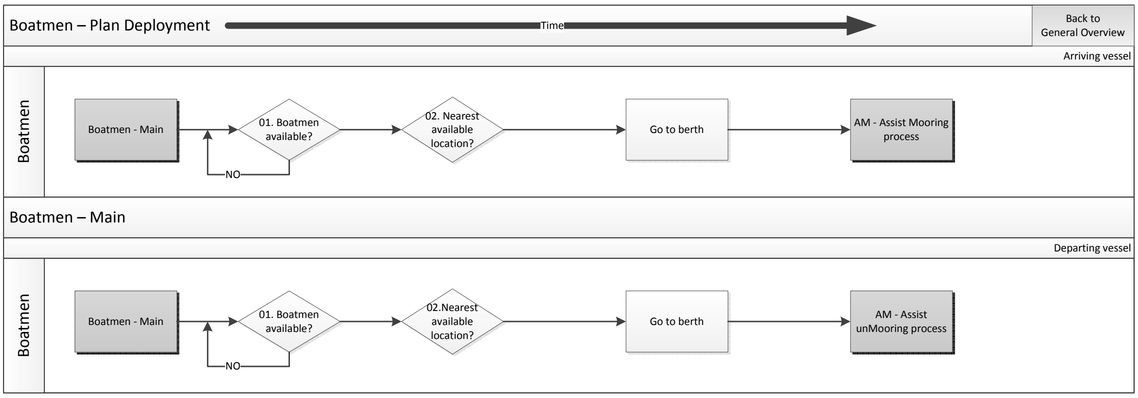


Figure 12.20: Boatmen - Plan Deployment

01. Boatmen available As mentioned above, the boatmen are almost always available. All boatmen are qualified to assist in the mooring of all vessels. So this is different compared to the pilots and tugboats.
The boatmen work with a four-shift system and when the capacity of one shift is exceeded the standby team is called upon (KRVE, 2017).

02. Nearest available location Boatmen travel to the designated berth either by car and/or with a mooring boat (figure 12.21).

Figure 12.21: Mooring boat

The mooring boats are deployed from various locations in the Port of Rotterdam. These locations are shown in table 12.15 and figures 12.22 and 12.23, larger images are available in the Appendix.
The model could see if these locations are indeed optimal and determine the best distribution of capacity along the locations.

Table 12.15: Boatmen locations

	Name	Section
1	Prinses Margriet haven	59
2	Pistoolhaven	17
3	Scheurhaven	8
4	4e PET	8
5	Wezerhaven	8
6	Geulhaven	78
7	Sleepboothaven	105

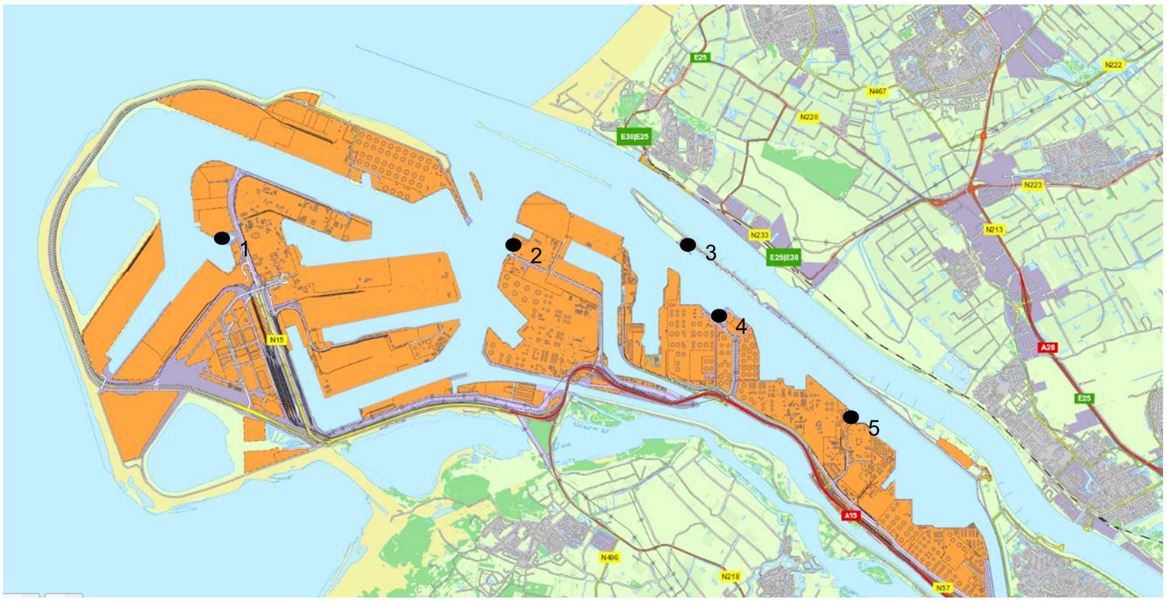


Figure 12.22: Boatmen locations - West

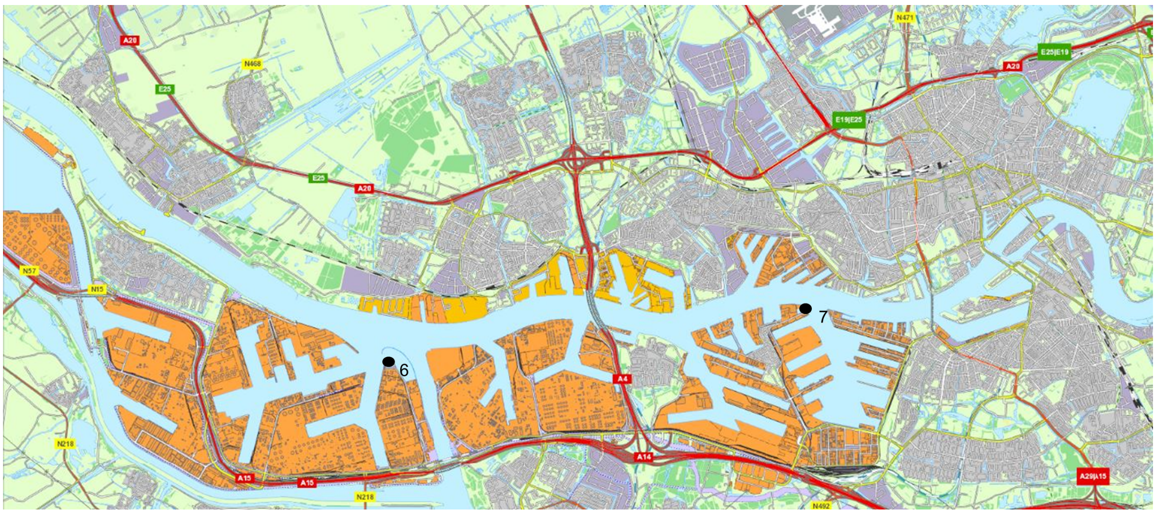


Figure 12.23: Boatmen locations - East

For class 1 vessels at a quay or berth only personnel is needed, for the other classes mooring boats and winch trucks[15] are needed as well. If a vessel is (un)mooring at a buoy or jetty

[15] A winch truck is a small flatbed truck with a small winch in the back to pull in the mooring lines from

only mooring boats are used.

12.4.2 AM - Assist (un)Mooring

After the planning phase has been completed the boatmen will arrive at the berth and assist the vessel in (un)mooring. The (un)mooring is usually coordinated by a maritime pilot.
As was discussed before, the duration of an (un)mooring process varies with vessel class and berth location. This is relevant for the duration of the boatmen deployment. As of now there is no information available on these durations and it is recommended to further analyse this with the help of AIS-data.

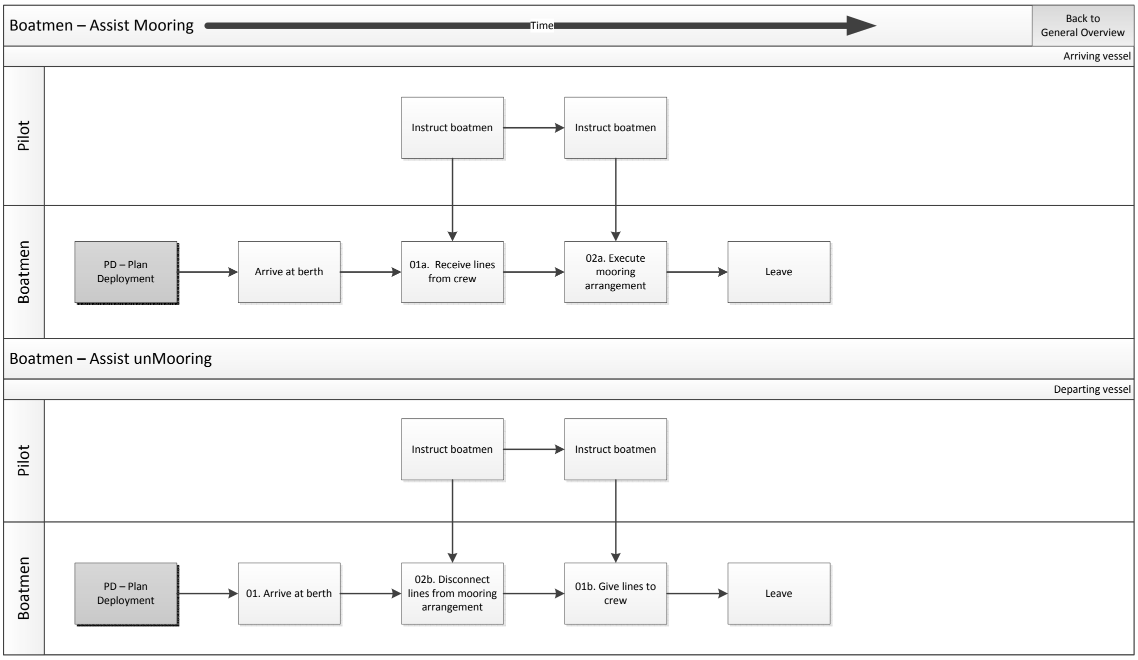


Figure 12.24: Boatmen - Assist (un)Mooring

<u>01a. Receive lines from crew</u> In the case of an arriving vessel the boatmen will receive the mooring lines from the crew. This can be done in two ways.
If a mooring boat is present the vessel crew will lower the lines to the mooring boat. The mooring boat will collect these lines and deliver them to the boatmen at the quay or mooring construction.
If there is no mooring boat present the crew will throw the lines ashore and the lines will be collected by the boatmen at the quay.

<u>01b. Give lines to crew</u> When the boatmen have disconnected the lines in the case of a departing voyage the vessel crew will pull in the lines with the help of winches.

<u>02a. Execute mooring arrangement</u> Each vessel has a mooring plan so that she is safely moored at the quay or mooring construction. The boatmen are there to make sure this mooring plan is safely executed.
This means that the boatmen connect the mooring lines to the correct boulders and together with the pilot and the vessel crew make sure that the right amount of tension is put

the vessel

on the lines.

02b. Disconnect lines from mooring arrangement Together with the vessel crew and the pilot the boatmen will disconnect the mooring lines from the mooring arrangement. First the tension on the lines is taken away by the crew aboard the vessel, when the tension is gone the boatmen will remove the lines from the mooring arrangement.

12.4.3 Conclusion

The model can use the data from table 12.14 to determine whether a generated vessel with a certain destination needs to employ the services of the boatmen.

The size of the boatmen teams that service a vessel depends on the vessel class and berth location. Further research into the size of these teams will positively affect the way the model deals with the boatmen capacity.
The boatmen are deployed from 13 locations in the Port of Rotterdam. The model may be able to determine whether these locations are the most optimal and allocate the most optimal capacity to each of the locations.

It is recommended that the duration of the (un)mooring process is further analysed with the help of AIS-data, since no data on this is available at the moment.

12.5 Terminal

This section will discuss the role the terminal plays in the nautical chain. This mainly involves planning. Often the terminal is the destination of a vessel calling at the port, to load and unload cargo. At the terminal other activities may also be performed, such as bunkering, repairs and crew change, but these, like the (un)loading, are not part of this research.

Table 12.16: Terminal service times [hrs] (TBA, 2017)

Terminal	Section	Class 1	2	3a	3b	4	5	6
Hoek van Holland Stena	5	6:00	6:00	6:00				
Shtandart Noord Berth	7		15:31	17:49	17:49		19:42	
Caland	8	6:00	11:00	11:00	11:00	19:00	19:00	
MV1 - Gate	11							
MV1 - MOT	11			21:00		21:00	21:00	21:00
Tennessee haven	11		15:31	17:49	17:49		19:42	5:38
Indorama	11	10:00	10:00					
BP	19	16:00	16:00	16:00	16:00	18:00	17:00	

Table 12.16 shows the average terminal service times for some of the terminals in the Port of Rotterdam. This table is an exert of the table found in Appendix F.
The model will be able to use these times to determine when a vessel is ready to leave the berth. This data does not cover all terminals in the Port of Rotterdam but a good indication is provided on average service times.
To be able to model the terminal even better it is suggested that information on the capacity[16] of the various terminals is retrieved.

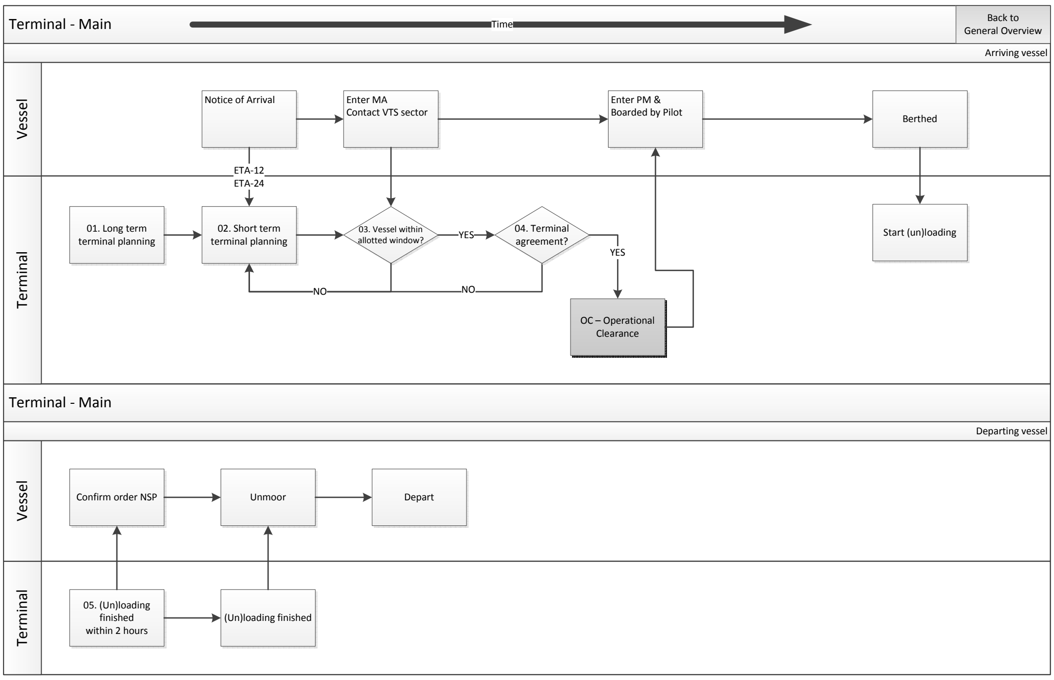


Figure 12.25: Terminal processes

[16]The amount of various types of vessel classes that can be serviced at the same time

Processes

All the processes relevant for this research are shown in figure 12.25 and will be explained below.
The processes mainly occur before the vessel arrives in the port and when the vessel makes operational contact.

12.5.1 Arriving vessel

This subsection discusses the processes of a terminal in case of an arriving voyage, the next subsection will discuss a departing voyage.

<u>01. Long term terminal planning</u> The terminal will make a long term planning based on the contracts it has with various shipping companies.
A container terminal, for example, mostly receives line-services, vessels sailing a fixed itinerary. This means that it is known when a vessel will call on the Port of Rotterdam. All these vessels can be planned in advance, with a certain flexibility.
Not all type of terminals work with this kind of planning, oil trader (using oil terminals) for instance react on the situation on the oil market which is not a long term process.

<u>02. Short term terminal planning</u> Based on the Notice of Arrival with the ETA, the terminal will also be able to plan their berths more precise.
This is also done in combination with the ETA the vessel has given in her Notice of Arrival. Eventually a vessel is given an allotted window in which she has to arrive to keep the terminal planning on schedule. This is also communicated to the vessel.

The planner needs to plan a two hour window between the ETD of the leaving vessel and the ETA of the arriving vessel. This gives the leaving vessel time to leave the port before the arriving vessel arrives. This is to make sure that the arriving vessel has a free berth when entering the port, since a vessel that has entered the port is difficult to turn around. This also anticipates for any possible delays.
The model may be able to analyse whether this window can be altered for certain sections or vessel classes.

> NB: Figure 12.25 shows that operational clearance is, among other factors, dependent on whether the requested berth if free and if the terminal agrees to receive the vessel. This means that the output of the nautical chain is to a large extent dependent on the terminal.
> The terminal operates in a private (business) domain, whereas the Harbour Master and the nautical service providers operate in a public domain. There is a difference between the domains of the terminal and the nautical service providers. The vessel operates in both.
> This could have consequences, when planning in the business domain cannot be followed by the planning in the public domain, and vice versa. The planning of the waterway is subjected to the planning of the terminals, since a berth must be available for the incoming vessel at the time she arrives at this berth.
> Currently, the planning of the nautical chain is not always aligned with the berth planning of the terminals.
> If the model would be able to align the planning of the terminal with the planning of the nautical chain, it could show that there would be a decrease in delays due to a misalignment in the planning.

<u>03. Vessel in allotted windows</u> If the vessel arrives within the allotted window the berth is

available to the vessel. This does not mean that the vessel is allowed to sail to the berth. This is decided in the operational clearance process (section 12.1.2).
If the vessel arrives outside of the allotted window she has to wait until a berth is available.

04. Terminal agreement When the berth is not occupied, it does not mean that the vessel can automatically come in. The terminal may have other reasons to not allow the vessel. This could, for instance, be planning issues.

How often an occupied berth causes delays in the nautical chain is not clear. The logging of this kind of delays is not sufficient. More data on these delays and the reasons behind them will be valuable for the model and it is recommended to investigate this further.

12.5.2 Departing vessel

The most important thing regarding a departing vessel is notifying the nautical service providers in time, so the departing vessel will not have a delay.

04. (Un)loading finished within two hours If the (un)loading process has reached the point that two hours are left before (un)loading is finished this will be communicated to the vessel. The vessel will subsequently confirm the order of the NSP. These have been already ordered in advance but require a confirmation at least two hours before departure.
When the unloading and other services are actually finished the vessel will unmoor and sail to her next destination.

12.5.3 Conclusion

With the data provided in table 12.16 the model will be able to model the average time a vessel is serviced at various terminals. This list is, however, not exhaustive. Adding more terminals and information on terminal capacities in the model would increase the modelling of the terminals.

The mismatch between the planning of the terminal and the planning of the nautical chain can cause delays. Using the model to show the difference between a situation when there is more communication between the two and when there is not, could provide useful insights.

As of now a two hour window needs to be scheduled between an arriving and a departing vessel. The model may be able to determine shorter times for certain situations, sections and vessel classes.

The delays caused by an occupied berth are not logged sufficiently to be able to model them. It is recommended that more research is done into the delays caused by occupied berths and the reasons behind it.

12.6 Vessel

The services provided in the nautical chain are provided to the vessel. In the previous sections the vessel has been used to describe the processes of the actors in the nautical chain. In this research all the actions regarding the vessel are described as taken by the vessel. However, in reality some of these actions are taken by other parties. For instance, the notice of arrival is submitted by a shipping agent and not by the vessel herself.

In reality the shipping company or shipping agent provides the information needed for the administrative process. The shipping agent is the representative of the vessel or shipping company in the port. The agent takes care of the arrangements and shares the information with the relevant parties.
In this research the choice has been made to not include the agent as the representative of the vessel. Because this would create an extra level of complexity that, as of now, would not benefit the research or the model. This would introduce an extra actor that would split up the already minimal actions taken by the vessel. Although the agent prepares the port call of the vessel, normally he/she is not actively engaged in the processes as described in this research (the nautical chain).
Should the model be extended to encompass services that are provided when the vessel is berthed, such as bunkering, it is advised to include the agent in the model since that is the party that arranges for such services. But until the point these services need to be simulated it is recommended to not include the agent.

In coordinating the traffic planning and the deployment of the NSP, it appears that he voyage planning of the vessel is usually not aligned with the concerted planning of the NSP (Seignette, 2010). This can cause delays in the nautical chain. For example when the deployment of a tugboat is scheduled three hours in advance for a specific vessel, and the tugboat is asked to assist the unscheduled departure of another vessel.

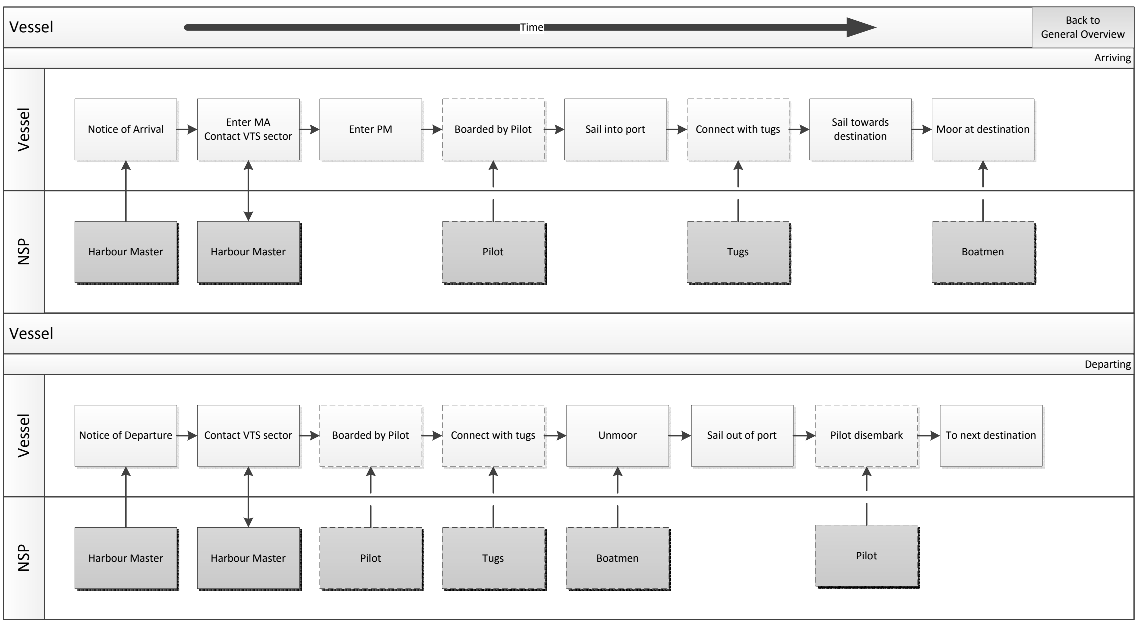


Figure 12.26: Vessel processes

Figure 12.26 shows the processes the vessel has when on a arriving or departing voyage and when the actors play a role in these processes. The pilots, tugs and boatmen are in dotted squares since they do not always play a part.

12.6.1 Conclusion

The vessel is the actor receiving all the services. In reality the vessel is supported by other parties such as a shipping agent. In this research those parties have not been included. Should the model want to extend to services provided outside of the nautical chain, it is recommended to include the shipping agent as an actor.

The mismatch between the planning horizon of the vessel and that of the nautical service providers may cause delays in the nautical chain.

12.7 Chapter conclusion

The activities of the actors described in this chapter can function in the environment described in the previous chapter.

As of now there is no available data on the amount of rejected administrative or operational clearances. So, the model cannot incorporate this, thus the model will assume all vessels are allowed to enter the port.

The distribution of pilots among the various vessel classes can be used by the model to determine if a generated vessel requires a pilot. If a pilot is required it is decided how the pilot will board the vessel, depending on, among others, vessel class and weather conditions.
The amount of the pilots in the Port of Rotterdam is 220 pilots, but the various qualifications of these pilots are not known.
When a generated vessel requires a pilot, the boarding time of that pilot can be determined with the durations of the pilot voyage.
This durations encompasses the entire time a pilot is on board, it would be beneficial if the mooring time could be determined separately. With the available data this is not possible.

How long tugboats and boatmen are deployed per voyage is not known. It is only registered how often tugboats and boatmen are deployed per voyage.
This distribution for the tugboats will enable the modelling of their deployment. However, information on the distribution of specific tugboat types is not available.
The various locations of the tugboats, either rendezvous- or meeting-locations, can also be modelled.
Sometimes extra tugboats are required to assist a vessel due to various reasons. As of now, there is insufficient information available to incorporate this in the model, but it has an impact on the tugboat capacity.

The distribution of boatmen teams among the vessel classes can also be modelled, just as the locations the boatmen are deployed from. The boatmen-organisation has a capacity of 280 persons, but the size of the teams varies per assignment. To fully model the capacity the size of the teams needs to be determined.

The average service time of a vessel at the terminal will help the model determine how long a berth is occupied by a vessel. These times do not reflect all terminals in the network.
The two hour window required between two vessels at a terminal can also be modelled to fully reflect actual terminal operations.

The environment described proves to be a good image in which the activities of the actors can be function.

13 Information systems & sharing

Within the nautical chain and in its planning, information is exchanged between the actors in the chain.
This chapter will discuss the required information, the relevant systems used to process the information and will show which information is shared among which actors.

With the information in this chapter the model will be able to simulate the events the information flows within the nautical chain trigger. This may result in new insights about to whom and when information is shared.

13.1 Required information

The table below shows when the vessel needs to share the relevant information. Below the table this information is further explained.

Table 13.1: Required information (Port of Rotterdam, 2016a)

	Arrival		Departure	
Class	Time	Report	Time	Report
1-5	ETA Pilot Station -24hrs	ETA	ETD -2hrs	ETD
	In transit	VTS	In transit	VTS
			Upon departure	ATD
6	ETA Rendezvous -48hrs	ETA	ETD -12hrs	ETD
	In transit	VTS	In transit	VTS
			Upon departure	ATD

Estimated Time of Arrival (ETA)
The Notice of Arrival (NoA) should be sent at least 24 hours before the ETA at the pilot station, for class 6 vessels at least 48 hours. This notice should include the ETA Pilot Station and the ETA needs to be updated when it changes more than 30 minutes.
This notification should also include the ordering of the applicable nautical service providers.

Estimated Time of Departure (ETD)
The vessel is required to send a Notice of Departure (NoD), at least 2 hours before the ETD. Formally this is 3 hours, but in the Port of Rotterdam the NSP are able to provide their services with a 2 hour notice. Class 6 vessels have to report 12 hours before ETD. And the ETD, just as with the ETA, should be update when it changes more than 30 minutes.
This notification should also include the ordering of the applicable nautical service providers.

Vessel Traffic Service (VTS)
When a vessel enters the VTS-area of the Port of Rotterdam she needs to report her actual draught, position, destination and any particulars[1] to the VTS-operator.
During the in-port voyage, constant communication between the vessel and VTS is maintained.
The actual draught, destination and any particulars need to be provided to the VTS-operator just before departure of the berth.

Actual Departure
When the vessel is departing the berth she needs to report this to the VTS, as was mentioned above.

The model may consider using this operational information (between vessel and VTS) for improving the efficiency of the nautical chain, where possible.

13.2 Information systems

There are various information systems that are being used by the actors to support them in their processes in the nautical chain.
The systems that will be discussed are the Port Community System (PCS), the Harbour Master Management Information System (HaMIS), Aramis, GIDS and COS. This are the relevant systems for this research used in the nautical chain.

13.2.1 Port Community System

The Port Community System (PCS) in the Port of Rotterdam is used to share information, regarding vessel voyages and cargo, between various other information systems and actors. According to the IPCSA (International Port Community Systems Association) a PCS is a neutral and open electronic platform, which enables secure exchange of information among public and private actors (*Port Community Systems* 2014). It can make the port processes more efficient because information has to be delivered only once.
Without a system such as PCS the actors would have to send information separately to all the others requiring this information. With a PCS an actor can deliver the information to the PCS from where it is shared among the relevant actors, see figure 13.1.

[1] This are any particulars related to the navigational status of the vessel

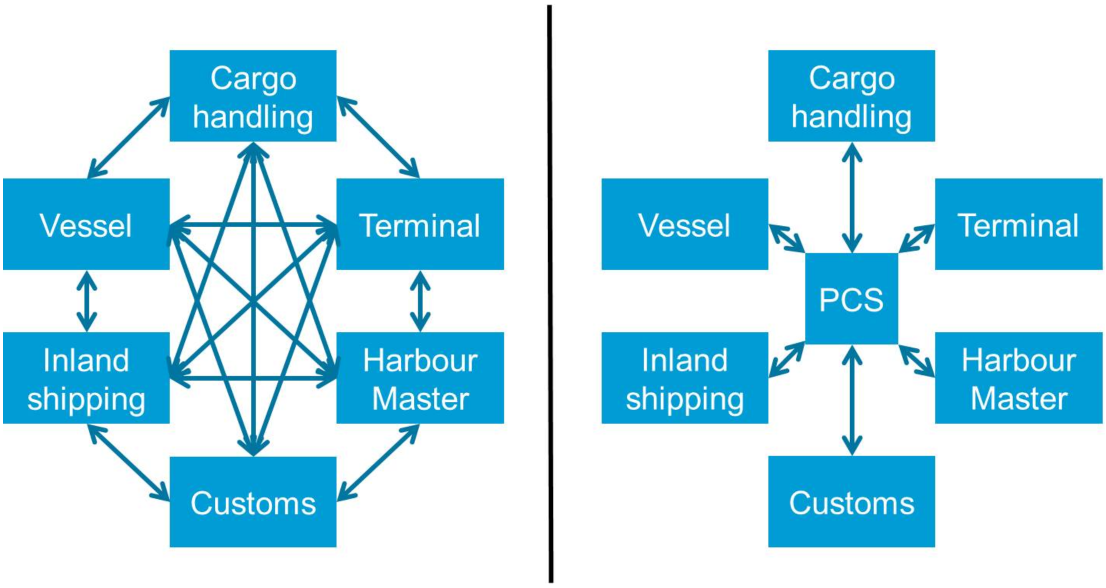


Figure 13.1: With and without PCS

Many stakeholders are connected to the PCS, some are shown in the figure above. The stakeholders in the figure that are relevant for this research are the Harbour Master, the terminal and the vessel.

The vessel is obligated by law to notify the Harbour Master on her arrival/departure, dangerous goods, waste and security. For this research the notification on the arrival and departure are relevant.

This notification has to be made in the PCS and contains information on the ETA and ETD of the vessel, the name and identification-number of the vessel, the destination port, total amount of people on board and, if applicable, the ordering of nautical service providers.

13.2.2 HaMIS

The Harbour Master Management Information System (HaMIS) is the information system that is used by the Harbour Master to support its processes. This system is developed by the Harbour Master and is used by the HCC and VTS and the nautical service providers. In this system the operators are able to see, among other things, the actual traffic image, incidents, information on the vessels and occupied berths.
The HCC uses this system to provide administrative and operational clearance and the VTS-operators use it to supplement the traffic image with specific port call data.

Examples of data in HaMIS are the ETA, ETD, destination, whether or not pilot/tugs/boatmen were ordered and vessel particulars. This information is fed to HaMIS from the Port Community System.

13.2.3 ARAMIS

The Advanced Radar Monitor and Information System (ARAMIS) provides the VTS-operators of a real time traffic image.
This system combines the radar images from the various radar posts in the port and AIS-data, which is projected on electronic nautical charts of the waterway.

13.2.4 GIDS

The Gemeenschappelijk Informatie Delings Systeem (GIDS) (Nederlands Loodswezen, 2014) is a system developed by the pilot-organisation to coordinate the deployment of their services and those of the tugs and boatmen.
In this system the nautical service providers align the deployment of their services in accordance with each other and the ETA/ETD of the vessel.
When the pilot is on board the vessel this system can also be used to update the times of the events ahead to the other NSP.

13.2.5 COS

The Coordination tool Oversized Ships (COS), which is integrated into HaMIS, checks at four locations whether very large sea-going vessels might have unwanted encounters. Table 13.2 and figure 13.2 show the four locations, the number zero in the figure indicates that there are no unwanted encounters. This relates to the encounter and passing rules discussed in section 11.1.3.

If COS signals that two vessel will encounter each other at a location where this is not permitted, this is shown in HaMIS. The HCC is expected to notice this, communicate with the pilots and discuss further action. This could for example be slowing down one of the vessels.

Table 13.2: COS locations

Name	Section
Yangtzekanaal	45
Beerkanaal	19
Maasmond	4
Calandkanaal	8

Figure 13.2: Screenshot of HaMIS with the COS locations (HaMIS, 2017)

13.3 Information sharing

The information systems that were discussed in the previous section are used to share information among the various actors. This can be split up into two phases, the planning/admission phase and the operational phase.
The first phase takes place in the tactical domain, the time between ETA-24hrs and the ETA. Here the port-call is evaluated and planned by the HCC and the nautical service providers.

The operational phase is part of the operational domain, where the planning from the tactical domain is executed and monitored.
Next to tactical and operational domain the strategic domain exists, this is the phase until ETA-24hrs. This phase is not discussed in this research.

13.3.1 Planning/admission phase

This subsection will discuss the information flows before a vessel starts her voyage, this can be seen in figure 13.3.
This information is used in the tactical domain during the planning and assessing the vessel voyage.

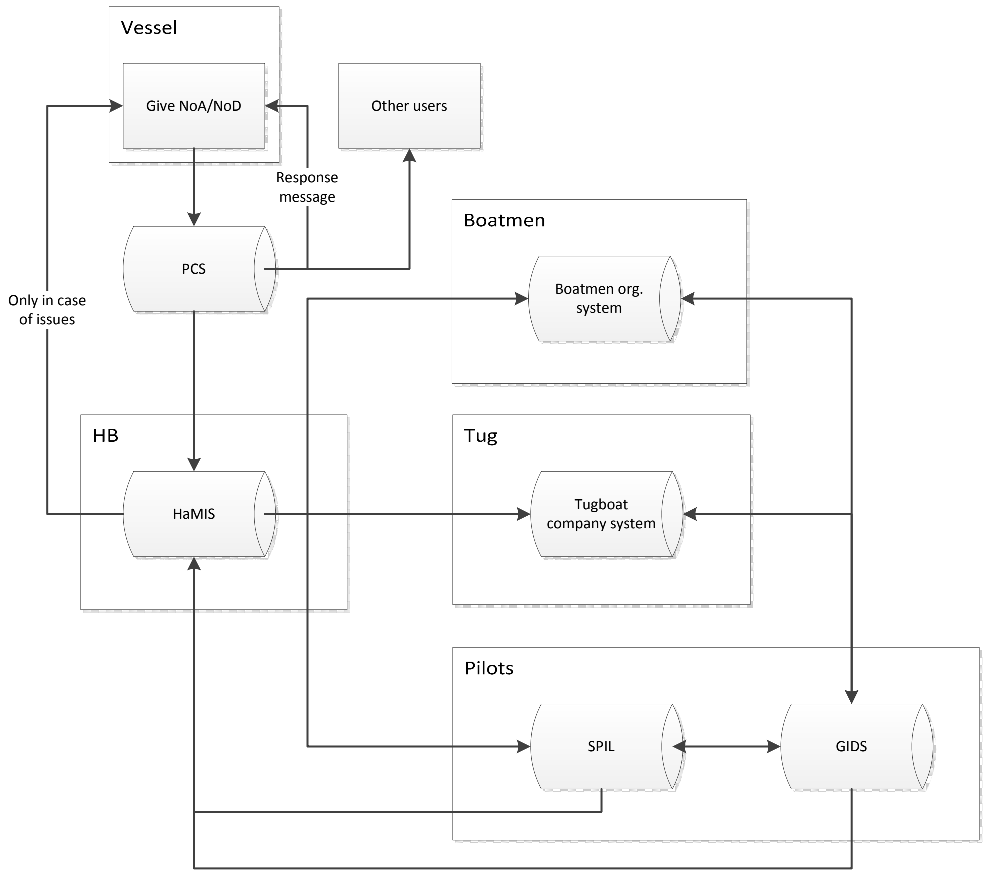


Figure 13.3: Pre-arrival information

The vessel will provide a Notice of Arrival/Departure before she will start her voyage (see

table 13.1). This information is provided to the Port Community System. PCS replies with a message that the information has been retrieved, this message does not comment on the correctness of the information.
Via the PCS the relevant information is forwarded to HaMIS, where it is processed and further distributed to the nautical service providers. Via HaMIS a message can be sent to the supplier of the information that certain information is missing or is incorrect.

The information sent to HaMIS is used by the HCC to provide the administrative clearance and later the operational clearance. This is explained in section 12.1.1 and 12.1.2.
HaMIS shares information on the ETA and ETD, destination, vessel particulars and other relevant information with the nautical service providers.

The pilot-organisation uses an internal system, called SPIL, for their planning and deployment. The tugboat companies and boatmen organisation have such a system as well.
GIDS is the tool used by the nautical service providers to coordinate their deployment.

Via SPIL the expected time the pilot will embark, the actual time the pilot embarks and the actual time the pilot disembarks is provided to HaMIS. If via GIDS a new ETD is suggested this will be provided to HaMIS, in order for the HCC to this ETD.

13.3.2 Operational phase

During the voyage information is also exchanged between the information systems and actors. This will now shortly be discussed and is illustrated in figure 13.4.
The information exchanged here is part of the operational domain.

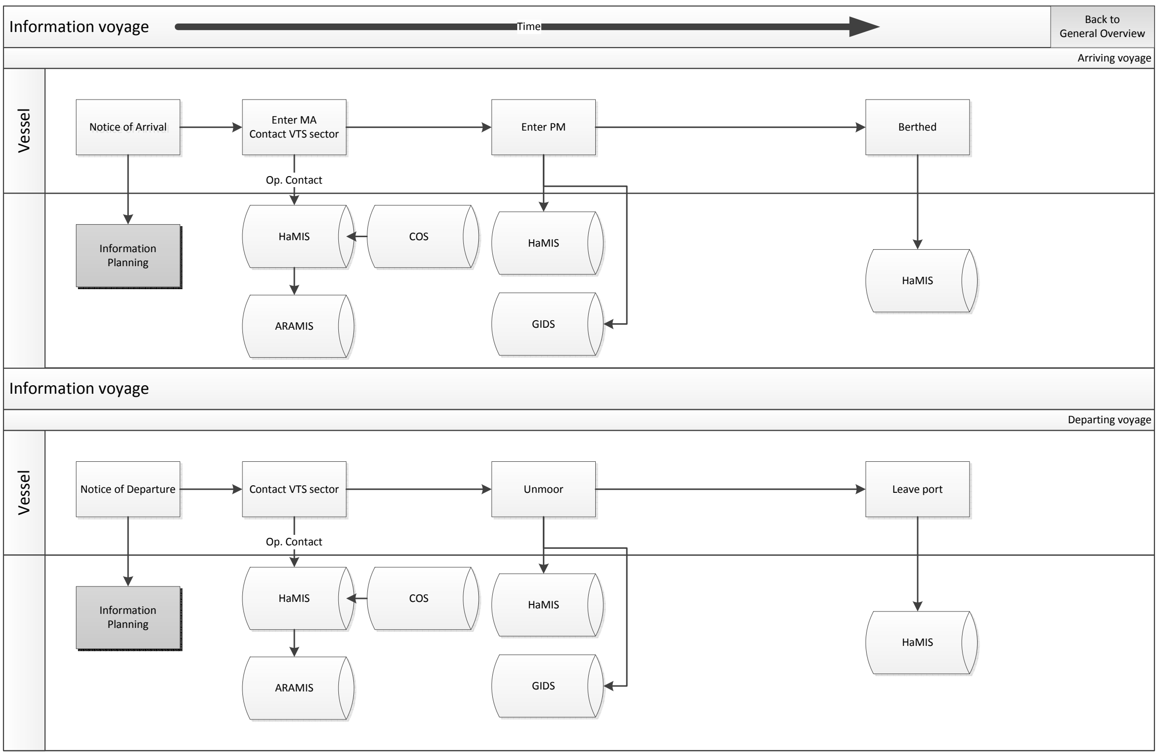


Figure 13.4: Information during voyage

When an arriving vessel contacts sector Maas Aanloop or a departing vessel contacts her

departing sector this will be logged in HaMIS by the responsible VTS-operator.
When operational clearance is granted this will be logged and the vessel can enter the port or leave her berth.

During this time COS will automatically check whether the vessel will encounter any other vessel she is not allowed to encounter.

If the vessel is boarded by a pilot, the pilot will update the expected times in GIDS, so that all the actors are aware of the most recent expected times.

During the voyage the vessel is constantly monitored by VTS-operators. When necessary VTS will inform the pilots that the fairway planning has changed.

When the vessel has either left the port or has finished her voyage this time will be logged into HaMIS by the responsible VTS-operator.

During the voyage the nautical service providers do not only communicate via the information systems. They also use their mobile phones to call each other to make arrangements. This does not only happen between the various NSP but also within an organisation. For example, two pilots who both pilot a large vessel will encounter each other at a location where this in not possible. The pilot may phone each other and make arrangements. This happens outside of the official procedures.

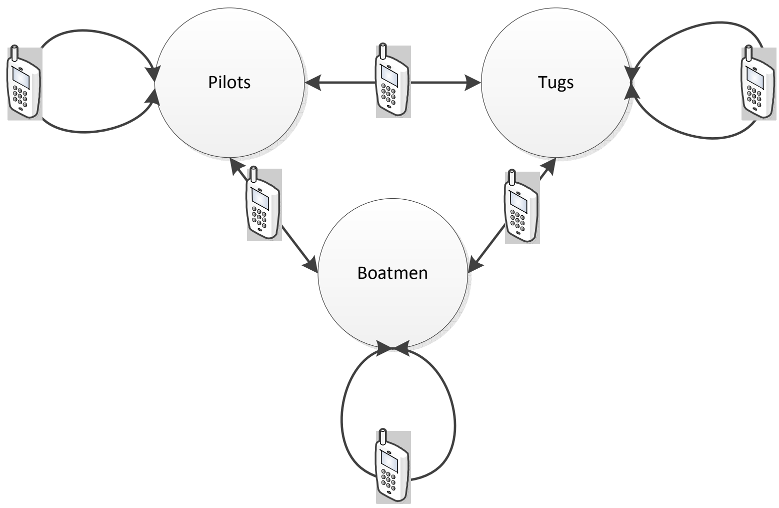


Figure 13.5: Phone communication

In the model these information flows can be modelled and possibly visualized. This can lead to new insights regarding the reporting and sharing of information within the nautical chain.

13.4 Chapter conclusion

Simulating the information that is provided and subsequently shared among and used by the various actors in the nautical chain provides an overview from which lessons may be learned.

Information is the fuel of the processes in the nautical chain, it leads to activities. To coordinate the activities in the chain it is important that information is shared and agreements are made regarding this information.

Part IV

Conclusions & Recommendations

14 | Conclusions

In this thesis the relations between the nautical service providers in the Port of Rotterdam and relations between their processes have been analysed.

With the information provided in this master thesis it is possible to construct a simulation model of the nautical chain in the Port of Rotterdam.
To this end, the process analysis presents data on the activities and processes of the nautical chain. This includes the environment which will function as the basis of the model and the activities of the actors which can be implemented in this environment.
The actor analysis provides information on the relations, interests, objectives and interdependencies of the actors. It also provides an insight into their business models.
The information flows that are a key part of the functioning of the nautical chain are described as well.

The environment can be used as the basis of the simulation model.
The model can be further enhanced by extending the network, and by logging more events (timestamps) in the nautical chain.

In the environment the activities (process steps) of the actors in the nautical chain can be described and most of these process steps can be simulated.
These process steps can be further specified by including parameters, like qualifications of pilots and team-size of the boatmen.

The actors in the nautical chain have their own interests and objectives, based on their business model, and these are merged on chain level, to a certain extent.
At this moment it is recognised that the pilot-organisation and the tugboat-companies are somewhat reluctant to share operational information with the Harbour Master, in order to limit the influence of the Harbour Master on their processes.

The information processes described can govern the process steps in the model.
These processes can be complemented by identifying the relevant information exchanged via mobile phone communication.

15 | Recommendations

The recommendations are given regarding three subjects. First, recommendations regarding the simulation model are presented.
Secondly, recommendations regarding the SwarmPort project and how it should proceed are given.
Lastly, some recommendations on changes in the nautical chain are given.

Model

At the moment the port network is divided into various sections, some sections however cover large areas. It is recommended to split up some sections, such as section 8, to further detail the model.

The duration before port entry should not yet be incorporated into the model. Not before the data allows for a better split in the durations and causes of delays.
This can be done by better logging of events by the Harbour Master. For instance by logging not only the first operational contact but also the time the vessel starts her voyage towards the port entry. If a vessel stays at anchorage for a long time, the reasons behind this should also be logged.
Analysing AIS-data may also provide more insight in the duration and processes before port-entry.

Delays that occur in the port are also not logged consistently and constantly enough to provide useful data for the model.
It is recommended that the Harbour Master logs all delays including accurate causes. This way, analyses of the main causes of delays in the nautical chain can support the simulation model.

Another recommendation regarding the logging by the Harbour Master refers to administrative and operational clearance. At the moment, no data of the amount of times administrative or operational clearance was rejected is available.

In the period June-July 2017 pilotage was only amended once, partly for small shipping and partly for all vessels. During this time shore based pilots and helicopters were deployed. It is recommended to investigate this for a greater period of time since the amount of amended pilotage is seasonal dependent. This would provide more reliable data on the deployment of helicopters and shore based pilots.

The capacity of the maritime pilots in the Port of Rotterdam is 220 pilots. But no information is available on their qualifications. It is recommended to investigate this further to improve the modelling of the pilot capacity and their assignment to a vessel.

The (un)mooring process is an essential part of the nautical chain and the pilots, tugboats and boatmen take part in this process. However, there is no data on the duration of this process. It is recommended that by analysing AIS-data more information on the durations is gathered.
This would benefit the modelling of the actions of the pilots, tugboats and boatmen.

The average amount of tugboats in the port of Rotterdam is known. This is the average amount of all the tugboat-companies combined. By investigating the average amount per company the modelling of the tugboat capacity will improve.
This can further be improved by analysing the types of tugboats used per vessel class with regard to bollard pull.

The total capacity of the boatmen in the Port of Rotterdam is 280, but the size of teams deployed differs per assignment. By investigating the team size and equipment used per vessel class modelling the capacity of the boatmen will be improved.

It is recommended to obtain service times for more terminals than are provided at this moment. These times could, for instance, be obtained by analysing AIS-data. Next to this it is advised to investigate the capacity of the terminals.

SwarmPort

The SwarmPort project it advised to commit the pilot-organisation, tugboat companies and boatmen-organisation to the project. This would increase the available information as well as increase support for eventual use of the model.

In starting the actual modelling it is advised to start by modelling the environment, the behaviour of vessels and the pilot-organisation. Secondly, the modelling of the Harbour Master, tugboats and the terminal. Modelling the boatmen is of lesser importance since observations have shown that they almost never are the root-cause for delays or inefficiencies.

Nautical chain

More cooperation within in the nautical chain is recommended because this will most likely improve the efficiency. Cooperation between the pilots, tugs and boatmen is already on a sufficient level, extending the involvement of the Harbour Master to this cooperation would be beneficial.

An increase of information towards the pilot before boarding could increase the situational awareness or enhance the adaptive planning. This may lead to less delays due to, for example, ordering of extra tugs. It is recommended to further investigate this.

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Part V

Appendix

A | Port

In this Appendix the more extensive tables discussed in chapter 11 are found.

A.1 Vessel classes

Table A.1 shows the vessel classes as used in this research. These classes have also been used in a research performed by TBA and the Port of Rotterdam and are in accordance with the vessel classes of the admittance policy of the Harbour Master.

Table A.1: Vessel classes (TBA, 2017)

Class	L [m]	T[m]
1	$<$120	
2	120-200	
3a	200-300	$<$14.3
3b	200-300	$>$14.3
4	$>$300	$<$14.3
5	$>$300	14.3-17.4
6	$>$300	$>$17.4

A.2 Sections

Table A.2 shows the length of the sections in the port, their sequence and whether they are destined for sailing or manoeuvring. In figure A.1 the sections are shown on a map of the Port of Rotterdam.

Table A.2: Section lengths (TBA, 2017)

Section	Sailing (S) /Maneuver(M)	Length [nm]	Follows after Section
1	S	5,9	0
2	S	2,9	1
3	S	3	2
4	S	1,8	3
5	S	2,4	4
6	S	0,9	4
7	M	0,2	6
8	S	5,4	7
10	S	0,65	4
11	M	0,5	10
17	M	0,2	11
18	S	0,3	42
19	M	0,2	42
22	S	0,3	46
27	S	0,8	49
32	S	0,65	49
35	S	0,6	55
42	S	1,1	59
45	M	0,01	11
46	S	1,35	17
49	M	0,3	32
50	S	0,6	17
55	S	0,3	18
59	M	0,3	19
60	S	0,4	19
70	S	6,8	5
71	S	1,9	70
78	M	0,3	71
79	S	0,4	78
80	M	0,2	79
81	S	0,4	80
82	S	0,5	80
83	S	0,5	78
84	M	0,2	83
85	S	0,4	84
86	M	0,3	84
87	M	0,3	86
88	S	0,6	87
89	S	0,7	87
90	S	0,4	98
91	S	1,2	78
92	S	3,3	91
104	S	2,5	78
105	S	2	104

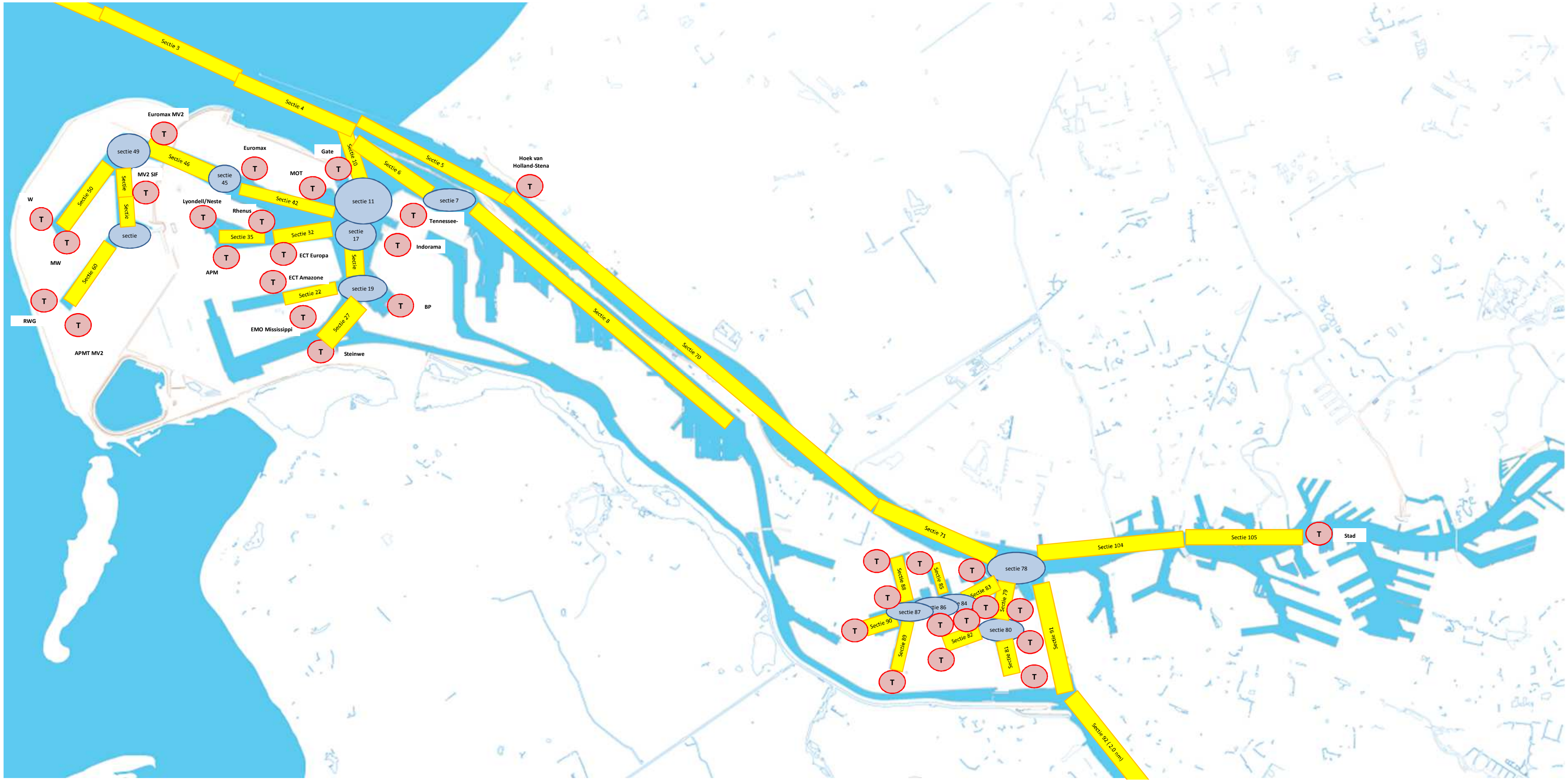

Figure A.1: Network overview (TBA, 2017)

A.3 Section rules

Tables A.3 to A.8 show per section whether it is allowed for certain classes of vessels to overtake. The row shows the overtaking vessel, the column the vessel to be overtaken. A "1" shows that it is allowed, "0"means that it is not allowed, "-1" means the class occur in that section.
For example, in section 22 a class 4 vessel is allowed to overtake a class 1 vessel but none of the other classes.

Table A.3: Section 1-8 overtaking rules (TBA, 2017)

Section 1	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	1	0
Class 6	1	1	1	1	1	0	0

Section 2	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	0	0
Class 6	1	1	1	1	1	0	0

Section 3	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	0	0
Class 5	1	1	1	1	0	0	0
Class 6	1	1	1	1	0	0	0

Section 4	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	0	0	0	0	0
Class 3b	1	1	0	0	0	0	0
Class 4	1	1	0	0	0	0	0
Class 5	1	1	0	0	0	0	0
Class 6	1	1	0	0	0	0	0

Section 5	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	0	0
Class 5	1	1	1	1	0	0	0
Class 6	1	1	1	1	0	0	0

Section 6	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	0	0
Class 3b	1	1	1	1	1	0	0
Class 4	1	1	1	0	0	0	0
Class 5	1	1	1	0	0	0	0
Class 6	1	1	1	0	0	0	0

Section 7	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	0	0	0	0	0
Class 3b	1	1	0	0	0	0	0
Class 4	1	1	0	0	0	0	0
Class 5	1	1	0	0	0	0	0
Class 6	1	1	0	0	0	0	0

Section 8	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	0	0	0	0	0	0
Class 3a	1	0	0	0	0	0	0
Class 3b	1	0	0	0	0	0	0
Class 4	1	0	0	0	0	0	0
Class 5	1	0	0	0	0	0	0
Class 6	1	0	0	0	0	0	0

Table A.4: Section 10-32 overtaking rules (TBA, 2017)

Section 10	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	0	0
Class 3b	1	1	1	1	1	0	0
Class 4	1	1	1	1	1	0	0
Class 5	1	1	0	0	0	0	0
Class 6	1	1	0	0	0	0	0

Section 11	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	0	0
Class 5	1	1	1	1	0	0	0
Class 6	1	1	1	1	0	0	0

Section 17	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	0
Class 2	1	1	1	1	1	1	0
Class 3a	1	1	0	0	0	0	0
Class 3b	1	1	0	0	0	0	0
Class 4	1	1	0	0	0	0	0
Class 5	1	1	0	0	0	0	0
Class 6	0	0	0	0	0	0	0

Section 18	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	0	0
Class 2	1	1	0	0	0	0	0
Class 3a	1	0	0	0	0	0	0
Class 3b	1	0	0	0	0	0	0
Class 4	1	0	0	0	0	0	0
Class 5	0	0	0	0	0	0	0
Class 6	0	0	0	0	0	0	0

Section 19	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	0	0
Class 2	1	1	0	0	0	0	0
Class 3a	1	0	0	0	0	0	0
Class 3b	1	0	0	0	0	0	0
Class 4	1	0	0	0	0	0	0
Class 5	0	0	0	0	0	0	0
Class 6	0	0	0	0	0	0	0

Section 22	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	0	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	1	0	0	0	0	0	-1
Class 3b	1	0	0	0	0	0	-1
Class 4	1	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 27	1	2	3a	3b	4	5	6
Class 1	0	0	0	0	0	0	0
Class 2	0	0	0	0	0	0	0
Class 3a	0	0	0	0	0	0	0
Class 3b	0	0	0	0	0	0	0
Class 4	0	0	0	0	0	0	0
Class 5	0	0	0	0	0	0	0
Class 6	0	0	0	0	0	0	0

Section 32	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	0	0	0	0	-1
Class 3a	1	0	0	0	0	0	-1
Class 3b	1	0	0	0	0	0	-1
Class 4	1	0	0	0	0	0	-1
Class 5	1	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.5: Section 35-59 overtaking rules (TBA, 2017)

Section 35	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	0	0	0	0	-1
Class 3a	1	0	0	0	0	0	-1
Class 3b	1	0	0	0	0	0	-1
Class 4	1	0	0	0	0	0	-1
Class 5	1	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 42	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	1	0	0	0	0	0	-1
Class 3b	1	0	0	0	0	0	-1
Class 4	1	0	0	0	0	0	-1
Class 5	1	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 45	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	0	-1
Class 2	1	1	0	0	0	0	-1
Class 3a	0	0	0	0	0	0	-1
Class 3b	0	0	0	0	0	0	-1
Class 4	0	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 46	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	1	0	0	0	0	0	-1
Class 3b	1	0	0	0	0	0	-1
Class 4	1	0	0	0	0	0	-1
Class 5	1	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 49	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	0	-1
Class 2	1	1	0	0	0	0	-1
Class 3a	0	0	0	0	0	0	-1
Class 3b	0	0	0	0	0	0	-1
Class 4	0	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 50	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	0	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	0	0	0	0	0	0	-1
Class 3b	0	0	0	0	0	0	-1
Class 4	0	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 55	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	0	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	0	0	0	0	0	0	-1
Class 3b	0	0	0	0	0	0	-1
Class 4	0	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 59	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	0	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	0	0	0	0	0	0	-1
Class 3b	0	0	0	0	0	0	-1
Class 4	0	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.6: Section 60-82 overtaking rules (TBA, 2017)

Section 60	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	0	-1
Class 2	1	0	0	0	0	0	-1
Class 3a	0	0	0	0	0	0	-1
Class 3b	0	0	0	0	0	0	-1
Class 4	0	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 70	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	0	0	0	0	-1	-1
Class 3b	1	0	0	0	0	-1	-1
Class 4	1	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 71	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 78	1	2	3a	3b	4	5	6
Class 1	0	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 79	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 80	1	2	3a	3b	4	5	6
Class 1	0	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 81	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 82	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	-1	-1	-1
Class 2	0	0	0	0	-1	-1	-1
Class 3a	0	0	0	0	-1	-1	-1
Class 3b	0	0	0	0	-1	-1	-1
Class 4	-1	-1	-1	-1	-1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.7: Section 83-90 overtaking rules (TBA, 2017)

Section 83	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	-1	-1
Class 2	1	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 84	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	-1	-1
Class 2	1	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 85	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 86	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	-1	-1
Class 2	1	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 87	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 88	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 89	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 90	1	2	3a	3b	4	5	6
Class 1	0	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.8: Section 91-105 overtaking rules (TBA, 2017)

Section 91	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	-1	-1	-1
Class 2	0	0	0	0	-1	-1	-1
Class 3a	0	0	0	0	-1	-1	-1
Class 3b	0	0	0	0	-1	-1	-1
Class 4	-1	-1	-1	-1	-1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 92	1	2	3a	3b	4	5	6
Class 1	1	-1	-1	-1	-1	-1	-1
Class 2	-1	-1	-1	-1	-1	-1	-1
Class 3a	-1	-1	-1	-1	-1	-1	-1
Class 3b	-1	-1	-1	-1	-1	-1	-1
Class 4	-1	-1	-1	-1	-1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 104	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 105	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Tables A.9 to A.14 addresses vessels meeting each other. A "1" shows that it is allowed, "0"means that it is not allowed, "-1" means the class occur in that section.
For example, in section 27 a class 5 vessel is allowed to encounter a class 1 vessel but she is to avoid encountering one of the other classes in section 27.

Table A.9: Section 1-8 encounter rules (TBA, 2017)

Section 1	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	1	1
Class 6	1	1	1	1	1	1	0

Section 2	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	1	1
Class 6	1	1	1	1	1	1	0

Section 3	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	1	1
Class 6	1	1	1	1	1	1	0

Section 4	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	0
Class 3b	1	1	1	1	1	1	0
Class 4	1	1	1	1	1	1	0
Class 5	1	1	1	1	1	0	0
Class 6	1	1	0	0	0	0	0

Section 5	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 6	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	0	0	0
Class 5	1	1	1	1	0	0	0
Class 6	1	1	1	1	0	0	0

Section 7	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	0	0	0
Class 5	1	1	1	1	0	0	0
Class 6	1	1	1	1	0	0	0

Section 8	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	1	1
Class 6	1	1	1	1	1	1	0

Table A.10: Section 10-32 encounter rules (TBA, 2017)

Section 10	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	0	0
Class 5	1	1	1	1	0	0	0
Class 6	1	1	1	1	0	0	0

Section 11	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	1	1	1	1	1
Class 3a	1	1	1	1	1	1	1
Class 3b	1	1	1	1	1	1	1
Class 4	1	1	1	1	1	1	1
Class 5	1	1	1	1	1	1	0
Class 6	1	1	1	1	1	0	0

Section 17	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	0
Class 2	1	1	1	1	1	1	0
Class 3a	1	1	1	1	1	1	0
Class 3b	1	1	1	1	1	1	0
Class 4	1	1	1	1	1	1	0
Class 5	1	1	1	1	1	0	0
Class 6	0	0	0	0	0	0	0

Section 18	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	0	0
Class 2	1	1	0	0	0	0	0
Class 3a	1	0	0	0	0	0	0
Class 3b	1	0	0	0	0	0	0
Class 4	1	0	0	0	0	0	0
Class 5	0	0	0	0	0	0	0
Class 6	0	0	0	0	0	0	0

Section 19	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	0	0
Class 2	1	1	0	0	0	0	0
Class 3a	1	0	0	0	0	0	0
Class 3b	1	0	0	0	0	0	0
Class 4	1	0	0	0	0	0	0
Class 5	0	0	0	0	0	0	0
Class 6	0	0	0	0	0	0	0

Section 22	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	0	-1
Class 2	1	1	0	0	0	0	-1
Class 3a	1	0	0	0	0	0	-1
Class 3b	1	0	0	0	0	0	-1
Class 4	1	0	0	0	0	0	-1
Class 5	0	0	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 27	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	1
Class 2	1	1	0	0	0	0	0
Class 3a	1	0	0	0	0	0	0
Class 3b	1	0	0	0	0	0	0
Class 4	1	0	0	0	0	0	0
Class 5	1	0	0	0	0	0	0
Class 6	1	0	0	0	0	0	0

Section 32	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	1	-1
Class 3b	1	1	1	1	1	1	-1
Class 4	1	1	1	1	0	0	-1
Class 5	1	1	1	1	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.11: Section 35-59 encounter rules (TBA, 2017)

Section 35	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	0	0	-1
Class 3b	1	1	1	1	0	0	-1
Class 4	1	1	0	0	0	0	-1
Class 5	1	1	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 42	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	1	-1
Class 3b	1	1	1	1	1	1	-1
Class 4	1	1	1	1	1	1	-1
Class 5	1	1	1	1	1	1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 45	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	1	-1
Class 3b	1	1	1	1	1	1	-1
Class 4	1	1	1	1	1	1	-1
Class 5	1	1	1	1	1	1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 46	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	1	-1
Class 3b	1	1	1	1	1	1	-1
Class 4	1	1	1	1	1	1	-1
Class 5	1	1	1	1	1	1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 49	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	1	-1
Class 3b	1	1	1	1	1	1	-1
Class 4	1	1	1	1	1	1	-1
Class 5	1	1	1	1	1	1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 50	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	0	-1
Class 3b	1	1	1	1	1	0	-1
Class 4	1	1	1	1	1	0	-1
Class 5	1	1	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 55	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	0	-1
Class 3b	1	1	1	1	1	0	-1
Class 4	1	1	1	1	1	0	-1
Class 5	1	1	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 59	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	1	-1
Class 3b	1	1	1	1	1	1	-1
Class 4	1	1	1	1	1	1	-1
Class 5	1	1	1	1	1	1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.12: Section 60-82 encounter rules (TBA, 2017)

Section 60	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	1	-1
Class 2	1	1	1	1	1	1	-1
Class 3a	1	1	1	1	1	0	-1
Class 3b	1	1	1	1	1	0	-1
Class 4	1	1	1	1	1	0	-1
Class 5	1	1	0	0	0	0	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 70	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 71	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 78	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 79	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	0	0	0	-1	-1
Class 3a	1	0	0	0	0	-1	-1
Class 3b	1	0	0	0	0	-1	-1
Class 4	1	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 80	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 81	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 82	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	-1	-1	-1
Class 2	1	1	0	0	-1	-1	-1
Class 3a	0	0	0	0	-1	-1	-1
Class 3b	0	0	0	0	-1	-1	-1
Class 4	-1	-1	-1	-1	-1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.13: Section 83-90 encounter rules (TBA, 2017)

Section 83	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	-1	-1
Class 2	1	1	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 84	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	-1	-1
Class 2	1	1	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 85	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 86	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	0	-1	-1
Class 2	1	1	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 87	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 88	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 89	1	2	3a	3b	4	5	6
Class 1	1	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 90	1	2	3a	3b	4	5	6
Class 1	0	0	0	0	0	-1	-1
Class 2	0	0	0	0	0	-1	-1
Class 3a	0	0	0	0	0	-1	-1
Class 3b	0	0	0	0	0	-1	-1
Class 4	0	0	0	0	0	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Table A.14: Section 91-105 encounter rules (TBA, 2017)

Section 91	1	2	3a	3b	4	5	6
Class 1	1	1	0	0	-1	-1	-1
Class 2	1	0	0	0	-1	-1	-1
Class 3a	0	0	0	0	-1	-1	-1
Class 3b	0	0	0	0	-1	-1	-1
Class 4	-1	-1	-1	-1	-1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 104	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 92	1	2	3a	3b	4	5	6
Class 1	1	-1	-1	-1	-1	-1	-1
Class 2	-1	-1	-1	-1	-1	-1	-1
Class 3a	-1	-1	-1	-1	-1	-1	-1
Class 3b	-1	-1	-1	-1	-1	-1	-1
Class 4	-1	-1	-1	-1	-1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

Section 105	1	2	3a	3b	4	5	6
Class 1	1	1	1	1	1	-1	-1
Class 2	1	1	1	1	1	-1	-1
Class 3a	1	1	1	1	1	-1	-1
Class 3b	1	1	1	1	1	-1	-1
Class 4	1	1	1	1	1	-1	-1
Class 5	-1	-1	-1	-1	-1	-1	-1
Class 6	-1	-1	-1	-1	-1	-1	-1

A.4 Separation times

Each section has certain separation times for each vessel-class. These times apply if a vessel is not able or not allowed to overtake another vessel. The times given in table A.15 reflect the amount of minutes that have to be between the vessel class and the vessel in front and behind it.
For example, in section 59, if a class 3a vessel cannot be overtaken, the vessels in front and behind her need to keep a distance of 4.1 minutes.

Table A.15: Section separation times [min] (TBA, 2017)

Section	Class 1	2	3a	3b	4	5	6
1	0,1	0,1	0,1	0,1	0,1	0,1	45
2	0,1	0,1	0,1	0,1	0,1	0,1	45
3	0,1	0,1	0,1	0,1	0,1	3,7	45
4	0,1	0,1	2,8	2,8	3,5	3,7	45
5	0,1	1,7	2,8	2,8	3,5		
6	1,1	1,8	3,5	3,5	4,6	4,9	45
7	1,1	1,8	3,5	3,5	4,6	4,9	45
8	1,2	1,9	3,5	3,5	5,1	5,4	45
10	1,2	1,9	3,5	3,5	4,6	4,9	45
11	1,3	2,1	4,1	4,1	5,1	5,4	45
17	1,3	2,3	4,1	4,1	5,1	5,4	45
18	1,3	2,3	4,1	4,1	5,1	5,4	45
19	1,3	2,3	4,1	4,1	5,1	5,4	45
22	2,4	3,8	6,2	6,2	7,6	8	45
27	1,6	2,6	4,1	4,1		5,4	45
32	1,4	2,3	3,7	3,7	5,9	6,3	
35	1,4	2,3	4,8	4,8	5,9	6,3	
42	1,3	2	3,5	3,5	4,3	4,5	
45	1,6	2,6	4,8	4,8	5,9	6,3	
46	1,4	2,3	3,7	3,7	4,6	4,9	
49	1,6	2,6	4,8	4,8	5,9	6,3	
50	1,6	2,6	4,8	4,8	5,9	6,3	
55	1,6	2,6	4,1	4,1	5,9	6,3	
59	1,6	2,6	4,1	4,1	5,9	6,3	
60	1,6	2,6	4,8	4,8	5,9	6,3	
70	1,5	2,5	2,5	2,5	5		
71	1,5	2,5	2,5	2,5	5		
78	5	7	15	20	20		
79	5	7	15	20	20		
80	5	7	15	20	20		
81	5	7	15	20	20		
82	5	7	15	20	20		
83	5	7	15	20	20		
84	5	7	15	20	20		
85	5	7	15	20	20		
86	5	7	15	20	20		
87	5	7	15	20	20		
88	5	7	15	20	20		
89	5	7	15	20	20		
90	5	7	15	20	20		
91	1,5	2,5	2,5	2,5			
92	1,5	5					
100	1,5	2,5					
104	1,5	2,5	2,5	2,5	5		
105	1,5	2,5	2,5	2,5	5		

A.5 Section speeds

The minimum and maximum speeds for each vessel class in each section are shown in the table below. If no speed is presented, that vessel class does not occur in that section.

Table A.16: Section speeds [kn] (TBA, 2017)

Section	Class 1		2		3a		3b		4		5		6	
	Min.[kn]	Max.[kn]												
1		15		15		15		15		15		15		10
2	8	15	8	15	8	15	8	15	8	15	8	15	5	10
3	8	15	8	15	6	12	5	12	5	12	5	12	5	8
4	6	15	6	15	6	12	5	11	5	11	5	12	4	8
5	6	12	6	12	6	12	5	11	5	11				
6	4	10	4	10	4	6	4	6	3	5	3	5	1	4
7		10		10		6		6		5		5		4
8		8		8		6		6		4		4		3
10	4	8	4	8	4	6	4	6	3	5	3	5	1	4
11	4	6	4	6	2	4	2	4	2	4	2	4	1	3
17	4	6	3	5	2	4	2	4	2	4	2	4	1	3
18	4	6	3	5	2	4	2	4	2	4	2	4	1	3
19	4	6	3	5	2	4	2	4	2	4	2	4	1	3
22	2	3	2	3	2	3	2	3	1	2	1	2		
27	2	4	2	4	4	4	4	4	2	4	2	4	1	2
32	3	5	3	5	3	5	3	5	1	3	1	3		
35	3	5	3	5	3	3	3	3	1	3	1	3		
42	1	7	1	7	4	6	4	6	3	6	3	6		
45	4	4	4	4	4	3	4	3	3	3	3	3		
46	4	5	4	5	3	5	3	5	3	5	3	5		
49	3	4	3	4	2	3	2	3	2	3	2	3		
50	3	4	3	4	2	3	2	3	2	3	2	3		
55	3	4	3	4	3	4	3	4	2	3	2	3		
59	3	4	3	4	3	4	3	4	2	3	2	3		
60	3	4	3	4	2	3	2	3	2	3	2	3		
70	4	12	4	11	4	11	4	11	4	10				
71	4	12	4	10	4	10	4	9	4	8				
78	4	7	3	4	3	4	3	4		3				
79	4	6	3	4	3	4	3	4						
80	4	4	3	3	3	3	3	3	3					
81	4	4	3	3	3	3	3	3	3					
82	4	4	3	3	3	3	3	3	3					
83	4	6	3	4	3	4	3	4	3	3				
84	4	6	3	4	3	4	3	4	3	3				
85	4	6	3	3	3	3	3	3	3	3				
86	4	6	3	4	3	4	3	4		3				
87	4	4	3	3	3	3	3	3		3				
88	4	4		3	3	3	3	3		3				
89	4	4		3		3		3						
90		3		3		3		3						
91		10		3		3		3						
92		12												
100	4		3		3		3							
104		11		8		8		7		6				
105		6		4		4		4		3				

A.6 Swing-table

When a vessel leaves or arrives at a terminal it may have to swing around to have the bow facing the right way. The time it takes to perform these manoeuvres for the various classes in various sections is shown in table A.17. It is also indicated whether this manoeuvre has to be performed at arrival (A) or when departing (D).
The column 'Small block.' shows the smallest class of vessel that will be hindered by this manoeuvre.

Table A.17: Swing-table(TBA, 2017)

		Class 1			2			3a			3b			4			5			6		
Terminal	Section	Arr/ Dep	Dur. [min]	Small block.	Arr/ Dep	Dur. [min]	Small block.	Arr/ Dep	Dur. [min]	Small block.	Arr/ Dep	Dur. [min]	Small block.	Arr/ Dep	Dur. [min]	Small block.	Arr/ Dep	Dur. [min]	Small block.	Arr/ Dep	Dur. [min]	Small block.
MV1 - MOT	11																			A	30	1
MV1 - APMT Rotterdam	17																D	25				
MV1 - ECT Delta Europahaven	17																D	25				
MV1 - ECT Delta Amazonehaven	19							D	30	1	D	30	1	D	30	1	D	30				
MV1 - Euromax	49							D	15		D	15		D	20		D	25				
MV1 - Euromax	45							D	15	1	D	15	1	D	20	1	D	25				
MV2 - Eurmax	49							D	15		D	15		D	20		D	25				
MV2 - T3 West	49							D	15		D	15		D	15		D	20				
MV2 - T3 Oost	59							D	15		D	15		D	15		D	20				
MV2 - RWG (T2)	59							D	15		D	15		D	15		D	20				
MV2 - APMT (T1)	59							D	15		D	15		D	15		D	20				
MV1 - EMO Mississipihaven	27													D	30		D	30		D	30	
MV1 - Gate	11																					
Shtandart Noord Berth	7							A	12	3a	A	12	3a	A	12	3a	A	12	3a	D	12	3a
Tennesseehaven	11				A	10	3a	A	10	3a	A	10	3a									
1e werkhaven	78	A	4	1	A	4	1	A	5	1	A	8	1	A	6	1						
3e PET noord	80	A	4	1	A	4	1	A	5	1	A	8	1	A	nvt							
Botlek centrale geul 2e WH	84	A	4	1	A	4	1	A	5	1	A	8	1	A	10	1						
Botlek centrale geul TH	86	A	4	1	A	4	1	A	5	1	A	8	1	A	nvt							
Botlek centrale geul west	87	A	4	1	A	4	1	A	5	1	A	8	1	A	8	1						

A.7 Voyage distribution

The table below shows all the arriving voyages in the period June-July 2017.

Table A.18: Arriving voyages per class per section (June - July 2017)

Destination	Class 1	2	3a	3b	4	5	6	**Total**
Section 5			181	2				183
8	195	605	195	41	6	1	11	1054
11	4	1	21	13	1		8	48
17		1						1
19	7	29	6	5				47
22	15	111	44	21	48	5		244
27	15	2	1	1				19
32	18	37	86		21			162
35	14	55	33		21	1		124
42	9	74			25	5		113
45	1							1
46	2							2
50		3	6	5				14
55	5	5						10
60	4	66	44	1	31	9		155
71	1	3	2					6
78	6	7	2					15
79	43	30						73
80	22	12						34
81	29	25	1					55
82	17	25						42
83	1							1
84	3	1						4
85	23	18	4					45
86	22	14						36
87	8	4						12
88	50	27	3					80
89	54	22						76
90	14	9	1					24
92	9	5						14
104	169	292	9					470
105	990	579	46		1			1616
Total	1750	2062	685	89	154	21	19	4780

The table below shows all the departing voyages in the period June-July 2017.

Table A.19: Departing voyages per class per section (June - July 2017)

Departing from	Class 1	2	3a	3b	4	5	6	**Total**
Section 5			181	2				183
8	208	599	190	43	6		12	1058
11	4	1	21	10	1	1	6	44
17	1							1
19	6	28	10	6				50
22	14	111	42	21	45	5		238
27	19	2	1	1				23
32	30	35	83		20			168
35	22	35	35	1	25	1		119
42	6	73			25	5		109
45	1							1
46	2							2
50		1	5	4			1	11
55	8	5						13
60	5	75	49		31	9		169
71	2	3	2					7
78	4	8	4					16
79	42	25						67
80	15	12						27
81	26	32	1	1				60
82	18	29						47
83	1							1
84	7	1						8
85	21	21	4					46
86	22	12						34
87	9	6						15
88	56	29	3					88
89	52	16						68
90	12	8	1					21
92	8	4						12
104	183	276	6					465
105	943	602	46		1			1592
Total	1747	2049	684	89	154	21	19	4763

The table below shows all the shifting voyages in the period June-July 2017. In following tables these have been further split up.

Table A.20: Shifting voyages per class per section (June - July 2017)

Shifting from	Class 1	2	3a	3b	4	5	6	**Total**
Section 8	78	181	40	9	7	1	2	318
11			2	4			3	9
17	5	129						134
19	1	4		2	1			8
22	26	298	5		3			332
27	14	47						61
32	26	185	5		1			217
35	8	112	5					125
42	19	264						283
50		3	7	3				13
55	2	2						4
60	17	236	4	1	1			259
71	2							2
78	11	12						23
79	5	25						30
80	10	19						29
81	18	15						33
82	6	19						25
84	2							2
85	23	15						38
86	7	20						27
87	7	6						13
88	19	5						24
89	12	28						40
90	6	2						8
92	3	2						5
104	96	53	3					152
105	514	513	8					1035
NiN		4						4
Total	937	2199	79	19	13	1	5	3253

A.8 Voyage duration

The following tables show the average duration of a class paired with a destination. This has been split up in to two phases. The duration of the voyage in the port and the duration of operational contact until the start of the voyage. The voyage in the port is measured from the port entry until the ATA for arriving voyages and from the ATD until port exit for departing voyages. The other phase is measured from operational contact until port entry for arriving vessels and from operational contact to the ATD for departing vessels.
For example, from the moment a class 2 vessel with destination section 19 passes buoy CA4 or NW3 it takes on average 48 minutes until she is moored. That same vessel has to wait on average more than 12 hours before passing those buoys after making operational contact.

Only vessels that arrive at the port from sea have been taken into account. Vessels arriving from the hinterland have been left out, this would cause an extra level of complexity without haven any benefits. Also in the case of the arriving vessels the voyages with a duration shorter than one hour have been left out. This is to short and is caused by errors in the data.
Some large durations are shown in the tables, this is caused by the fact that a vessel made operational contact but did not yet receive operational clearance. So the vessel had to wait before being allowed to sail towards its destination.

Table A.21: Port entry until ATA - Average duration per section per class (June-July 2017)

Arrival	Class 1			2			3a			3b			4			5			6			Total		
To	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
Section 5							0:26	0:09	181	0:21	0:00	2										0:25	0:09	183
8	1:02	0:32	195	1:12	0:26	605	1:21	0:35	195	1:28	0:26	41	2:03	0:33	6	2:28	0:00	1	1:57	0:28	11	1:13	0:30	1054
11	1:15	0:49	4	1:00	0:00	1	1:02	0:15	21	1:04	0:10	13	1:19	0:00	1				1:50	0:49	8	1:12	0:32	48
17				1:44	0:00	1																1:44	0:00	1
19	0:48	0:08	7	0:48	0:12	29	1:12	0:18	6	0:59	0:08	5										0:52	0:14	47
22	0:44	0:07	15	0:48	0:19	111	1:08	0:17	44	1:19	0:19	21	1:09	0:17	48	1:05	0:08	5				0:58	0:21	244
27	0:44	0:10	15	1:01	0:08	2			1	1:24	0:00	1										0:49	0:14	19
32	0:43	0:18	18	0:44	0:17	37	0:49	0:18	86				0:51	0:16	21							0:47	0:18	162
35	1:05	1:10	14	0:54	0:22	55	1:05	0:15	33				1:24	0:37	21			1				1:03	0:36	124
42	0:39	0:29	9	0:52	0:33	74							1:11	0:12	25	2:06	0:58	5				0:58	0:35	113
45			1																					1
46	0:58	0:18	2																			0:58	0:18	2
50				1:18	0:05	3	1:45	0:18	6	2:04	0:36	5										1:46	0:30	14
55	2:03	0:04	5	1:03	0:03	5																1:27	0:29	10
60	0:58	0:08	4	1:14	0:35	66	1:34	0:16	44	1:36	0:00	1	2:08	0:44	31	1:48	0:14	9				1:29	0:37	155
71	1:07	0:00	1	1:52	0:16	3	2:05	0:17	2													1:49	0:24	6
78	1:43	0:22	6	2:08	0:32	7	3:03	0:45	2													2:06	0:40	15
79	1:43	0:20	43	1:53	0:20	30																1:47	0:20	73
80	1:31	0:22	22	1:51	0:21	12																1:37	0:24	34
81	1:45	0:19	29	1:56	0:30	25	2:53	0:00	1													1:52	0:26	55
82	1:41	0:22	17	1:53	0:19	23																1:48	0:21	40
83	2:24	0:00	1																			2:24	0:00	1
84	1:30	0:14	3	2:21	0:00	1																1:43	0:25	4
85	1:34	0:20	23	2:06	0:34	18	2:30	0:18	4													1:52	0:33	45
86	1:43	0:20	22	1:53	0:18	14																1:47	0:20	36
87	1:42	0:13	8	2:27	0:06	4																1:55	0:23	12
88	1:56	0:25	50	2:08	0:27	27	2:21	0:01	3													2:01	0:26	80
89	1:49	0:24	54	2:12	0:30	22																1:56	0:27	76
90	1:57	0:23	14	2:14	0:16	9	2:04	0:00	1													2:03	0:22	24
92	1:48	0:11	9	2:21	0:40	5																2:00	0:30	14
104	1:59	0:38	169	1:44	0:22	292	1:55	0:18	9													1:49	0:29	470
105	2:17	1:27	990	2:01	0:33	579	2:32	0:26	46				2:18	0:00	1							2:11	1:11	1616
Total	1:56	1:14	1750	1:32	0:38	2060	1:06	0:43	685	1:21	0:27	89	1:20	0:36	154	1:42	0:38	21	1:54	0:39	19	1:37	0:57	4778

Table A.22: ATD until port exit - Average duration per section per class (June-July 2017)

Departure	Class 1			2			3a			3b			4			5			6			Total		
From	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
Section 5							1:15	0:30	181	1:07	0:00	2										1:15	0:30	183
8	2:18	1:15	208	2:07	0:37	599	2:18	1:03	190	3:02	3:04	43	3:30	0:48	6				2:49	0:29	12	2:14	1:05	1058
11	1:40	0:12	4	1:58	0:00	1	2:21	0:17	21	2:19	0:19	10	2:23	0:00	1	2:03	0:00	1	2:36	0:08	6	2:20	0:19	44
17	1:47	0:00	1																			1:47	0:00	1
19	1:45	0:14	6	2:00	0:15	28	2:15	0:18	10	2:29	0:19	6										2:05	0:20	50
22	2:06	1:16	14	1:37	0:18	111	2:09	0:28	42	2:51	0:25	21	2:19	0:15	45	2:23	0:23	5				2:00	0:37	238
27	3:21	5:00	19	1:47	0:01	2	2:36	0:00	1	2:22	0:00	1										3:08	4:34	23
32	3:21	2:50	30	1:35	0:23	35	1:54	0:18	83				2:04	0:25	20							2:08	1:27	168
35	2:03	0:31	22	1:59	0:20	35	2:00	0:42	35	2:03	0:00	1	3:09	3:50	25			1				2:16	1:56	119
42	1:31	0:18	6	2:01	1:58	73							2:28	0:25	25	2:33	0:07	5				2:05	1:41	109
45			1																					1
46	1:45	0:06	2																			1:45	0:06	2
50				2:48	0:00	1	2:25	0:09	5	2:29	0:17	4							3:10	0:00	1	2:32	0:18	11
55	5:41	2:50	8	8:28	9:40	5																6:45	6:32	13
60	5:14	5:19	5	2:03	0:28	75	2:32	0:19	49				3:03	0:23	31	2:41	0:27	9				2:27	1:17	169
71	2:22	0:14	2	2:16	0:09	3	2:27	0:12	2													2:21	0:12	7
78	2:59	0:35	4	2:32	0:16	8	3:54	0:36	4													2:55	0:41	16
79	2:41	0:18	42	2:50	0:21	25																2:44	0:20	67
80	2:22	0:15	15	3:17	1:00	12																2:45	0:49	27
81	2:32	0:19	26	2:52	0:57	32	2:36	0:00	1	3:26	0:00	1										2:44	0:45	60
82	2:44	0:24	18	2:51	0:23	29																2:48	0:23	47
83	2:34	0:00	1																			2:34	0:00	1
84	2:43	0:25	7	3:10	0:00	1																2:46	0:25	8
85	3:16	1:47	21	3:39	2:42	21	3:24	0:15	4													3:27	2:11	46
86	2:39	0:21	22	2:54	0:19	12																2:45	0:22	34
87	2:42	0:19	9	3:15	0:17	6																2:55	0:24	15
88	2:59	1:13	56	3:04	0:37	29	3:06	0:16	3													3:01	1:03	88
89	2:41	0:17	52	3:01	0:22	16																2:46	0:20	68
90	2:43	0:22	12	3:05	0:20	8	3:58	0:00	1													2:55	0:27	21
92	2:52	0:16	8	3:10	0:16	4																2:58	0:18	12
104	3:26	2:51	183	2:34	1:26	276	2:32	0:45	6													2:54	2:08	465
105	3:58	2:49	943	2:59	1:29	602	3:28	0:35	46				3:58	0:00	1							3:35	2:24	1592
Total	3:25	2:32	1747	2:29	1:21	2049	2:02	0:55	684	2:47	2:11	89	2:39	1:46	154	2:32	0:25	21	2:46	0:24	19	2:47	1:56	4763

These tables show the shifting duration. This is shown as the average duration from section to section for each vessel class.
Here the section NiN refers to 'Not in Network', this means that the section is not part of the network shown in figure A.1 (e.g. Dordrecht).

So for example, there were 3 class 1 voyages from section 8 to 32 and those voyages had an average duration of one hour and ten minutes.

Table A.23: Shifting average duration, deviation and amount - section 8-27

		Class 1			2			3a			3b			4			5			6			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
8	8	0:51	0:37	43	0:49	1:50	115	1:16	0:21	24	1:52	0:23	5	1:51	1:14	5				3:06		1	0:56	1:29	193
	11							1:56	0:09	2	2:37		1				3:21		1	2:23		1	2:27	0:35	5
	19				1:23	0:11	3	2:24	0:21	3	2:13		1	3:08		1							2:05	0:40	8
	22				1:55	0:18	4	0:56		1													1:40	0:33	5
	32	1:10	0:08	3				1:16		1													1:11	0:07	4
	35	1:04	0:16	5	1:42	0:17	7							2:04		1							1:29	0:26	13
	50							2:56	0:24	6	2:57	0:24	2										2:56	0:22	8
	60	1:14		1	1:54		1																1:34	0:28	2
	79				3:18	0:14	2																3:18	0:14	2
	80				3:36		1																3:36		1
	81				2:52	0:26	14																2:52	0:26	14
	82				2:59	0:13	3																2:59	0:13	3
	85	2:11	0:17	3																			2:11	0:17	3
	86	2:14	0:08	2	2:55	0:14	2																2:34	0:25	4
	88				3:45	0:41	2																3:45	0:41	2
	89				2:47	0:43	4																2:47	0:43	4
	104	2:29		1	3:11	0:33	4	5:08		1													3:24	0:59	6
	105	2:41	0:45	20	3:11	0:38	19	4:27	0:02	2													3:01	0:47	41
11	8							2:54	0:08	2	2:19	0:34	4							2:55	0:18	2	2:37	0:30	8
	50																			1:45		1	1:45		1
17	22	0:55	0:38	3	0:46	0:23	64																0:47	0:23	67
	32				0:12	0:13	2																0:12	0:13	2
	35				0:57	0:20	3																0:57	0:20	3
	42	0:35		1	1:00	0:53	40																0:59	0:53	41
	60	0:47		1	1:21	0:27	17																1:19	0:27	18
	105				2:42	0:23	3																2:42	0:23	3
19	8	1:25		1	1:25	0:25	3				2:20		1	3:09		1							1:51	0:46	6
	19										0:00		1										0:00		1
	81				2:47		1																2:47		1
22	8	0:58		1	1:44	0:43	2	1:54	0:13	2				2:34		1							1:48	0:36	6
	17	0:26	0:08	2	0:49	0:21	39																0:48	0:21	41
	22	0:01		1	0:29	0:27	8																0:25	0:27	9
	27				0:50	0:14	14																0:50	0:14	14
	32	1:09	0:39	4	0:59	0:20	47	1:41		1													1:00	0:22	52
	35				1:00	0:16	12			1				1:45	0:23	2							1:07	0:23	15
	42	0:44	0:05	5	1:10	0:46	62																1:08	0:45	67
	60	1:05	0:19	5	1:27	0:22	48																1:25	0:23	53
	105	2:45	1:38	8	2:32	0:31	64	10:00		1													2:40	1:08	73
	NiN				1:02	0:08	2																1:02	0:08	2
27	22				0:58	0:19	13																0:58	0:19	13
	27	1:42	4:23	8																			1:42	4:23	8
	32	0:13	0:26	4	0:55		1																0:21	0:29	5
	35				1:04	0:36	4																1:04	0:36	4
	42				0:54	0:17	14																0:54	0:17	14
	60				1:19	0:29	14																1:19	0:29	14
	105	2:58	0:31	2	2:28		1																2:48	0:28	3

Table A.24: Shifting average duration, deviation and amount - section 32-55

		Class 1			2			3a			3b			4			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
32	8				2:19	0:50	3										2:19	0:50	3
	17	0:22		1	0:45	0:25	3										0:39	0:23	4
	22	0:55	0:19	5	0:57	0:20	46	1:10		2							0:57	0:19	53
	27	4:16	8:32	4													4:16	8:32	4
	32	0:23	0:13	7	0:48	0:48	6										0:34	0:35	13
	35				0:52	0:37	7							1:13		1	0:55	0:35	8
	42	0:44	0:26	3	0:52	0:30	52										0:51	0:29	55
	60	1:05	0:19	3	1:23	0:39	45	1:55	0:17	3							1:24	0:38	51
	105	2:30	1:02	3	2:44	0:39	22										2:42	0:41	25
	NiN				1:24		1										1:24		1
35	8	1:43		1	2:26	1:18	2										2:12	1:00	3
	17	0:34		1	0:55	0:16	6										0:52	0:16	7
	22	0:58		1	1:20	0:58	16										1:18	0:57	17
	27				0:47	0:09	5										0:47	0:09	5
	32				0:41	0:13	18										0:41	0:13	18
	35	0:37	0:52	2				0:51		1							0:42	0:38	3
	42				0:58	0:18	8										0:58	0:18	8
	60				1:15	0:26	22	1:49	0:00	3							1:18	0:27	25
	79				3:04		1										3:04		1
	80				2:50	0:52	3										2:50	0:52	3
	82				3:56	1:25	4										3:56	1:25	4
	86				3:53	2:18	2										3:53	2:18	2
	87				3:05	0:37	4										3:05	0:37	4
	90				3:44		1										3:44		1
	104	2:03		1	2:27		1										2:15	0:16	2
	105	2:29	0:16	2	2:47	0:42	19	5:28		1							2:53	0:53	22
42	17				0:58	0:26	32										0:58	0:26	32
	22	0:53	0:17	7	1:10	0:29	51										1:08	0:29	58
	27				1:08	0:21	13										1:08	0:21	13
	32	0:30	0:12	4	0:57	0:20	44										0:55	0:21	48
	35				0:54	0:25	5										0:54	0:25	5
	42				0:21	0:18	3										0:21	0:18	3
	60	0:39	0:13	4	1:10	0:43	50										1:08	0:42	54
	105	2:26	0:03	2	2:43	0:42	64										2:42	0:42	66
	NiN	0:52	0:04	2	1:34	0:19	2										1:13	0:27	4
50	8				1:34		1	2:46	0:14	7	3:22		1				2:42	0:30	9
	19										1:42		1				1:42		1
	78				5:15		1										5:15		1
	81				3:33		1				5:03		1				4:18	1:03	2
55	55				15:21	21:42	2										15:21	21:42	2
	104	2:13		1													2:13		1
	105	2:57		1													2:57		1

Table A.25: Shifting average duration, deviation and amount - section 60-80

		Class 1			2			3a			3b			4			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
60	8				1:55		1										1:55		1
	17	1:11		1	1:13	0:23	27										1:13	0:22	28
	22	1:01	0:22	5	1:25	0:53	33										1:22	0:50	38
	27				1:13	0:14	12										1:13	0:14	12
	32	0:46		1	1:01	0:27	41										1:00	0:27	42
	35	0:44	0:09	2	1:15	0:35	19	1:53	0:01	3	1:40		1				1:18	0:34	25
	42	0:35	0:02	4	1:15	1:04	37										1:10	1:02	41
	60	0:56	0:47	2	0:24	0:20	10	0:16		1				0:00		1	0:26	0:26	14
	104	3:00		1													3:00		1
	105	2:55		1	2:49	0:34	56										2:49	0:34	57
71	32	1:30		1													1:30		1
	105	0:59		1													0:59		1
78	27	1:41		1													1:41		1
	80				1:09	0:06	2										1:09	0:06	2
	81				0:51		1										0:51		1
	86				0:32		1										0:32		1
	87	0:37	0:06	2													0:37	0:06	2
	89				0:40		1										0:40		1
	104	0:58	0:10	2	1:15	0:08	2										1:07	0:12	4
	105	0:45	0:26	6	1:08	0:16	5										0:54	0:24	11
79	8	2:34	1:14	2	2:57	0:42	6										2:51	0:47	8
	35				3:27		1										3:27		1
	78				1:10	0:14	2										1:10	0:14	2
	79				1:17		1										1:17		1
	80				0:33	0:12	2										0:33	0:12	2
	82				0:38	0:18	2										0:38	0:18	2
	86				1:56	0:18	2										1:56	0:18	2
	89	0:37		1	1:21	0:30	2										1:06	0:33	3
	92				2:26		1										2:26		1
	104	1:06		1	1:30	0:08	3										1:24	0:14	4
	105	1:29		1	1:19	0:10	3										1:22	0:10	4
80	8	3:26		1	2:16	0:45	3										2:34	0:51	4
	35				2:15		1										2:15		1
	78				1:19	0:09	2										1:19	0:09	2
	79				0:30	0:14	2										0:30	0:14	2
	81				1:13		1										1:13		1
	82	0:51		1	0:38	0:22	4										0:41	0:19	5
	84	0:56	0:20	2													0:56	0:20	2
	85	1:18	0:05	2	1:05	0:05	3										1:10	0:08	5
	86	1:06		1													1:06		1
	89	0:56		1	1:11	0:10	3										1:07	0:11	4
	90	1:00		1													1:00		1
	105	0:58		1													0:58		1

Table A.26: Shifting average duration, deviation and amount - section 81-87

		Class 1			2			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#
81	8	1:57	0:31	2	2:36	0:26	7	2:27	0:30	9
	50				2:53		1	2:53		1
	78				1:03	0:26	3	1:03	0:26	3
	79				0:34	0:14	3	0:34	0:14	3
	85	2:55	3:01	2				2:55	3:01	2
	86				0:55		1	0:55		1
	105	1:26	0:22	14				1:26	0:22	14
82	8				2:43	0:42	3	2:43	0:42	3
	35				2:43	0:54	2	2:43	0:54	2
	79				1:27		1	1:27		1
	80				0:28		1	0:28		1
	82	0:00		1	1:04	1:01	2	0:43	0:57	3
	84	0:56		1				0:56		1
	85				1:02	0:02	3	1:02	0:02	3
	86				1:20	0:20	2	1:20	0:20	2
	105	1:22	0:11	4	1:33	0:27	5	1:28	0:20	9
84	79	0:44		1				0:44		1
	105	7:19		1				7:19		1
85	8	1:53		1	2:50	0:29	3	2:36	0:37	4
	79	0:57	0:02	2	0:48		1	0:54	0:04	3
	80	0:41		1	1:01	0:18	3	0:56	0:18	4
	81	1:05	0:16	3	1:19	0:18	2	1:10	0:16	5
	84	0:43		1				0:43		1
	85	0:55	0:22	6				0:55	0:22	6
	86				1:28		1	1:28		1
	87	0:37		1				0:37		1
	89	0:47		1	1:12		1	1:00	0:17	2
	104				1:38		1	1:38		1
	105	1:16	0:22	7	1:05	0:14	3	1:13	0:20	10
86	8	2:05	0:18	3	3:25	0:00	2	2:37	0:45	5
	35	2:13		1				2:13		1
	78				1:25		2	1:25		2
	79				1:11	0:08	2	1:11	0:08	2
	80				1:03		1	1:03		1
	82				1:20	0:16	2	1:20	0:16	2
	85	1:00		1	0:49		1	0:54	0:07	2
	86	0:00		1	0:00		1	0:00	0:00	2
	104				1:24	0:03	2	1:24	0:03	2
	105	0:00		1	1:20	0:19	7	1:10	0:33	8
87	82				0:58		1	0:58		1
	85	0:39		1				0:39		1
	87	0:16		1				0:16		1
	89	0:34		1				0:34		1
	104				1:19	0:25	3	1:19	0:25	3
	105	1:00	0:13	4	2:05	0:04	2	1:22	0:35	6

Table A.27: Shifting average duration, deviation and amount - section 88-104

		Class 1			2			3a			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
88	8	1:27	0:02	2	4:04		1				2:19	1:30	3
	88	1:06	2:40	6	0:46	0:26	2				1:01	2:16	8
	90	0:51		1							0:51		1
	104	0:59		1							0:59		1
	105	1:23	0:16	9	1:53	0:09	2				1:29	0:19	11
89	8	3:22		1	2:55	0:25	4				3:01	0:24	5
	35				3:25	0:12	2				3:25	0:12	2
	78				1:13	0:07	2				1:13	0:07	2
	79				1:30	0:06	2				1:30	0:06	2
	80				1:05	0:01	2				1:05	0:01	2
	81	0:41		1							0:41		1
	82	1:22	0:59	3	1:32	0:06	3				1:27	0:38	6
	85	0:00		1	0:53	0:15	2				0:35	0:32	3
	86	0:21		1	1:15		1				0:48	0:38	2
	87				0:34		1				0:34		1
	89	0:14	0:24	3	0:49	0:27	5				0:36	0:30	8
	105	1:07	0:11	2	1:43	0:24	4				1:31	0:26	6
90	8				1:51		1				1:51		1
	78	0:56		1							0:56		1
	88	0:39	0:26	4							0:39	0:26	4
	92	0:28		1							0:28		1
	105				1:55		1				1:55		1
92	86				1:14		1				1:14		1
	105	2:00	0:59	3	1:18		1				1:49	0:52	4
104	8	1:58	0:53	7	2:54	0:44	7				2:26	0:55	14
	19							4:03		1	4:03		1
	22				2:56		1				2:56		1
	27	2:10	0:34	2							2:10	0:34	2
	32	2:01	0:00	2							2:01	0:00	2
	35				2:35	0:45	3				2:35	0:45	3
	78				0:43		1	1:41	0:03	2	1:22	0:33	3
	79				1:16	0:24	2				1:16	0:24	2
	81				1:59	0:59	2				1:59	0:59	2
	82				1:02		1				1:02		1
	84	2:30	2:20	2							2:30	2:20	2
	85	0:59		1	1:27	0:27	4				1:21	0:26	5
	86				1:41	0:21	2				1:41	0:21	2
	87	1:03		1	1:15	0:04	2				1:11	0:07	3
	88	1:02		1							1:02		1
	89				1:40	0:00	2				1:40	0:00	2
	90	1:35		1							1:35		1
	92	1:26		1							1:26		1
	104	1:10	2:28	26	0:21	0:27	8				0:58	2:12	34
	105	1:11	1:43	52	1:02	0:15	18				1:08	1:29	70

Table A.28: Shifting average duration, deviation and amount - section 105-NiN

		Class 1			2			3a			3b			4			5			6			Total		
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
105	8	2:57	1:11	30	3:04	0:42	11																2:59	1:04	41
	17	1:47		1	2:33	0:49	21																2:31	0:49	22
	22	2:27	0:19	3	2:44	0:44	65																2:44	0:44	68
	27	3:04	1:01	3	2:28	0:20	3																2:46	0:45	6
	32	2:19	1:00	12	2:26	0:28	22																2:23	0:42	34
	35	2:26	0:49	6	2:46	1:41	26	4:34	0:09	2													2:49	1:34	34
	42	1:58	0:14	3	2:31	0:25	48																2:29	0:25	51
	55	2:44	0:21	5																			2:44	0:21	5
	60	2:53	0:19	2	2:58	0:52	38	4:56	2:08	2													3:03	0:59	42
	71	2:24	1:12	3																			2:24	1:12	3
	78	1:04	0:55	7																			1:04	0:55	7
	79	1:42	0:23	2	1:31	0:30	3																1:35	0:25	5
	80	1:14	0:17	2	0:47	0:26	4																1:00	0:23	6
	81	1:32	0:32	11																			1:32	0:32	11
	82	1:11	0:31	2	1:32	0:22	2																1:22	0:25	4
	85	1:12	0:23	4	2:07	1:09	5																1:43	0:59	9
	86	0:36	0:51	2	1:27	0:35	3																1:07	0:45	5
	87	0:47	0:42	3	2:09		1																1:07	0:53	4
	88	1:25	0:24	13	1:58	0:13	3																1:31	0:25	16
	89	1:37	1:14	3	1:26	0:10	4																1:30	0:43	7
	90	1:02		1																			1:02		1
	104	1:01	0:31	72	1:14	0:52	13																1:03	0:35	85
	105	1:22	2:34	324	1:01	0:57	240	0:28	0:15	4													1:13	2:02	568
	NiN				2:39		1																2:39		1
NiN	32				1:14	0:06	2																1:14	0:06	2
	60				1:37		1																1:37		1
	105				8:43		1																8:43		1
Total		1:24	1:54	937	1:32	1:16	2199	2:13	1:33	79	2:17	1:00	19	1:55	1:04	13	3:21		1	2:37	0:34	5	1:31	1:29	3253

Table A.29: Op. contact until port entry - Average duration per section per class (June-July 2017)

Arrival	Class 1			2			3a			3b			4			5			6			Total		
From	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
5							1:57	0:16	181	2:19	0:06	2										1:57	0:16	183
8	7:18	7:58	195	5:23	7:10	605	7:55	9:47	195	9:54	7:09	41	21:42	5:39	6	3:38	0:00	1	14:00	6:33	11	6:33	8:02	1054
11	6:23	2:59	4	5:39	0:00	1	13:30	11:06	21	13:01	8:49	13	4:02	0:00	1				15:34	6:54	8	12:53	9:33	48
17				6:47	0:00	1																6:47	0:00	1
19	17:23	7:31	7	12:48	11:39	29	19:23	9:09	6	20:07	12:44	5										15:06	11:22	47
22	8:35	8:40	15	8:03	7:28	111	7:09	7:06	44	7:57	5:49	21	6:55	6:29	48	9:02	9:59	5				7:43	7:15	244
27	7:16	10:06	15	20:34	16:47	2			1	4:07	0:00	1										8:44	11:46	19
32	7:30	7:03	18	8:54	10:14	37	8:41	8:55	86				9:01	8:30	21							8:38	9:00	162
35	7:58	6:25	14	7:23	7:21	55	10:57	9:48	33				13:38	12:06	21			1				9:19	9:08	124
42	4:34	2:53	9	6:59	6:31	74							5:43	4:27	25	3:51	1:03	5				6:25	5:52	113
45			1																					1
46	4:17	0:27	2																			4:17	0:27	2
50				16:05	9:30	3	4:31	2:25	6	4:51	1:42	5										7:07	6:41	14
55	3:39	0:03	5	4:13	0:26	5																3:59	0:26	10
60	16:18	9:47	4	8:28	9:39	66	8:27	7:34	44	3:42	0:00	1	5:23	3:47	31	7:38	4:29	9				8:06	8:22	155
71	2:26	0:00	1	7:22	6:32	3	5:55	1:16	2													6:04	5:00	6
78	3:04	0:24	6	3:27	0:43	7	9:18	1:15	2													4:05	2:10	15
79	16:05	11:30	43	9:08	8:24	30																13:14	10:53	73
80	13:13	10:41	22	10:41	10:54	12																12:22	10:50	34
81	15:43	11:18	29	21:19	10:36	25	5:02	0:00	1													18:06	11:21	55
82	10:08	9:50	17	11:48	10:26	23																11:05	10:13	40
83	3:46	0:00	1																			3:46	0:00	1
84	10:58	10:17	3	2:59	0:00	1																8:58	9:33	4
85	6:50	5:37	23	9:20	9:06	18	14:12	10:23	4													8:29	7:58	45
86	7:14	7:23	22	6:56	7:55	14																7:07	7:36	36
87	5:17	3:30	8	10:32	9:35	4																6:43	6:17	12
88	9:08	10:23	50	5:22	4:47	27	23:04	8:13	3													8:22	9:26	80
89	9:50	9:06	54	9:15	9:38	22																9:40	9:16	76
90	13:46	8:42	14	4:19	1:10	9	4:48	0:00	1													10:51	8:53	24
92	16:49	13:10	9	8:21	5:32	5																13:48	11:47	14
104	8:02	8:35	169	4:03	5:33	292	4:41	4:23	9													5:28	7:01	470
105	5:08	5:51	990	6:05	7:31	579	6:43	8:41	46				2:45	0:00	1							5:31	6:36	1616
Total	6:54	7:50	1750	6:24	7:52	2060	6:38	8:27	685	9:53	7:59	89	8:26	8:19	154	6:58	6:24	21	14:40	6:45	19	6:46	7:58	4778

Table A.30: Op. contact until ATD - Average duration per section per class (June-July 2017)

Departure	Class 1			2			3a			3b			4			5			6			Total		
From	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#
Section 5							1:36	0:29	181	1:22	0:14	2										1:36	0:29	183
8	2:22	1:17	208	2:15	0:36	599	2:25	1:04	190	3:10	3:05	43	3:28	0:27	6				3:04	0:30	12	2:22	1:05	1058
11	1:51	0:14	4	2:04	0:00	1	2:27	0:15	21	2:27	0:17	10	1:39	0:00	1	2:04	0:00	1	2:53	0:28	6	2:27	0:23	44
17	1:47	0:00	1																			1:47	0:00	1
19	1:49	0:16	6	2:05	0:16	28	2:27	0:10	10	2:39	0:18	6										2:12	0:21	50
22	2:07	1:15	14	1:41	0:18	111	2:17	0:30	42	2:57	0:15	21	2:28	0:18	45	2:08	0:22	5				2:05	0:38	238
27	3:27	4:59	19	2:03	0:13	2	2:53	0:00	1	2:25	0:00	1										3:15	4:33	23
32	3:21	2:56	30	1:38	0:23	35	2:02	0:18	83				2:14	0:23	20							2:14	1:27	168
35	2:06	0:33	22	2:04	0:23	35	2:13	0:55	35	2:03	0:00	1	3:16	3:49	25			1				2:23	1:57	119
42	1:43	0:12	6	2:06	1:57	73							2:33	0:31	25	2:48	0:12	5				2:11	1:41	109
45			1																					1
46	1:47	0:06	2																			1:47	0:06	2
50				2:50	0:00	1	2:43	0:10	5	2:34	0:20	4							3:08	0:00	1	2:43	0:17	11
55	5:40	2:45	8	8:29	9:39	5																6:45	6:30	13
60	5:12	5:25	5	2:08	0:27	75	2:40	0:21	49				3:12	0:24	31	2:57	0:17	9				2:34	1:18	169
71	2:25	0:11	2	2:18	0:09	3	2:32	0:08	2													2:24	0:11	7
78	2:57	0:30	4	2:34	0:16	8	4:07	0:37	4													2:59	0:44	16
79	2:45	0:19	42	2:51	0:19	25																2:47	0:19	67
80	2:25	0:16	15	3:16	1:03	12																2:47	0:49	27
81	2:32	0:23	26	2:56	0:56	32	2:41	0:00	1	3:39	0:00	1										2:46	0:46	60
82	2:48	0:25	18	2:56	0:24	29																2:53	0:25	47
83	2:36	0:00	1																			2:36	0:00	1
84	2:47	0:23	7	3:15	0:00	1																2:50	0:23	8
85	3:22	1:50	21	3:45	2:39	21	3:54	0:30	4													3:35	2:11	46
86	2:36	0:33	22	2:57	0:19	12																2:43	0:30	34
87	2:56	0:29	9	3:17	0:17	6																3:04	0:27	15
88	3:00	1:16	56	3:07	0:39	29	3:11	0:18	3													3:03	1:05	88
89	2:44	0:19	52	3:03	0:26	16																2:49	0:22	68
90	2:48	0:19	12	3:15	0:20	8	3:59	0:00	1													3:01	0:26	21
92	2:58	0:22	8	3:11	0:17	4																3:02	0:21	12
104	3:31	3:00	183	2:48	1:27	276	2:49	0:27	6													3:05	2:13	465
105	4:07	2:43	943	3:06	1:31	602	3:32	0:33	46				4:00	0:00	1							3:43	2:20	1592
Total	3:32	2:30	1747	2:37	1:22	2049	2:14	0:53	684	2:55	2:11	89	2:45	1:45	154	2:40	0:28	21	3:01	0:29	19	2:55	1:55	4763

B | Harbour Master

Figure B.1 shows the VTS area's in the Port of Rotterdam and figure B.2 the port approach area.

Port of Rotterdam

SAFETY THROUGH COMMUNICATION

SHIPPING INFORMATION - **VTS** - BASIC RULES

1 Responsibility as to safe navigation always remains with the master or skipper on board the vessel.

2 A continuous listening watch on the assigned VHF channels should be maintained to be kept well informed about the traffic situation.

3 Information should be given on request of the VTS-authority / VTS-operator.

4 The VTS provides information, navigational assistance when deemed necessary and possibly traffic instructions on behalf of the Harbourmaster.

5 All communication should be brief and relevant.

6 Any particulars with regard to navigation or the vessels equipment should be reported.

7 The language to be used is primarily Dutch and secondly English with the exception of the sectors Maas Approach (VHF 1), Pilot Maas (VHF 2) and Maas Entrance (VHF 3), where the language to be used is English and secondly Dutch.

Figure B.1: VTS - Basic rules (Port of Rotterdam, 2017b)

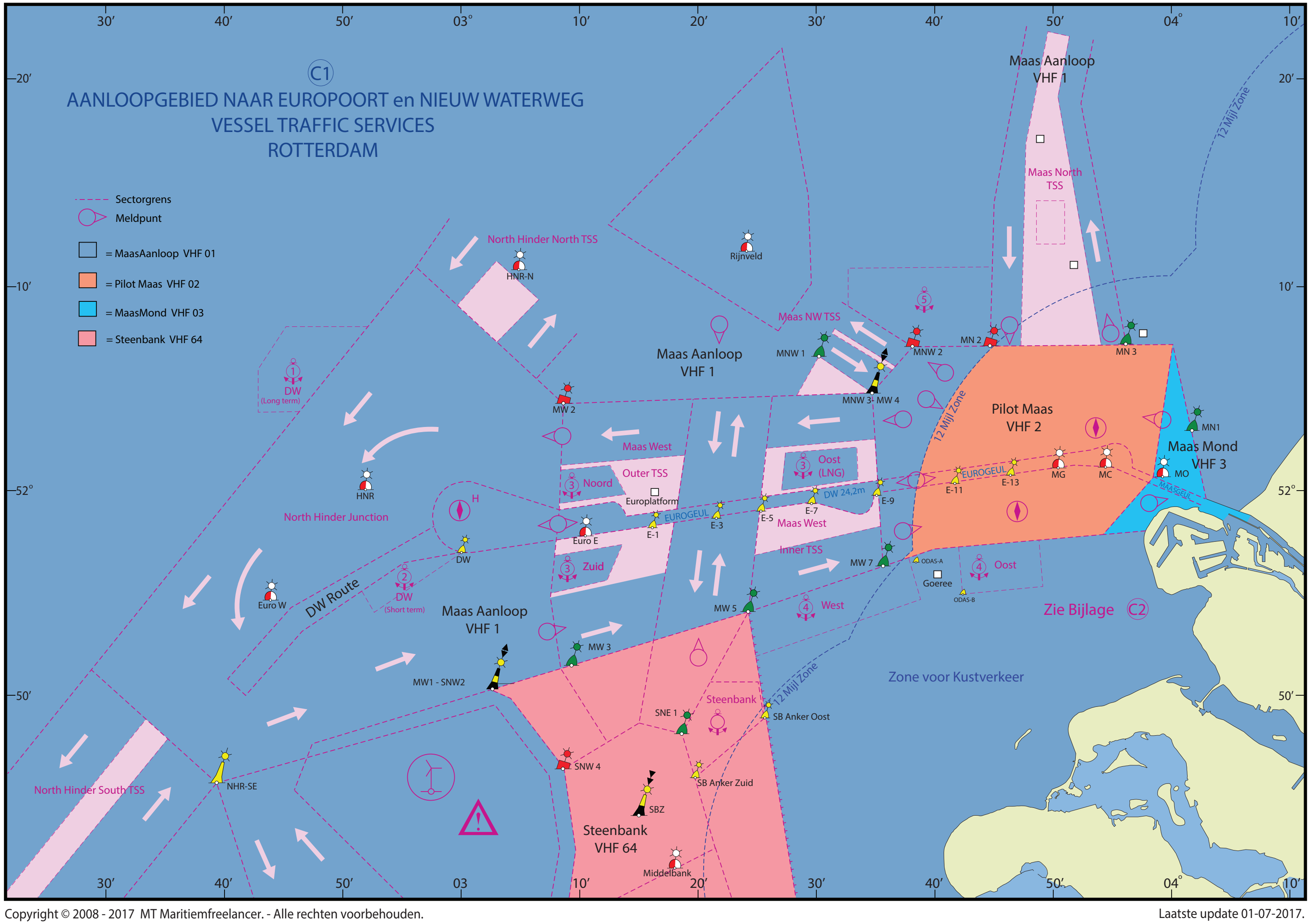

Figure B.2: Port approach area (MT Maritiemfreelancer, 2017)

C | Pilots

In this appendix the pilot boarding stations are shown in figure C.1. In appendix C.2, tables with the average pilot durations are shown.

C.1 Pilot boarding stations

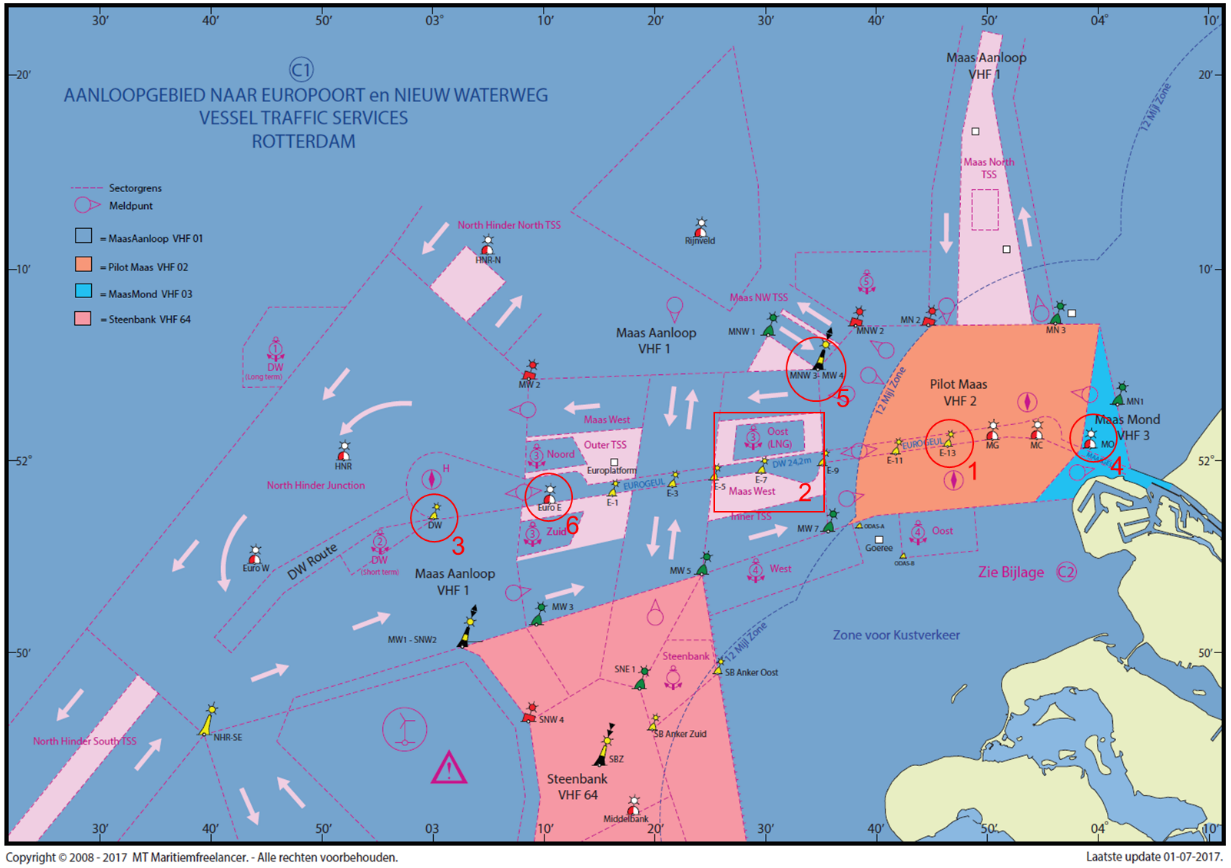

Figure C.1: Pilot boarding stations (MT Maritiemfreelancer, 2017)

C.2 Average duration

The following tables show the average duration of a pilot being on board. In the first table (C.1) arriving voyages are shown sorted by their destination and vessel class. The average duration from the time the pilot came on board until the time he or she disembarks is shown. As well as the deviation of these times and the amount of voyages with that destination and vessel class.

Table C.2 shows the same information for departing voyages and tables C.3 to C.8 for shifting voyages.

Table C.1: Arrival - Average duration pilot per section per class (June-July 2017)

Arrival	Class 1			2			3a			3b			4			5			6			Total
To	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
Section 8	2:10	0:41	162	2:24	0:36	297	3:09	0:31	117	4:25	1:11	41	4:15	0:42	6	3:50	0:00	1	7:15	0:43	11	635
11				2:28	0:00	1	3:12	0:42	20	3:27	0:35	13	4:49	0:00	1				7:04	0:17	8	43
17				2:22	0:00	1																1
19	2:03	0:09	7	2:16	0:27	29	2:44	0:24	6	3:01	0:12	5										47
22	1:34	0:07	13	1:43	0:22	98	2:32	0:27	43	4:56	1:28	21	2:45	0:49	42	2:42	0:10	5				222
27	1:53	0:14	11	2:24	0:00	2	2:55	0:00	1	3:01	0:00	1										15
32	1:50	0:15	17	1:58	0:34	34	1:59	0:23	76				2:09	0:21	17							144
35	1:55	0:13	10	1:58	0:21	46	2:20	0:24	21				2:43	0:25	19							96
42	1:44	0:23	3	1:41	0:20	61							2:42	0:19	21	3:13	0:20	4				89
46	2:36	0:19	2																			2
50				2:42	0:04	3	3:24	0:16	6	3:48	0:09	5										14
55	3:14	0:56	4	3:10	0:38	5																9
60	2:35	0:39	3	2:06	0:30	53	2:47	0:28	28	3:25	0:00	1	3:16	0:24	17	3:31	0:27	8				110
71	2:22	0:00	1	3:03	0:33	3	4:09	0:12	2													6
78	2:42	0:43	4	3:08	0:24	7	4:44	0:08	2													13
79	2:42	0:23	43	2:59	0:26	30																73
80	2:32	0:27	22	3:01	0:38	12																34
81	2:47	0:19	27	3:02	0:22	25	5:43	0:00	1													53
82	2:50	0:35	17	3:14	0:39	23																40
83	2:50	0:00	1																			1
84	2:44	0:14	3	3:12	0:00	1																4
85	2:46	0:22	23	3:25	1:08	18	3:49	0:17	4													45
86	2:43	0:21	22	2:56	0:23	14																36
87	2:45	0:24	8	3:36	0:31	4																12
88	2:59	0:25	44	3:19	0:41	27	4:09	0:24	3													74
89	2:54	0:25	54	3:14	0:22	22																76
90	2:47	0:20	14	3:38	0:33	9	3:33	0:00	1													24
92	2:53	0:19	9	3:12	0:44	5																14
104	3:01	0:33	116	3:08	0:38	95	3:04	0:51	8													219
105	3:47	1:06	554	3:15	0:51	434	3:35	0:30	40				3:17	0:00	1							1029
Total	3:09	1:04	1194	2:43	0:53	1359	2:51	0:45	379	4:15	1:15	87	2:49	0:45	124	3:15	0:30	18	7:10	0:35	19	3180

Table C.2: Departure - Average duration pilot per section per class (June-July 2017)

Departure	Class 1			2			3a			3b			4			5			6			Total
From	Average [hrs]	StDev [hrs]	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
Section 5							1:42	0:00	1													1
8	1:29	0:19	171	1:49	0:28	293	2:01	0:26	109	2:01	0:24	41	3:59	2:00	2				2:15	0:19	10	626
11				1:31	0:00	1	1:56	0:39	20	2:06	0:36	10	2:26	0:00	1	1:46	0:00	1	2:21	0:22	6	39
17	1:01	0:00	1																			1
19	1:20	0:12	6	1:25	0:15	27	1:48	0:06	10	1:45	0:14	6										49
22	1:20	0:25	8	1:23	0:23	86	1:54	0:35	40	2:11	0:17	20	2:07	0:19	38	2:13	0:28	4				196
27	1:21	0:07	13	1:17	0:17	2	1:22	0:00	1	1:56	0:00	1										17
32	1:23	0:20	21	1:16	0:19	31	1:38	0:21	73				1:47	0:25	15							140
35	1:26	0:26	16	1:28	0:18	32	1:52	0:56	22	1:38	0:00	1	2:03	0:29	23							94
42	1:20	0:10	6	1:25	0:18	63							2:14	0:23	20	2:25	0:04	3				92
46	1:28	0:06	2																			2
50				2:07	0:00	1	1:58	0:14	5	2:08	0:17	4							2:17	0:00	1	11
55	3:21	0:32	4	2:13	0:18	5																9
60	2:04	1:06	3	1:47	0:27	66	2:18	0:25	32				2:51	0:32	17	2:55	0:16	8				126
71	1:25	0:33	2	1:47	0:07	3	1:57	0:07	2													7
78	2:20	0:22	3	2:06	0:18	8	3:49	0:54	3													14
79	2:00	0:16	42	2:15	0:22	25																67
80	1:51	0:12	15	2:08	0:19	11																26
81	1:51	0:14	25	2:07	0:18	32	2:37	0:00	1	2:57	0:00	1										59
82	1:59	0:15	18	2:21	0:27	28																46
83	1:58	0:00	1																			1
84	2:01	0:22	7	2:29	0:00	1																8
85	2:41	1:45	20	2:16	0:21	20	3:23	0:35	4													44
86	2:06	0:17	22	2:20	0:17	12																34
87	2:02	0:14	5	2:37	0:22	6																11
88	2:17	0:29	48	2:37	0:34	27	2:31	0:09	3													78
89	2:05	0:13	52	2:26	0:30	16																68
90	2:05	0:12	12	2:34	0:15	8	3:27	0:00	1													21
92	2:08	0:26	8	2:34	0:23	4																12
104	2:13	0:28	86	2:22	0:26	77	2:28	0:17	6													169
105	3:06	0:59	522	2:39	0:42	428	3:11	0:34	40				3:23	0:00	1							991
Total	2:26	1:00	1139	2:07	0:42	1313	2:06	0:42	373	2:03	0:25	84	2:14	0:38	117	2:34	0:29	16	2:17	0:20	17	3059

Table C.3: Average duration pilot per section per class - Shifting section 8-27 (June-July 2017)

		Class 1			2			3a			3b			4			5			6			Total
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
8	8	1:02	0:23	24	1:36	0:27	37	2:12	0:31	21	3:00	0:26	5	3:17	0:29	5				3:50	0:00	1	93
	11							3:02	0:02	2	3:45	0:00	1				3:53	0:00	1	4:42	0:00	1	5
	19				2:15	0:22	3	3:22	0:15	3	2:45	0:00	1	4:45	0:00	1							8
	22				2:05	0:07	3	2:10	0:00	1													4
	32	1:22	0:09	3				2:00	0:00	1													4
	35	1:53	0:29	3	2:18	0:31	7							4:04	0:00	1							11
	50							4:03	0:24	6	3:58	0:13	2										8
	60				2:20	0:00	1																1
	79				3:42	0:03	2																2
	80				4:18	0:00	1																1
	81				3:12	0:28	14																14
	82				3:45	0:30	3																3
	85	2:49	0:16	3																			3
	86	2:40	0:00	2	3:35	0:15	2																4
	88				4:15	0:15	2																2
	89				3:12	0:33	4																4
	104	2:50	0:00	1	3:44	0:31	3	6:25	0:00	1													5
	105	3:48	1:12	13	3:47	0:51	19	5:35	0:23	2													34
11	8							3:47	0:28	2	2:53	0:29	4							4:32	0:27	2	8
	50																			3:40	0:00	1	1
17	22	0:59	0:18	3	1:08	0:21	46																49
	32				0:40	0:00	1																1
	35				1:33	0:13	2																2
	42	0:50	0:00	1	1:12	0:18	36																37
	60	0:48	0:00	1	1:49	0:29	14																15
	105				3:02	0:12	2																2
19	8	2:45	0:00	1	2:00	0:24	3				3:00	0:00	1	3:45	0:00	1							6
	19										0:45	0:00	1										1
	81				3:25	0:00	1																1
22	8	0:50	0:00	1	1:49	0:14	2	2:49	0:04	2				3:45	0:00	1							6
	17	1:32	0:27	2	1:09	0:28	34																36
	22				1:31	0:22	4																4
	27				1:21	0:23	14																14
	32	0:56	0:06	3	1:22	0:18	36	1:20	0:00	1													40
	35				1:32	0:16	7							2:57	0:18	2							9
	42	1:07	0:16	5	1:28	0:30	49																54
	60	1:12	0:08	4	1:48	0:23	45																49
	105	2:48	0:35	8	2:51	0:34	50	0:01	0:00	1													59
	NiN				1:25	0:05	2																2
27	22				1:18	0:17	12																12
	32				1:00	0:00	1																1
	35				1:18	0:13	2																2
	42				1:21	0:22	14																14
	60				1:36	0:19	12																12
	105	3:13	0:13	2	2:35	0:00	1																3

Table C.4: Average duration pilot per section per class - Shifting section 32-55 (June-July 2017)

		Class 1			2			3a			3b			4			5			6			Total
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
32	8				2:05	0:05	2																2
	17	0:35	0:00	1	0:51	0:03	2																3
	22	1:08	0:08	3	1:20	0:21	30	2:14	0:00	1													34
	32	0:40	0:03	3	1:31	0:37	3																6
	35				0:59	0:09	5							1:33	0:00	1							6
	42	1:08	0:23	3	1:14	0:30	43																46
	60	1:08	0:00	1	1:36	0:30	39	2:05	0:24	3													43
	105	3:24	0:20	3	3:18	1:10	21																24
	NiN				1:25	0:00	1																1
35	8	2:33	0:00	1	2:22	0:37	2																3
	17	2:15	0:00	1	1:19	0:11	3																4
	22	1:10	0:00	1	1:22	0:15	6																7
	27				1:10	0:06	3																3
	32				1:00	0:18	13																13
	35							1:40	0:00	1													1
	42				1:26	0:12	5																5
	60				1:37	0:32	17	2:25	0:05	2													19
	79				3:25	0:00	1																1
	80				3:17	0:44	3																3
	82				3:12	0:24	4																4
	86				2:52	0:07	2																2
	87				3:31	0:26	4																4
	90				4:10	0:00	1																1
	104	2:20	0:00	1	2:51	0:00	1																2
	105	2:17	0:02	2	3:15	0:48	17	6:07	0:00	1													20
42	17				1:13	0:18	23																23
	22	1:21	0:31	5	1:28	0:25	40																45
	27				1:33	0:22	11																11
	32	1:22	0:17	2	1:11	0:19	38																40
	35				1:14	0:15	3																3
	42				0:40	0:10	3																3
	60	0:53	0:11	2	1:22	0:21	37																39
	105	2:42	0:17	2	3:28	1:02	50																52
	NiN	1:14	0:21	2	1:31	0:04	2																4
50	8				2:40	0:00	1	4:06	0:42	7	3:55	0:00	1										9
	19										3:05	0:00	1										1
	78				6:30	0:00	1																1
	81				4:00	0:00	1				6:55	0:00	1										2
55	55				3:00	0:00	1																1
	105	3:15	0:00	1																			1

Table C.5: Average duration pilot per section per class - Shifting section 60-80 (June-July 2017)

		Class 1			2			3a			3b			4			5			6			
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
60	8				2:44	0:00	1																1
	17	1:35	0:00	1	1:36	0:21	24																25
	22	1:27	0:16	3	1:42	0:26	27																30
	27				1:45	0:26	12																12
	32				1:36	0:24	32																32
	35	1:13	0:28	2	1:35	0:18	17	2:55	0:41	3	2:00	0:00	1										23
	42	1:20	0:31	3	1:29	0:25	25																28
	60				1:23	0:46	3	0:25	0:00	1				1:30	0:00	1							5
	105	3:00	0:00	1	3:32	0:46	43																44
71	32	1:41	0:00	1																			1
	105	1:20	0:00	1																			1
78	27	2:10	0:00	1																			1
	80				1:47	0:12	2																2
	81				1:57	0:00	1																1
	86				1:11	0:00	1																1
	89				1:18	0:00	1																1
	104	1:14	0:01	2	2:20	0:35	2																4
	105	1:07	0:09	3	2:01	0:18	4																7
79	8	2:31	0:36	2	3:31	0:48	6																8
	35				3:45	0:00	1																1
	78				1:47	0:02	2																2
	79				1:35	0:00	1																1
	80				1:05	0:00	1																1
	82				1:19	0:29	2																2
	86				2:17	0:22	2																2
	89	0:50	0:00	1	1:16	0:03	2																3
	92				1:35	0:00	1																1
	104	1:45	0:00	1	2:09	0:26	3																4
	105	1:45	0:00	1	1:43	0:01	3																4
80	8	2:35	0:00	1	2:35	0:34	3																4
	35				2:40	0:00	1																1
	78				1:35	0:05	2																2
	79				1:27	0:43	2																2
	82	1:25	0:00	1	1:19	0:11	3																4
	84	1:05	0:10	2																			2
	85	1:16	0:01	2	1:36	0:11	3																5
	89	1:24	0:00	1	1:42	0:23	3																4
	90	1:15	0:00	1																			1
	105	1:13	0:00	1																			1
	105	3:15	0:00	1																			1

Table C.6: Average duration pilot per section per class - Shifting section 81-87 (June-July 2017)

		Class 1			2			3a			3b			4			5			6			Total
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
81	8	2:40	0:05	2	2:39	0:20	7																9
	50				4:05	0:00	1																1
	78				1:22	0:27	3																3
	79				1:20	0:07	3																3
	85	0:56	0:00	1																			1
	86				1:00	0:00	1	2:55	0:41	3	2:00	0:00	1										1
	105	1:44	0:21	12																			12
82	8				3:14	0:56	3	0:25	0:00	1				1:30	0:00	1							3
	35				3:35	0:24	2																2
	79				1:20	0:00	1																1
	80				0:50	0:00	1																1
	82				0:50	0:05	2																2
	84	1:00	0:00	1																			1
	85				1:39	0:12	3																3
	86				1:47	0:07	2																2
	105	1:39	0:07	3	2:05	0:13	4																7
84	79	1:04	0:00	1																			1
	105	1:29	0:00	1																			1
85	8	2:15	0:00	1	3:11	0:20	3																4
	79	1:11	0:00	2	1:30	0:00	1																3
	80	1:00	0:00	1	1:23	0:11	3																4
	81	1:25	0:14	3	1:36	0:01	2																5
	84	0:45	0:00	1																			1
	85	1:12	0:28	6																			6
	86				2:22	0:00	1																1
	87	0:49	0:00	1																			1
	89	1:10	0:00	1	1:24	0:00	1																2
	104				1:55	0:00	1																1
	105	3:02	0:52	7	1:33	0:25	3																10
86	8	2:39	0:21	3	3:32	0:12	2																5
	35	2:30	0:00	1																			1
	78				2:13	0:00	1																1
	79				4:02	0:00	1																1
	80				1:36	0:00	1																1
	82				1:46	0:06	2																2
	85	1:10	0:00	1	1:26	0:00	1																2
	104				1:47	0:32	2																2
	105				2:39	1:14	7																7
87	82				1:10	0:00	1																1
	85	1:15	0:00	1																			1
	87	0:32	0:00	1																			1
	89	1:05	0:00	1																			1
	104				2:13	0:23	3																3
	105	3:06	0:57	3	2:57	0:12	2																5

Table C.7: Average duration pilot per section per class - Shifting section 88-104 (June-July 2017)

		Class 1			2			3a			3b			4			5			6			Total
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
88	8	1:54	0:05	2	5:00	0:00	1																3
	88				1:37	0:47	2																2
	90	0:57	0:00	1																			1
	104	1:35	0:00	1																			1
	105	2:08	0:46	8	2:03	0:07	2																10
89	8	3:30	0:00	1	3:36	0:17	4				2:00	0:00	1										5
	35				3:41	0:31	2																2
	78				1:56	0:06	2							1:30	0:00	1							2
	79				1:52	0:07	2																2
	80				1:25	0:05	2																2
	81	1:30	0:00	1																			1
	82	1:11	0:04	3	1:54	0:18	3																6
	85	0:46	0:00	1	1:55	0:04	2																3
	86	0:35	0:00	1	1:20	0:00	1																2
	87				0:58	0:00	1																1
	89	0:38	0:00	1	0:51	0:12	5																6
	105	1:29	0:03	2	2:18	0:14	4																6
90	8				4:15	0:00	1																1
	78	0:48	0:00	1																			1
	88	1:06	0:20	4																			4
	92	0:45	0:00	1																			1
	105				2:59	0:00	1																1
92	86				1:15	0:00	1																1
	105	2:07	0:30	3	2:11	0:00	1																4
104	8	2:23	0:29	5	3:35	0:49	7																12
	19							5:23	0:00	1													1
	22				3:18	0:00	1																1
	27	2:09	0:10	2																			2
	32	2:32	0:27	2																			2
	35				2:56	0:31	3																3
	78				1:13	0:00	1	2:45	0:00	2													3
	79				1:51	0:09	2																2
	81				2:27	0:00	2																2
	82				1:45	0:00	1																1
	84	2:59	1:56	2																			2
	85	1:42	0:00	1	1:57	0:30	4																5
	86				2:10	0:05	2																2
	87				2:00	0:00	2																2
	88	2:10	0:00	1																			1
	89				2:15	0:10	2																2
	90	1:57	0:00	1																			1
	92	1:44	0:00	1																			1
	104	2:22	3:14	11	1:25	0:25	5																16
	105	1:51	1:19	35	1:38	0:24	15																50

Table C.8: Average duration pilot per section per class - Shifting section 105-NiN (June-July 2017)

		Class 1			2			3a			3b			4			5			6			Total
From	To	Average	StDev	Amount	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	$\bar{t}$	σ	#	#
105	8	3:12	1:00	18	3:40	0:39	11																29
	17	1:45	0:00	1	2:59	0:45	18																19
	22	2:51	1:07	3	3:05	0:46	59																62
	27	4:00	0:30	2	2:44	0:11	3																5
	32	3:05	1:13	6	3:00	0:55	18																24
	35	2:58	1:04	6	2:59	0:44	23	4:52	0:07	2													31
	42	2:16	0:20	3	2:49	0:30	37																40
	55	2:45	0:00	1																			1
	60	2:52	0:00	2	3:17	0:40	34	3:52	0:15	2													38
	71	2:40	1:07	3																			3
	78	1:49	0:52	4																			4
	79	2:27	0:57	2	2:19	0:23	3																5
	80	1:32	0:07	2	2:02	0:06	2																4
	81	1:38	0:15	11																			11
	82	1:49	0:27	2	2:04	0:04	2																4
	85	1:33	0:09	4	2:29	0:48	5																9
	86	2:48	0:17	2	2:27	0:48	3																5
	87	1:20	0:00	1	2:31	0:00	1																2
	88	1:40	0:17	11	2:33	0:37	3																14
	89	2:24	1:08	3	2:02	0:07	4																7
	90	1:20	0:00	1																			1
	104	1:34	0:47	27	1:56	0:52	11																38
	105	1:49	1:03	141	1:49	1:02	147	2:05	1:10	3													291
	NiN				2:40	0:00	1																1
NiN	32				1:32	0:02	2																2
	60				3:03	0:00	1																1
	105				5:05	0:00	1																1
	Total	1:54	1:09	549	2:03	1:02	1710	3:00	1:18	72	3:11	1:10	19	3:12	0:55	13	3:53	0:00	1	4:15	0:30	5	2369

D | Tugs

D.1 Average tugs per class

The amount of tugs that were needed for each class are shown in tables D.1 to D.8.

Table D.1: Number of tugs per class per section - Arrival (June-July 2017)

Arrival	Class 1				2					3a					3b					4					5			6		Total
Destination	0 tugs	1	2	3	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	2	3	3	4	
Section 5										173	8				2															183
8	177	16	2		448	49	107		1	78	3	111	3				15	26				1	5				1	2	9	1054
11	4					1				1		16		4		1	7	5						1					8	48
17					1																									1
19	2		5		15	7	7					6					2	3												47
22	15				98	12	1			1	5	38					2	18	1	5		40	3			4	1			244
27	15				1		1					1					1													19
32	18				16	16	5			10	50	26								4	8	9								162
35	14				37	6	12			11	3	19								2	1	16	2		1					124
42	9				67	6	1													3		21	1		1	4				113
45	1																													1
46	1	1																												2
50						1	2				1	4	1			1	4													14
55	2		3		3		1		1																					10
60	4				52	12	2			15	10	19					1			13		12	6		1	5	3			155
71	1					2	1				1	1																		6
78	6				2	1	4						2																	15
79	39	2	2		12	5	13																							73
80	22				3	6	3																							34
81	26	3			15	4	6						1																	55
82	17				8	7	8																							40
83	1																													1
84	3						1																							4
85	23				7	4	7					3	1																	45
86	20	2			4	5	5																							36
87	8					1	3																							12
88	50				8	2	17					2	1																	80
89	49	4	1		4	10	8																							76
90	13	1			2		7						1																	24
92	8	1			3	1	1																							14
104	160	6	3		225	22	45			2	3	3	1																	470
105	944	34	11	1	402	68	108	1		21	9	14	2									1								1616
Total	1652	70	27	1	1433	248	376	1	2	312	93	263	13	4	2	2	32	52	1	27	9	100	17	1	3	13	5	2	17	4778

Table D.2: Number of tugs per class per section - Departure (June-July 2017)

Departure	Class 1				2				3a					3b				4					5			6			Total
	0 tugs	1	2	3	0	1	2	3	0	1	2	3	4	0	1	2	3	0	1	2	3	4	0	2	3	0	2	3	
5									178	3				2															183
8	209	4	1		451	54	95		87	14	88	1		4	1	35	3	2	1		1	2				2	7	3	1065
11	4					1			2	1	17		1			10				1				1			5	1	44
17	1																												1
19	2	4			17	3	8		1		9			1		5													50
22	14				101	12	1		2	5	35			1		4	16	5	2	37	1		1	3	1				241
27	19				1		1				1					1													23
32	30				19	15	1		10	50	23							4	7	9									168
35	22				23	3	9		13	8	14					1		3	7	15			1						119
42	6				65	9												3		22				4	1				110
45	1																												1
46	2																												2
50						1			1		4				3	1											1		11
55	5		3		3		1	1																					13
60	4	1			62	13	1		17	5	27							12		15	4		1	7	1				170
71	2					3				1	1																		7
78	4				3	4	1				2	2																	16
79	42	1			9	7	9																						68
80	15				7	3	2																						27
81	26				24	3	5				1					1													60
82	18				15	10	5																						48
83	1																												1
84	7					1																							8
85	21				8	6	7				2	2																	46
86	19	3			3	9	1																						35
87	9				1	1	4																						15
88	56	1			10	2	17		1		2																		89
89	51	1			9	6	1																						68
90	12				2	1	5				1																		21
92	8				3		1																						12
104	183	6	2		232	14	30		3	2	1																		473
105	988	21	9	3	435	78	93		21	5	19	1								1									1674
Total	1781	42	15	3	1503	259	298	1	336	94	247	6	1	8	4	58	19	29	17	100	6	2	3	15	3	2	13	4	4869

Table D.3: Number of tugs per class - Shift section 8-27(June-July 2017)

		1			2					3a				3b				4			5	6			Total
From	To	0 tugs	1	2	0	1	2	3	4	0	1	2	3	0	1	2	3	2	3	4	3	2	3	4	
8	8	39	3	1	85	11	19			2	1	20	1		1	4			3	2			1		193
	11											2				1					1			1	5
	19					1	2					2	1				1		1						8
	22				4							1													5
	32	3									1														4
	35	5			3	2	2											1							13
	50									1		4	1	1		1									8
	60	1			1																				2
	79				1		1																		2
	80						1																		1
	81				13		1																		14
	82				1		2																		3
	85	3																							3
	86	1	1			1	1																		4
	88						2																		2
	89				2	1	1																		4
	104	1			1	1	2						1												6
	105	17	1	2	6	4	9					2													41
11	8											2			1	2	1							2	8
	50																					1			1
17	22	3			59	5																			67
	32				2																				2
	35				3																				3
	42	1			33	7																			41
	60	1			13	4																			18
	105				3																				3
19	8			1	2		1										1			1					6
	19															1									1
	81					1																			1
22	8	1			1	1						1	1					1							6
	17	2			37	2																			41
	22	1			7		1																		9
	27				12	2																			14
	32	4			43	4					1														52
	35				12					1								2							15
	42	5			56	6																			67
	60	5			47	1																			53
	105	7	1		61	2	1						1												73
	NiN				2																				2
27	22				12		1																		13
	27	8																							8
	32	4			1																				5
	35				4																				4
	42				12	2																			14
	60				13	1																			14
	105	2			1																				3

Table D.4: Number of tugs per class - Shift section 32-55 (June-July 2017)

		1			2					3a				3b				4			5	6			Total
From	To	0 tugs	1	2	0	1	2	3	4	0	1	2	3	0	1	2	3	2	3	4	3	2	3	4	
32	8				3																				3
	17	1			3																				4
	22	5			44	2				1	1														53
	27	4																							4
	32	6		1	4		2																		13
	35				7													1							8
	42	3			50	2																			55
	60	3			42	3					2	1													51
	105	3			19	1	2																		25
	NiN				1																				1
35	8	1			1		1																		3
	17	1			6																				7
	22	1			15	1																			17
	27				4	1																			5
	32				18																				18
	35	2								1															3
	42				7	1																			8
	60				21	1				1	1	1													25
	79						1																		1
	80				2		1																		3
	82				1	1	2																		4
	86				1	1																			2
	87					1	3																		4
	90						1																		1
	104	1					1																		2
	105	2			12	1	6						1												22
42	17				26	6																			32
	22	7			44	7																			58
	27				13																				13
	32	4			41	3																			48
	35				5																				5
	42				3																				3
	60	4			44	6																			54
	105	2			57	5	2																		66
	NiN	2			2																				4
50	8						1				1	6				1									9
	19															1									1
	78						1																		1
	81						1										1								2
55	55							1	1																2
	104	1																							1
	105	1																							1

Table D.5: Number of tugs per class - Shift section 60-80 (June-July 2017)

		1			2					3a				3b				4			5	6			Total
From	To	0 tugs	1	2	0	1	2	3	4	0	1	2	3	0	1	2	3	2	3	4	3	2	3	4	
60	8				1																				1
	17	1			24	3																			28
	22	5			29	4																			38
	27				10	2																			12
	32	1			39	2																			42
	35	2			19							2	1			1									25
	42	4			29	8																			41
	60	2			10					1								1							14
	104	1																							1
	105	1			52	4																			57
71	32	1																							1
	105	1																							1
78	27	1																							1
	80						2																		2
	81						1																		1
	86					1																			1
	87	2																							2
	89					1																			1
	104	2					2																		4
	105	6			2		3																		11
79	8	1		1	2	1	3																		8
	35						1																		1
	78						2																		2
	79					1																			1
	80				1	1																			2
	82				1	1																			2
	86						2																		2
	89	1			1	1																			3
	92					1																			1
	104	1				1	2																		4
	105			1	1	1	1																		4
80	8	1			2		1																		4
	35					1																			1
	78					1	1																		2
	79					1	1																		2
	81				1																				1
	82	1			1	1	2																		5
	84	2																							2
	85	1	1			1	2																		5
	86		1																						1
	89	1				2	1																		4
	90	1																							1
	105	1																							1

Table D.6: Number of tugs per class - Shift section 81-87 (June-July 2017)

		1			2					3a				3b				4			5	6			Total
From	To	0 tugs	1	2	0	1	2	3	4	0	1	2	3	0	1	2	3	2	3	4	3	2	3	4	
81	8	2			7																				9
	50						1																		1
	78				2		1																		3
	79					2	1																		3
	85	2																							2
	86				1																				1
	105	12	2																						14
82	8				1	1	1																		3
	35				1		1																		2
	79						1																		1
	80					1																			1
	82	1			1		1																		3
	84	1																							1
	85					2	1																		3
	86					1	1																		2
	105	4			1	1	3																		9
84	79	1																							1
	105	1																							1
85	8	1			1	1	1																		4
	79	2			1																				3
	80	1				2	1																		4
	81	3			2																				5
	84	1																							1
	85	6																							6
	86						1																		1
	87	1																							1
	89	1				1																			2
	104						1																		1
	105	6	1		1	1	1																		10
86	8	3				1	1																		5
	35		1																						1
	78						2																		2
	79						2																		2
	80					1																			1
	82					1	1																		2
	85	1			1																				2
	86	1			1																				2
	104					1	1																		2
	105	1			1	4	2																		8
87	82					1																			1
	85	1																							1
	87	1																							1
	89			1																					1
	104						3																		3
	105	4					2																		6

Table D.7: Number of tugs per class - Shift section 88-104 (June-July 2017)

		1			2					3a				3b				4			5	6			Total
From	To	0 tugs	1	2	0	1	2	3	4	0	1	2	3	0	1	2	3	2	3	4	3	2	3	4	
88	8	2					1																		3
	88	6			2																				8
	90	1																							1
	104	1																							1
	105	9			2																				11
89	8	1				4																			5
	35					1	1																		2
	78					1	1																		2
	79					1	1																		2
	80					1	1																		2
	81	1																							1
	82	3				3																			6
	85	1				2																			3
	86	1					1																		2
	87				1																				1
	89	3				4	1																		8
	105	2				1	3																		6
90	8					1																			1
	78	1																							1
	88	4																							4
	92	1																							1
	105						1																		1
92	86					1																			1
	105	3				1																			4
104	8	7			2	2	3																		14
	19											1													1
	22				1																				1
	27	2																							2
	32	2																							2
	35				2		1																		3
	78				1								2												3
	79					1	1																		2
	81						2																		2
	82				1																				1
	84	1	1																						2
	85	1			2		2																		5
	86						2																		2
	87	1					2																		3
	88	1																							1
	89					2																			2
	90		1																						1
	92	1																							1
	104	19	1	6	3	1	4																		34
	105	49	2	1	12	3	3																		70
	105	4					2																		6

Table D.8: Number of tugs per class - Shift section 105-NiN (June-July 2017)

		1			2					3a				3b				4			5	6			Total
From	To	0 tugs	1	2	0	1	2	3	4	0	1	2	3	0	1	2	3	2	3	4	3	2	3	4	
105	8	30			3	3	5																		41
	17	1			18	3																			22
	22	3			62	2	1																		68
	27	3			3																				6
	32	12			21	1																			34
	35	6			21		5				1	1													34
	42	3			46	2																			51
	55	5																							5
	60	2			37	1					1	1													42
	71	3																							3
	78	7																							7
	79	2				1	2																		5
	80	2			2	1	1																		6
	81	10	1																						11
	82	2				2																			4
	85	4			1	3	1																		9
	86	2				3																			5
	87	3			1																				4
	88	13			1	1	1																		16
	89	2	1			3	1																		7
	90	1																							1
	104	69	2	1	9		4																		85
	105	314	3	7	178	23	39			1	1		2												568
	NiN				1																				1
NiN	32				2																				2
	60				1																				1
	105				1																				1
Total		890	24	23	1733	243	221	1	1	9	11	47	12	1	2	12	4	6	4	3	1	1	1	3	3253

D.2 Tug locations

Table D.9 shows the locations were tugboats lay in wait between the various assignments. Table D.10 and figures D.1 and D.2 show the locations were the tug(s) will meet the vessel depending on the destination of the vessel.
This is the case for arriving vessels, if a vessel is leaving a berth the tugs will meet the vessel at the berth.

Table D.9: Tugboat waiting locations

Name	Section
Scheurhaven	8
4e PET	8
Tenessee-haven	11
Wilhelmina-haven	105

Table D.10: Tug rendezvous locations (Port of Rotterdam, 2016a)

	Destination section	Meeting section (approximate)
1	11 17 18 19 22 27 32 35 42 45 46 49 50 55 58 59 60	10
2	7	6
3	8	8
4	71 78 79 80 81 82 83 84 85 86 87 88 89 90	71
5	104 105	78

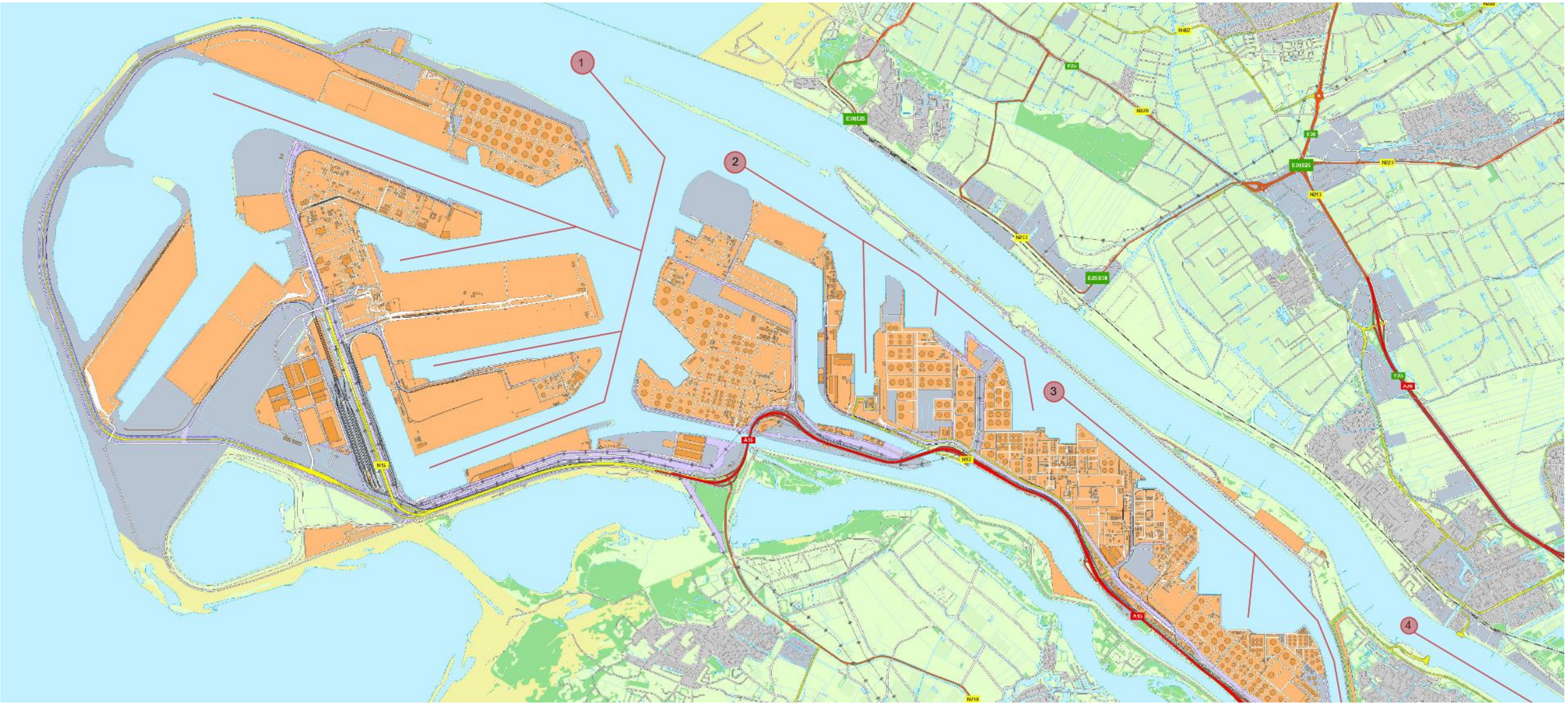

Figure D.1: Tugboat Rendezvous locations - (Port of Rotterdam, 2016a)

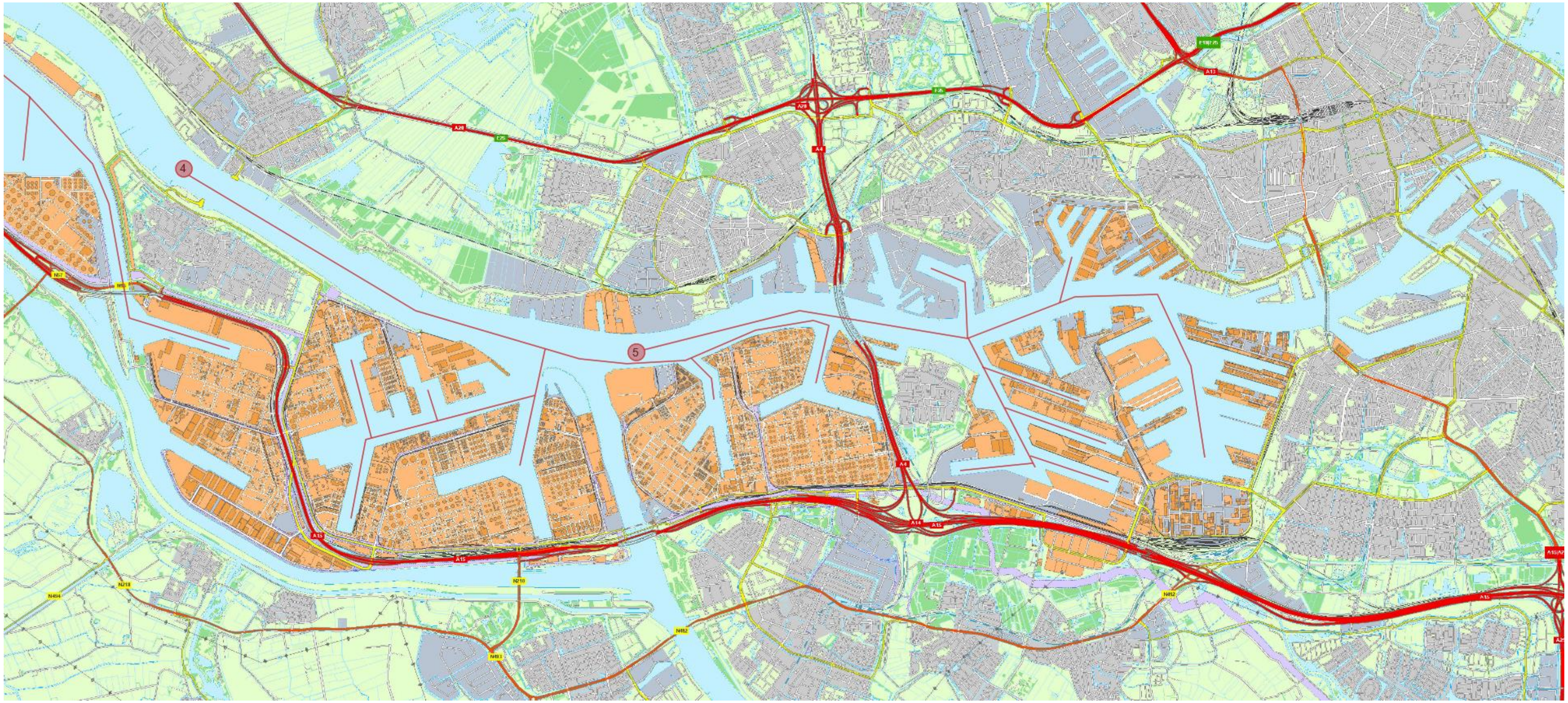

Figure D.2: Tugboat Rendezvous locations - East (Port of Rotterdam, 2016a)

E | Boatmen

E.1 Boatmen distribution

The following table shows whether boatmen were use or not for the voyages in the period June-July 2017. The tables show the sections the boatmen were deployed and which vessel class was serviced.
Table E.1 shows the boatmen deployment for arriving voyages and table E.2 for departing voyages.
Tables E.3 and E.4 show the usage of boatmen for shifting voyages. This has been divided into the usage at departure berths and arrival berths.

Table E.1: Boatmen team distribution per class per section - Arrival(June-July 2017)

Arrival	Class 1		2		3a		3b		4		5		6		Total
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	
Section 5					181		2								183
8	23	185	172	427	76	114		43		6				12	1058
11	3	1		1		21		10		1		1		6	44
17		1													1
19		6		28		10	1	5							50
22	1	13	1	110		42		21		45		5			238
27	5	14		2		1		1							23
32	3	27		35		83				20					168
35	2	20		35		35		1		25		1			119
42		6	1	72						25		5			109
45	1														1
46		2													2
50				1		5		4						1	11
55	4	4	3	2											13
60	2	3	2	73		49				31		9			169
71		2		3		2									7
78	1	3		8		4									16
79		42		25											67
80		15		12											27
81		26		32		1		1							60
82		18		29											47
83		1													1
84		7		1											8
85		21	1	20		4									46
86	1	21		12											34
87		9		6											15
88	10	46		29		3									88
89	2	50		16											68
90		12		8		1									21
92		8		4											12
104	53	130	161	115	5	1									465
105	296	647	92	510		46				1					1592
Total	407	1340	433	1616	262	422	3	86		154		21		19	4763

Table E.2: Boatmen team distribution per class per section - Departure(June-July 2017)

Departure	Class 1		2		3a		3b		4		5		6		Total
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	
Section 5					181		2								183
8	13	182	171	434	76	119		41		6		1		11	1054
11	3	1		1		21		13		1				8	48
17				1											1
19		7		29		6		5							47
22	1	14		111		44		21		48		5			244
27	4	11		2		1		1							19
32	1	17		37		86				21					162
35	1	13		55		33				21		1			124
42		9	1	73						25		5			113
45	1														1
46		2													2
50				3		6		5							14
55	2	3	3	2											10
60		4	2	64		44		1		31		9			155
71		1		3		2									6
78		6		7		2									15
79		43		30											73
80		22		12											34
81		29		25		1									55
82		17		23											40
83		1													1
84		3		1											4
85		23	1	17		4									45
86		22		14											36
87		8		4											12
88	1	49		27		3									80
89		54		22											76
90		14		9		1									24
92		9		5											14
104	23	146	165	127	6	3									470
105	282	708	90	489		46				1					1616
Total	332	1418	433	1627	263	422	2	87		154		21		19	4778

Table E.3: Boatmen team distribution per class per section - Shifting: departing berth (June-July 2017)

Shifting	Class 1		2		3a		3b		4		5		6		Total
Departing berth	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	
Section 8	17	60	39	142	2	38	1	8		7		1		2	317
11						2		4						3	9
17		5	4	125											134
19		1		4				2		1					8
22	2	24	14	283	1	4				3					331
27	7	7	3	43											60
32	5	21	12	173		5				1					217
35	1	7	9	103		5									125
42		19	13	251											283
50				3		7		3							13
55	1	1		2											4
60	2	15	19	215		4		1		1					257
71		2													2
78	2	9		12											23
79		5	1	24											30
80	1	9	1	18											29
81		18		15											33
82	1	5		19											25
84		2													2
85		23		15											38
86		7		20											27
87		7		6											13
88	3	16		5											24
89		12		28											40
90	5	1		2											8
92		3		2											5
104	24	70		53		3									150
105	217	289	75	435		8									1024
NiN				4											4
Total	288	638	190	2002	3	76	1	18		13		1		5	3235

Table E.4: Boatmen team distribution per class per section - Shifting: arriving berth (June-July 2017)

Shifting	Class 1		2		3a		3b		4		5		6		Total
Arriving berth	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	
Section 8	14	81	37	138	2	33		11		7				3	326
11						2		1				1		1	5
17		6		128											134
19				3		4		3		1					11
22		25	9	292		3									329
27	6	12	1	46											65
32	9	29		183		2									223
35	2	14	2	90		7		1		4					120
42	1	15	2	262											280
50				1		6		2						1	10
55	3	2		2											7
60	1	17	2	244		9				1					274
71		3													3
78	1	7		13		2									23
79		5		20											25
80		3		19											22
81		15		22				1							38
82		7		24											31
84	1	5													6
85		21		18											39
86		7		19											26
87		8		8											16
88	1	23		7											31
89		10		22											32
90		4		1											5
92		2		1											3
104	43	63		37		1									144
105	132	337	58	482		8									1017
NiN		2		6											8
Total	214	723	111	2088	2	77		19		13		1		5	3253

The following table and two figures show the locations the boatmen are stationed.

E.2 Boatmen locations

Table E.5: Boatmen locations

	Name	Section
1	Prinses Margriet haven	59
2	Pistoolhaven	17
3	Scheurhaven	8
4	4e PET	8
5	Wezerhaven	8
6	Geulhaven	78
7	Sleepboothaven	105

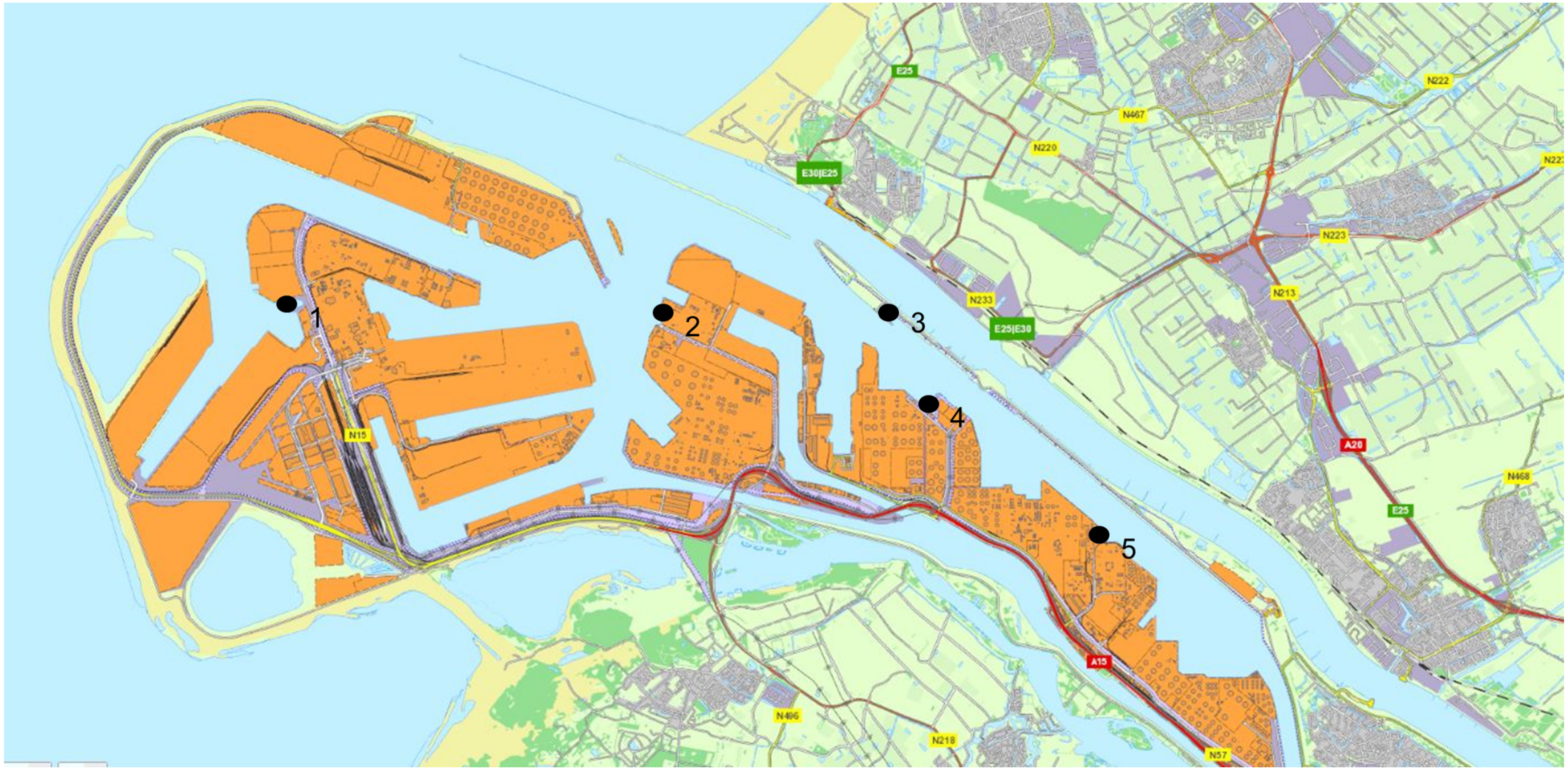

Figure E.1: Boatmen locations - West

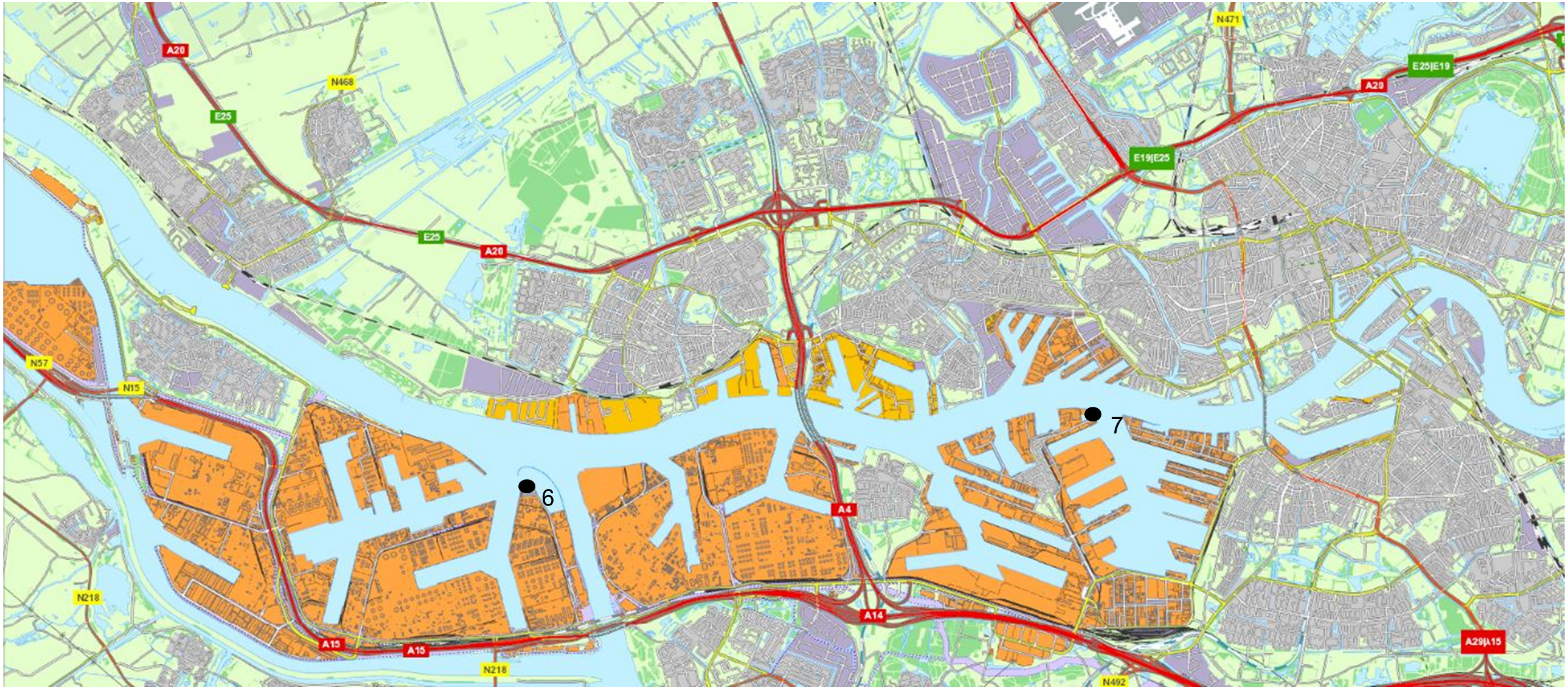

Figure E.2: Boatmen locations - East

F | Terminal

Table F.1 shows the average service time at various terminals in various sections.

Table F.1: Terminal average service times [hrs] (TBA, 2017)

Terminal	Section	Class 1	2	3a	3b	4	5	6
Hoek van Holland Stena	5	6:00	6:00	6:00				
Shtandart Noord Berth	7		15:31	17:49	17:49		19:42	
Caland	8	6:00	11:00	11:00	11:00	19:00	19:00	
MV1 - Gate	11							
MV1 - MOT	11			21:00		21:00	21:00	21:00
Tennesseehaven	11		15:31	17:49	17:49		19:42	5:38
Indorama	11	10:00	10:00					
BP	19	16:00	16:00	16:00	16:00	18:00	17:00	
MV1 - ECT Delta Amazonehaven	22		10:00	10:00	10:00	18:00	18:00	
MV1 - EMO Amazonehaven	22	10:00	10:00	10:00	10:00		17:00	17:00
MV1 - Brammernterminal Steinweg	27	6:00	11:00	11:00	11:00			
MV1 - EMO Mississippihaven	27	10:00	10:00	10:00	10:00	17:00	17:00	
MV1 - ECT Delta Europahaven	32		10:00	10:00	10:00	18:00	18:00	
MV1 - Rhenus Logistics	32		5:00	5:00	5:00			
MV1 - APMT Rotterdam	35		10:00	10:00	10:00	18:00	18:00	
MV1 - Lyondell	35	12:00	16:00	16:00				
MV1 - Euromax	42	10:00	10:00	10:00	10:00	18:00	18:00	
MV2 - Euromax	46	5:15	10:20	10:20	10:20	18:30	18:30	
MV2 - T3 west	50	5:15	10:20	10:20	10:20	18:30	18:30	0:00
MV2 - T3 oost	50	5:15	10:20	10:20	10:20	18:30	18:30	0:00
MV2 - SIF	55	5:15	10:20	10:20	10:20	18:30	18:30	0:00
MV2 - APMT (T1)	60	5:15	10:20	10:20	10:20	18:30	18:30	0:00
MV2 - RWG (T2)	60	5:15	10:20	10:20	10:20	18:30	18:30	
1e werkhaven	78	15:00	16:40	16:40	18:20			
3e PET centraal	79	15:00	16:40	16:40	18:20			
3e PET noord	80	15:00	16:40	16:40	18:20			
3e PET zuid-oost	81	15:00	16:40	16:40	18:20			
3e PET zuid-west	82	15:00	16:40	16:40	18:20			
Botlek centrale geul oost	83	15:00	16:40	16:40	18:20			
Botlek centrale geul 2e WH	84	15:00	16:40	16:40	18:20			
2e Werkhaven	85	15:00	16:40	16:40	18:20			
Botlek centrale geul TH	86	15:00	16:40	16:40	18:20			
Botlek centrale geul west	87	15:00	16:40	16:40	18:20			
Sint Laurenshaven	88	15:00	16:40	16:40	18:20			
Chemiehaven	89	15:00	16:40	16:40	18:20			
Botlek West	90	15:00	16:40	16:40	18:20			
Stad	105	7:38	12:38	12:33	12:33	20:33		
Achterland/Transit	105	0:00	0:00	0:00				

G | Information

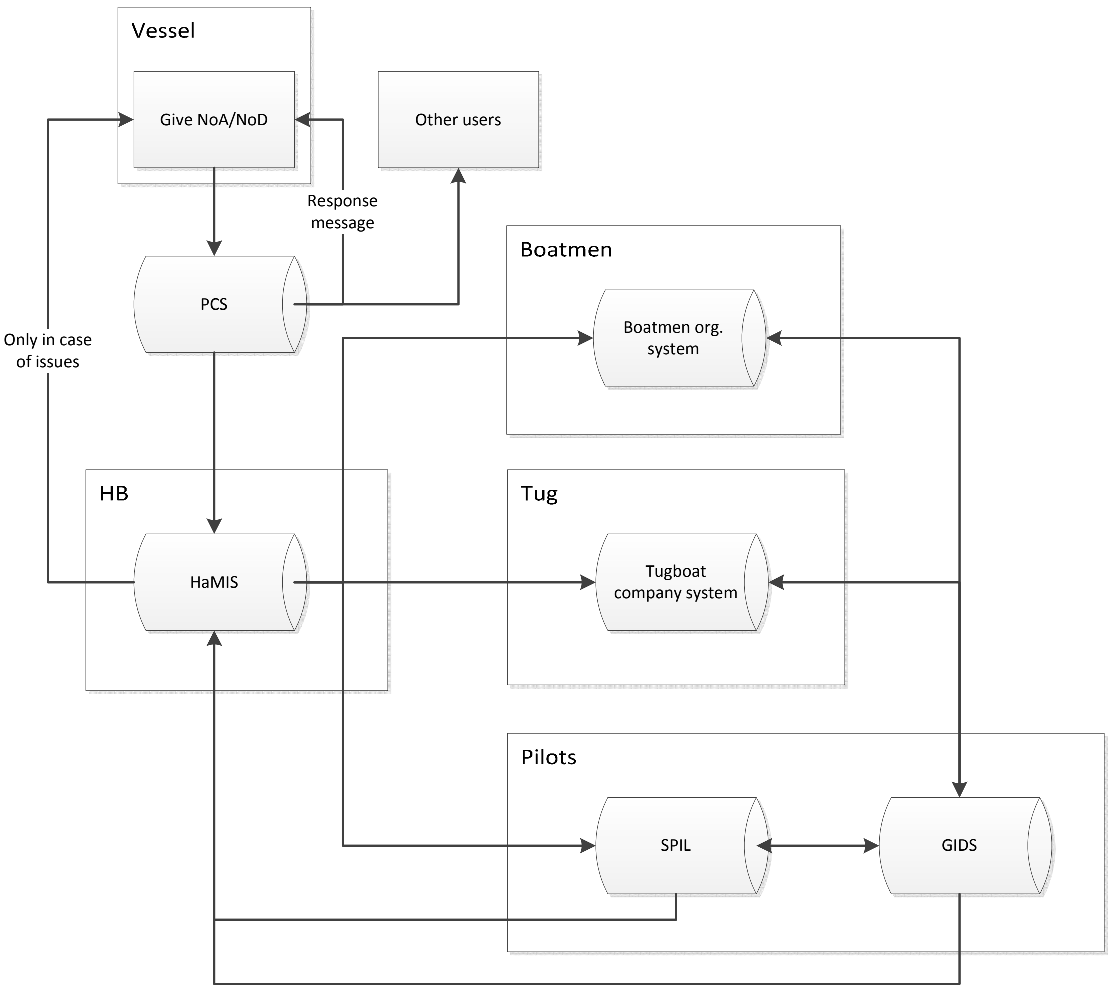

Figure G.1: Information sharing in the operational phase

H | Process maps

In this appendix all the process maps discussed and shown in part III are shown in a larger format.

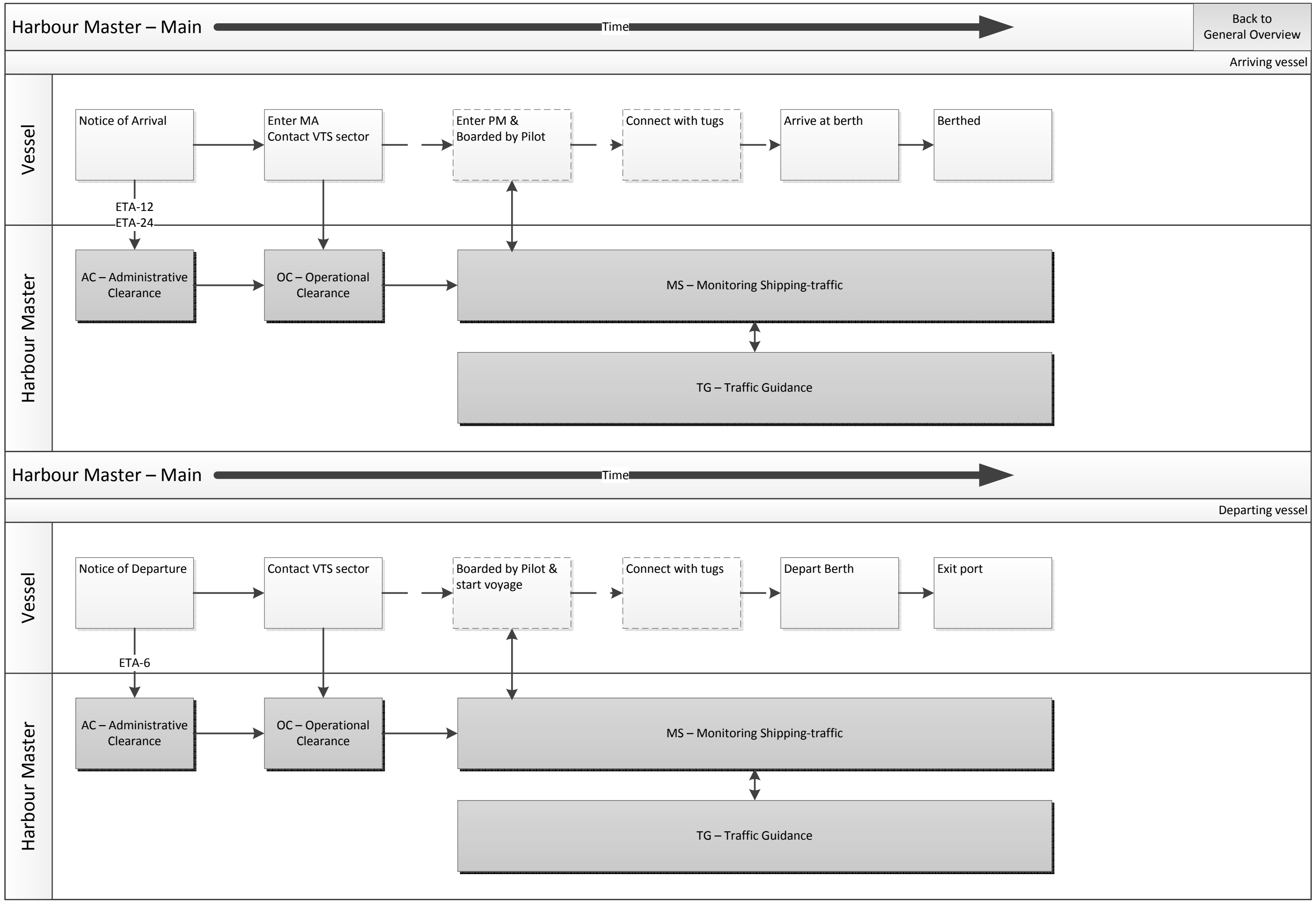

Figure H.1: Harbour Master - Main overview

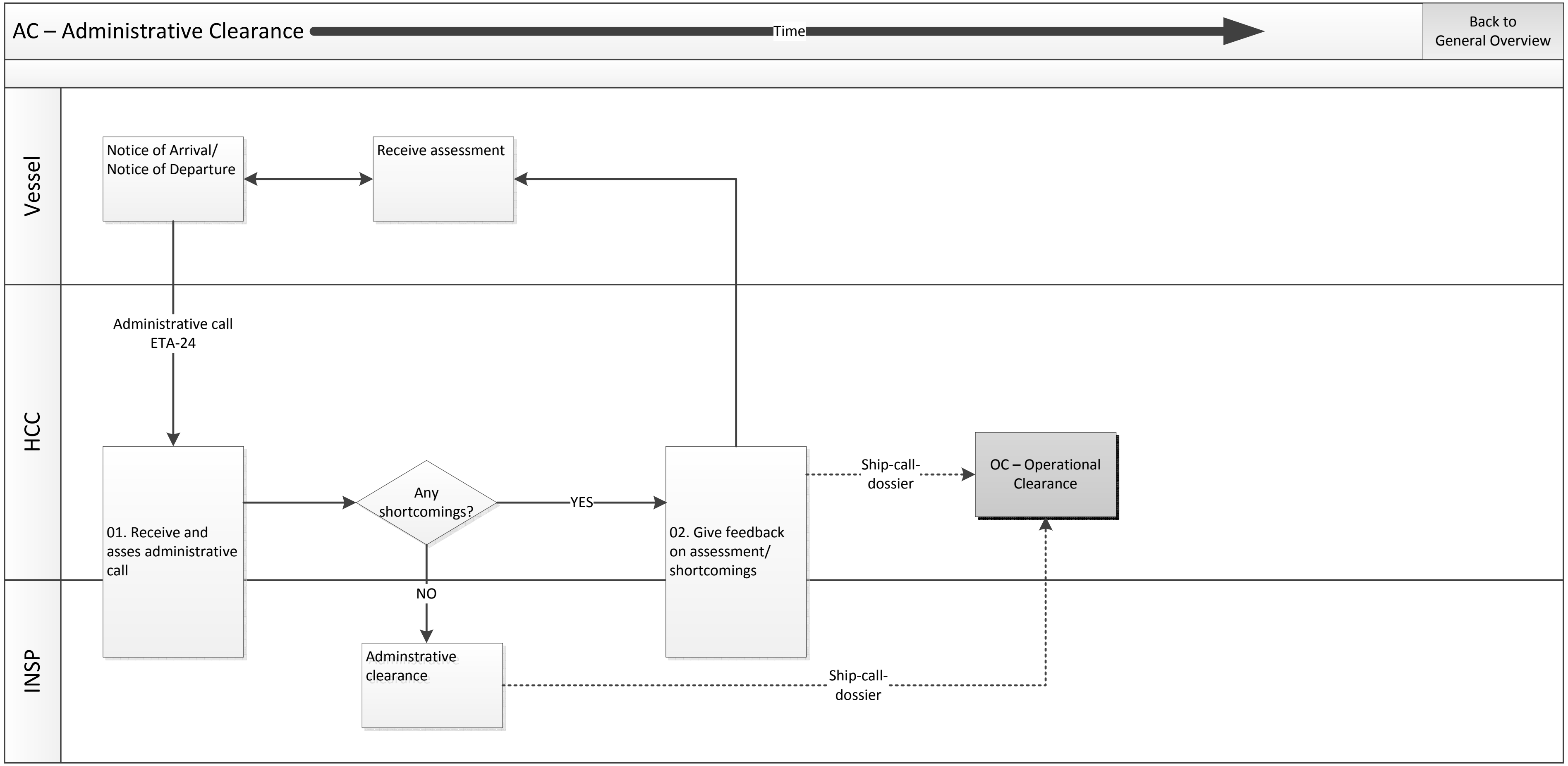

Figure H.2: Harbour Master - Administrative Clearance

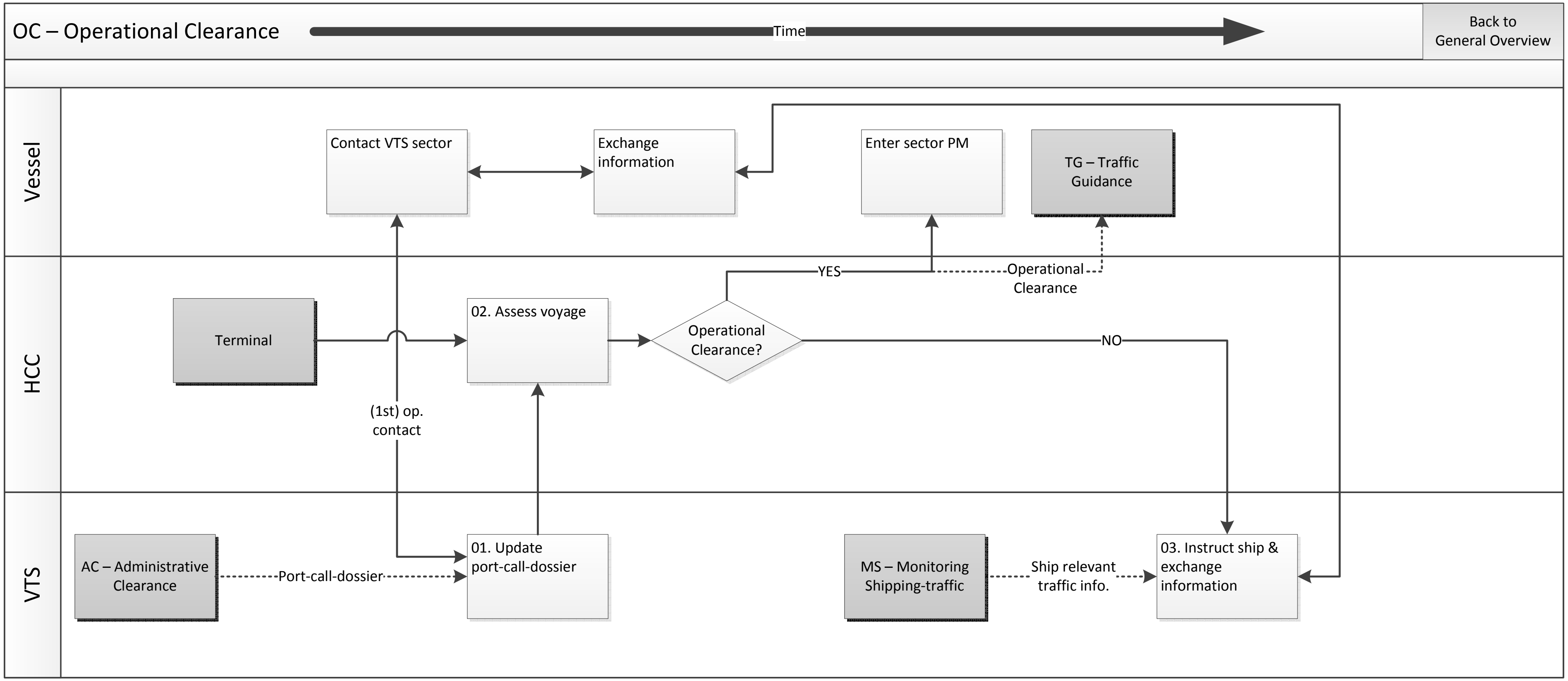

Figure H.3: Harbour Master - Operational Clearance

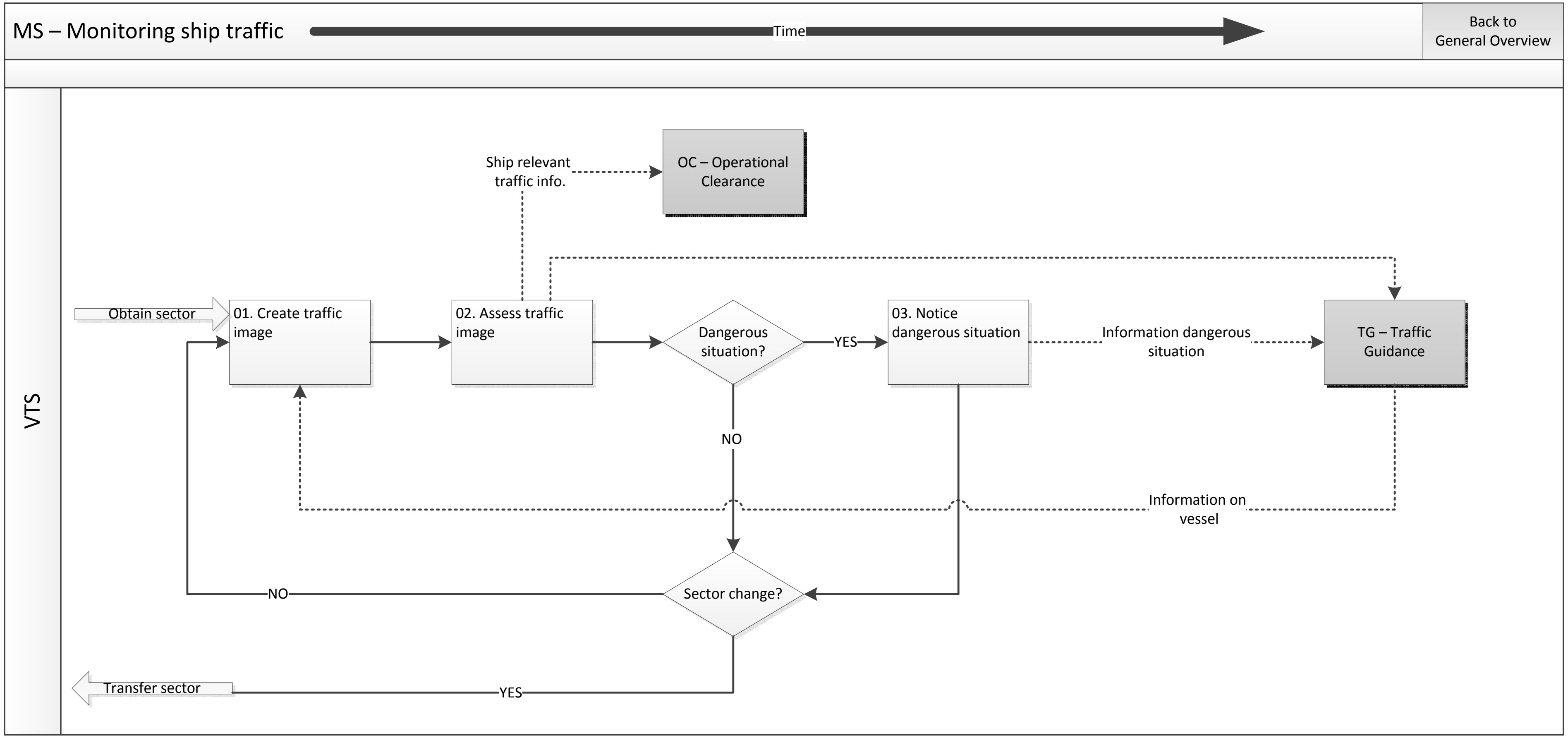

Figure H.4: Harbour Master - Monitoring Ship traffic

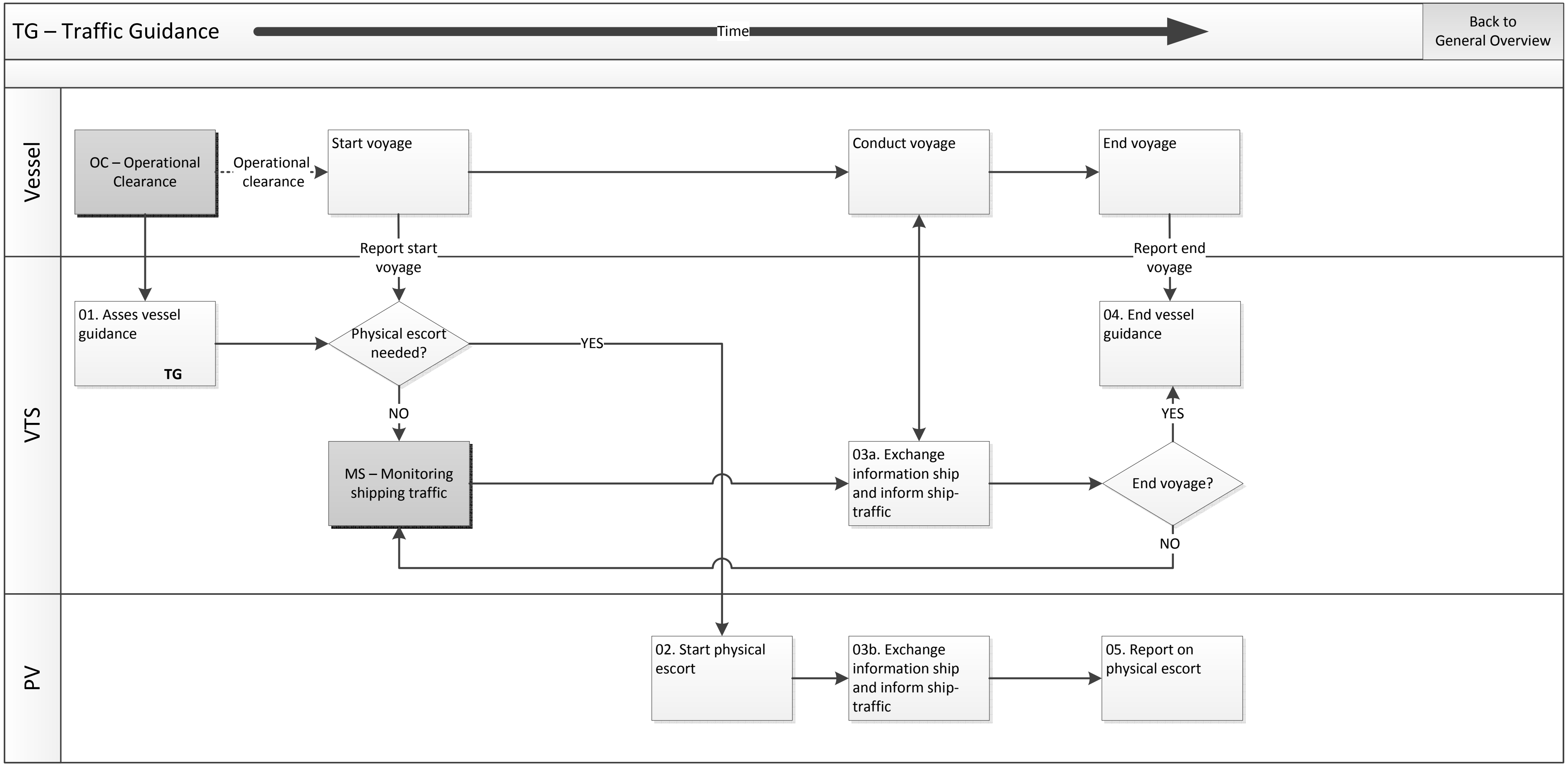

Figure H.5: Harbour Master - Traffic Guidance

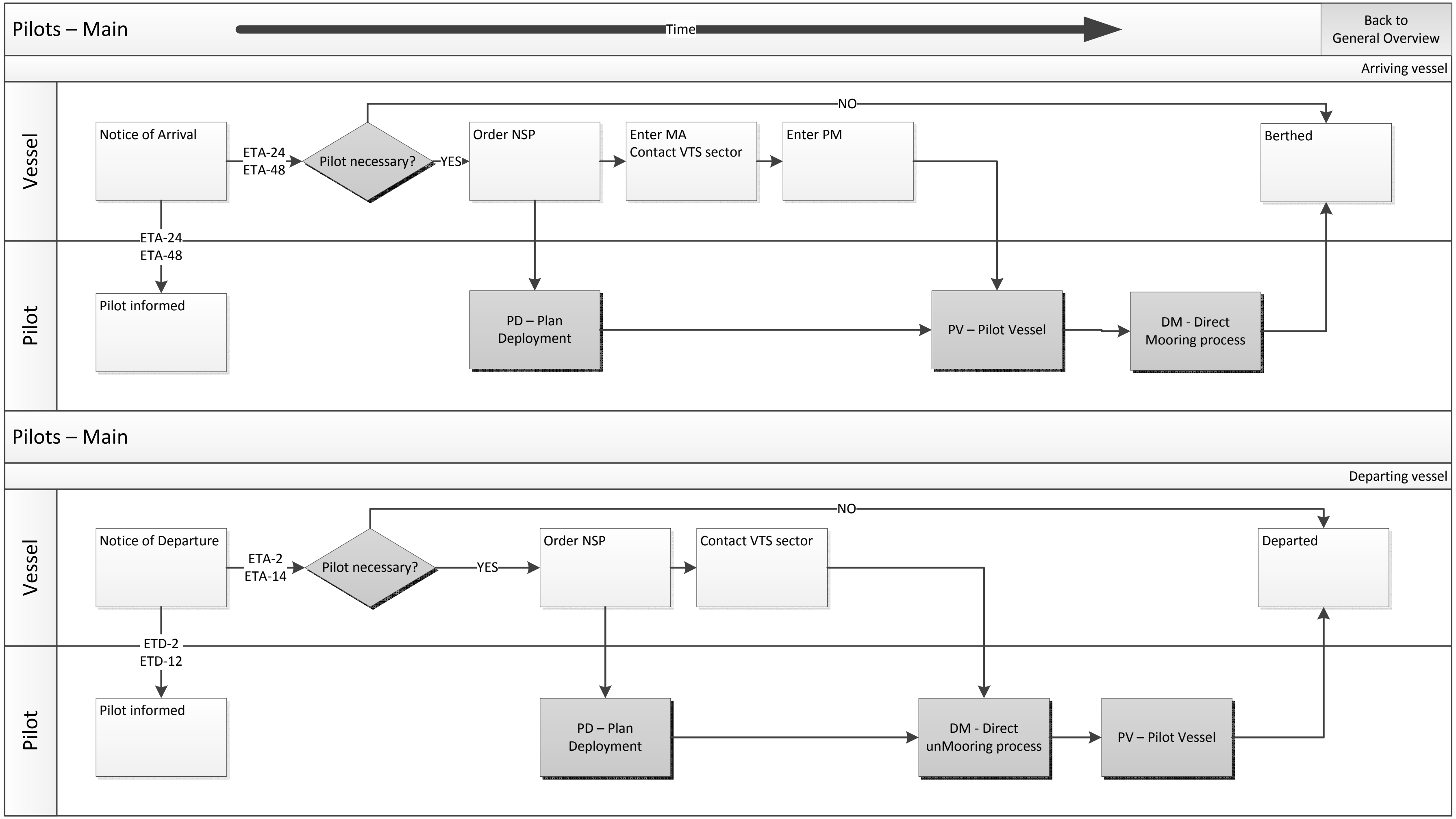

Figure H.6: Pilot Organisation - Main overview

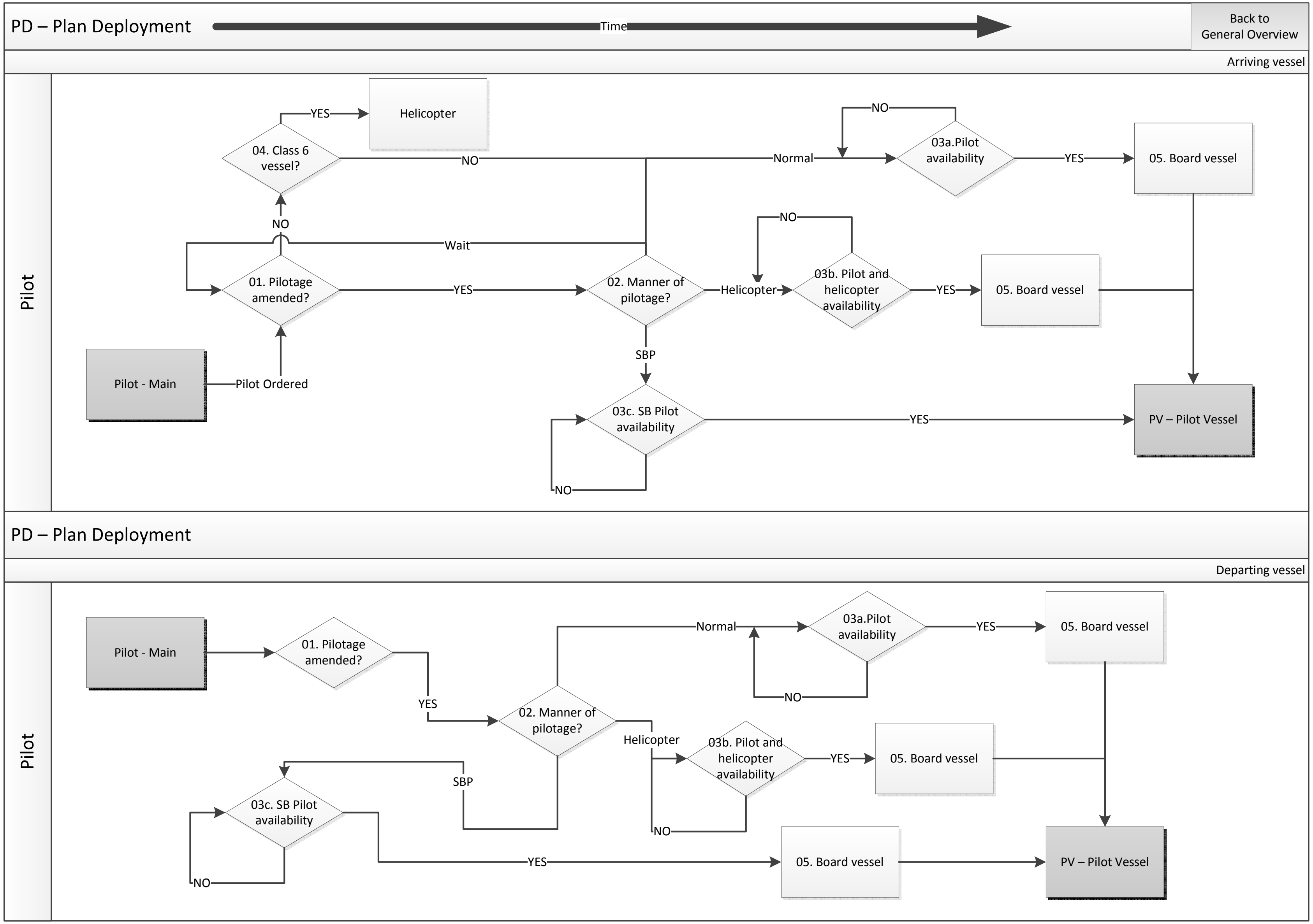

Figure H.7: Pilot Organisation - Plan Deployment

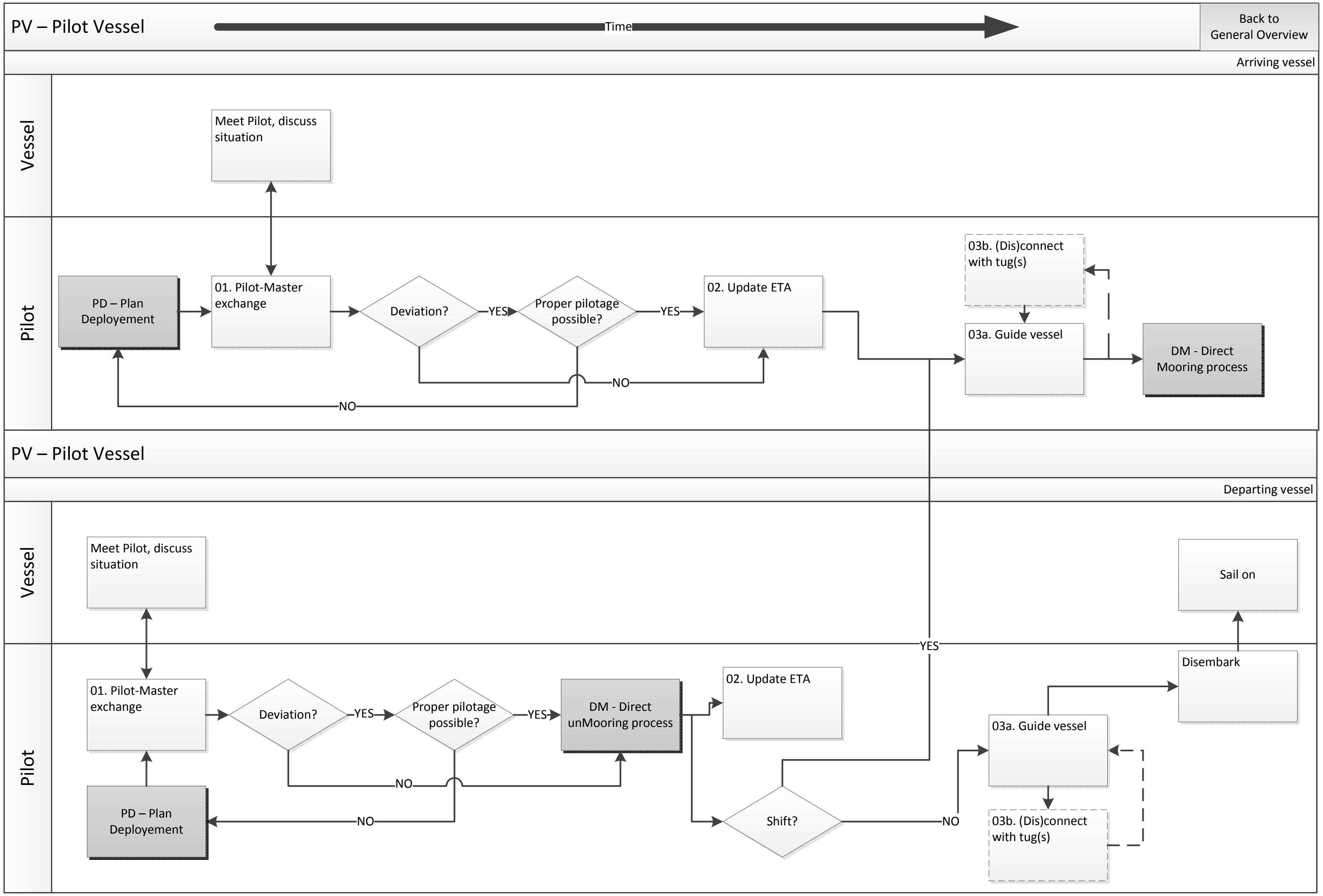

Figure H.8: Pilot Organisation - Pilot Vessel

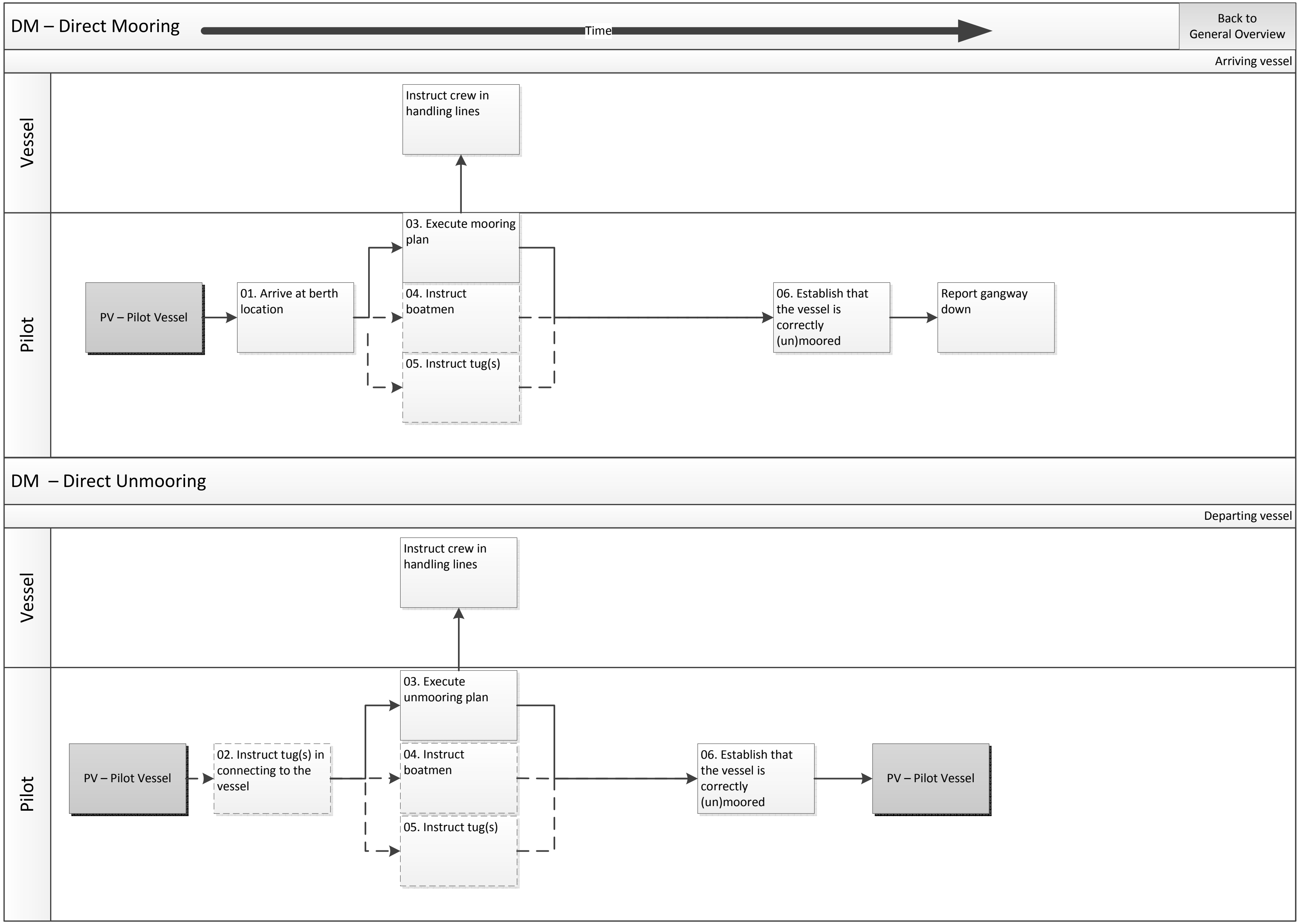

Figure H.9: Pilot Organisation - Direct (un)Mooring process

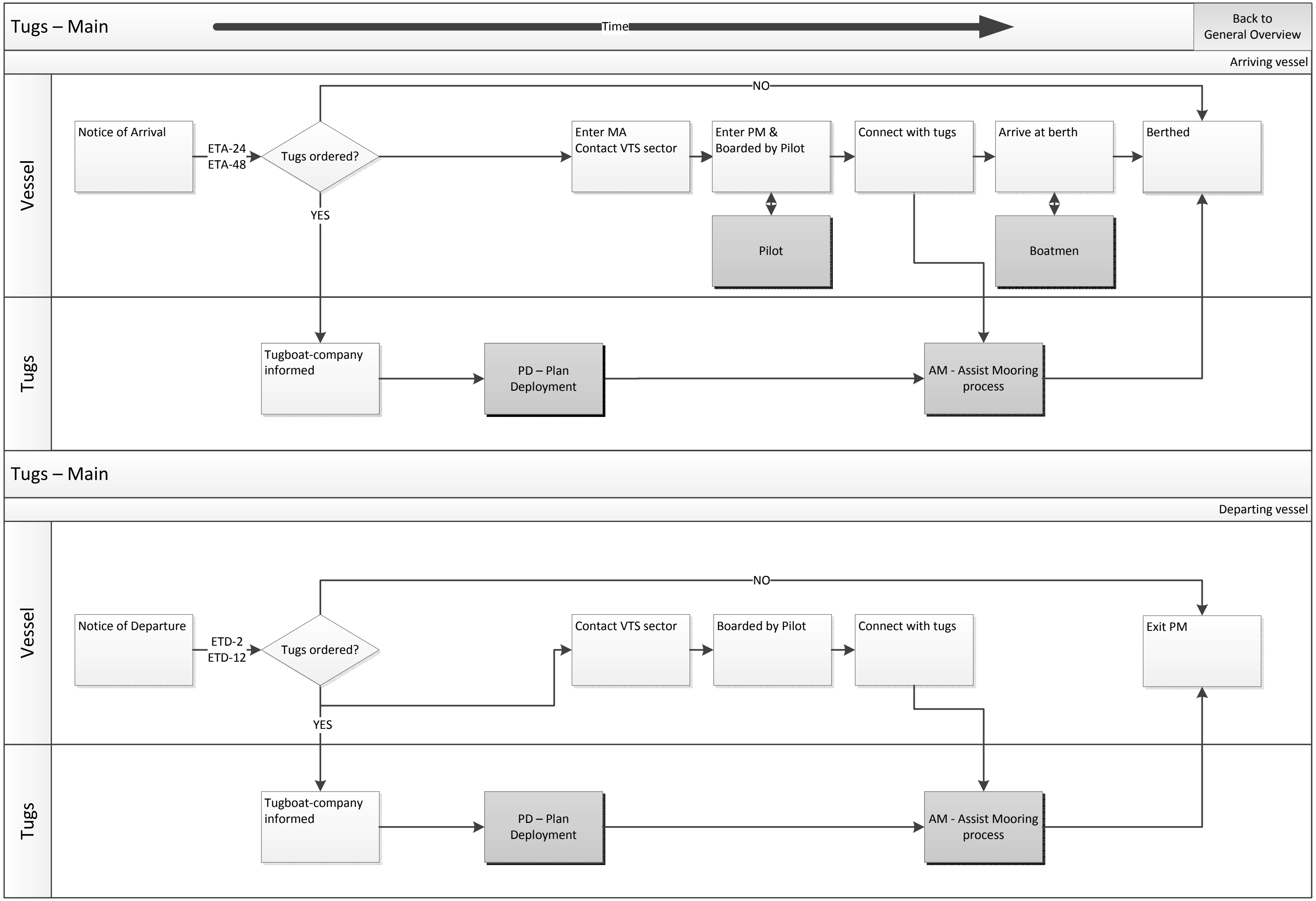

Figure H.10: Tugboat company - General overview

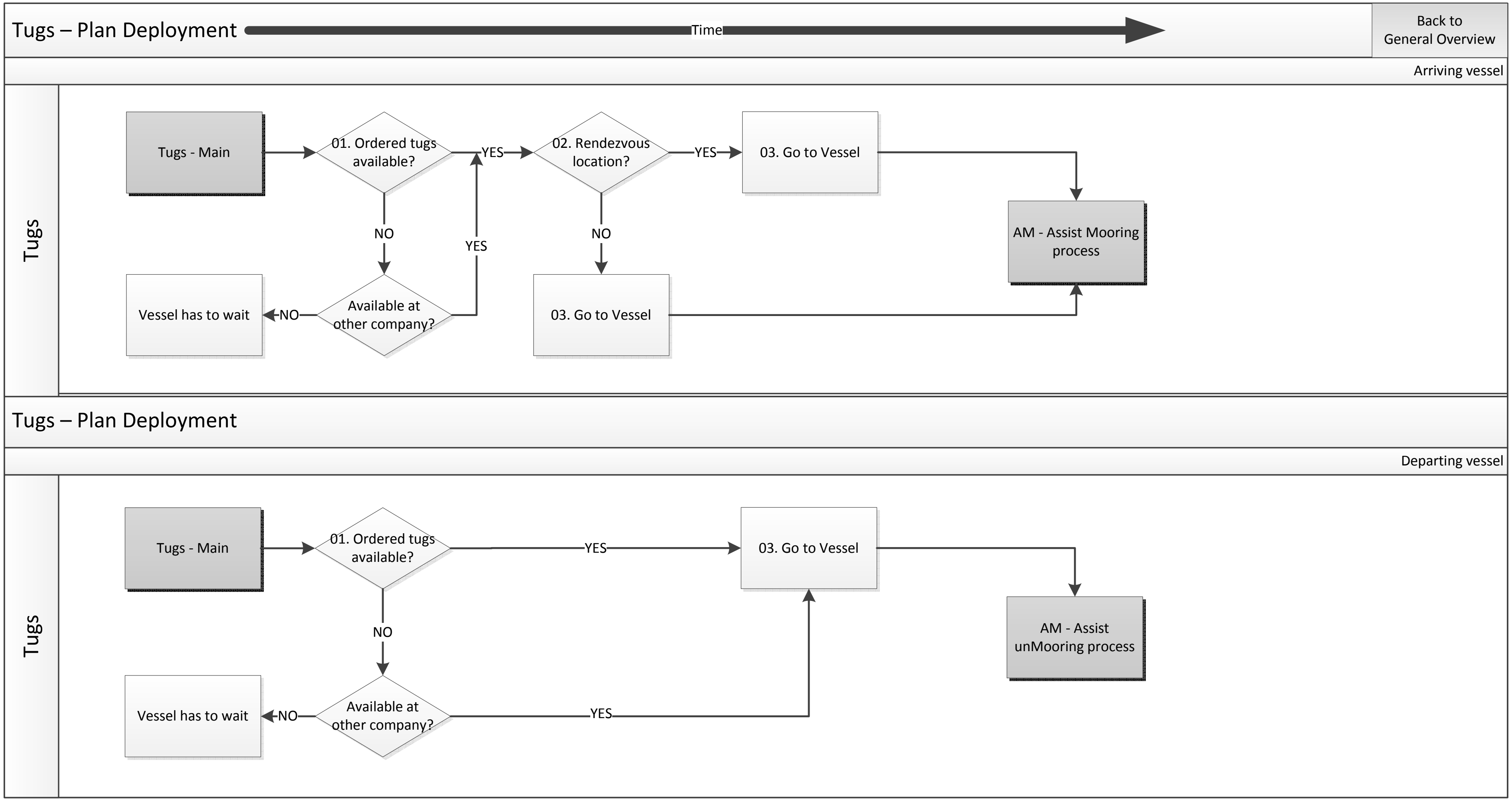

Figure H.11: Tugboat company - Plan Deployment

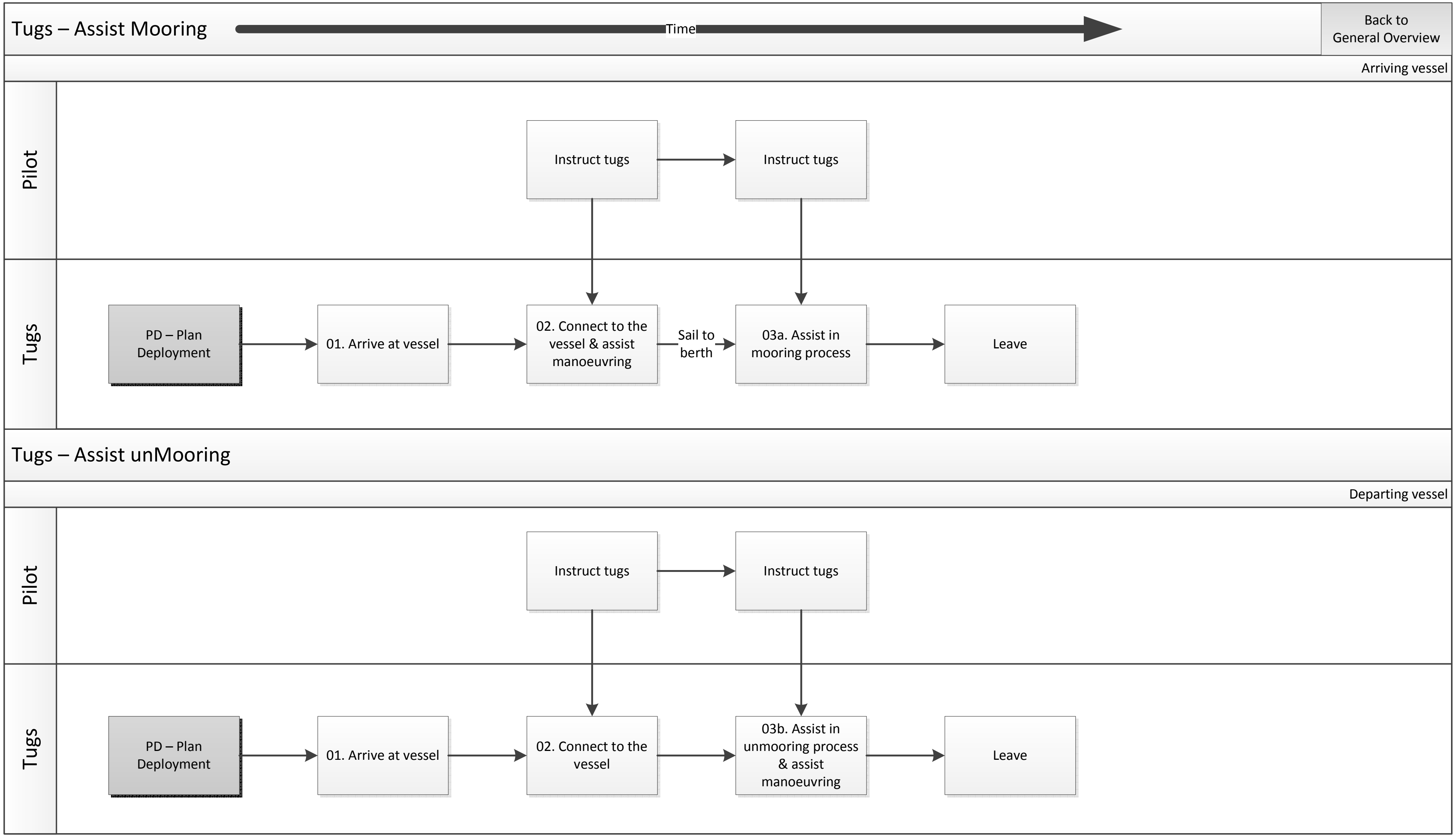

Figure H.12: Tugboat company - Assist (un)Mooring

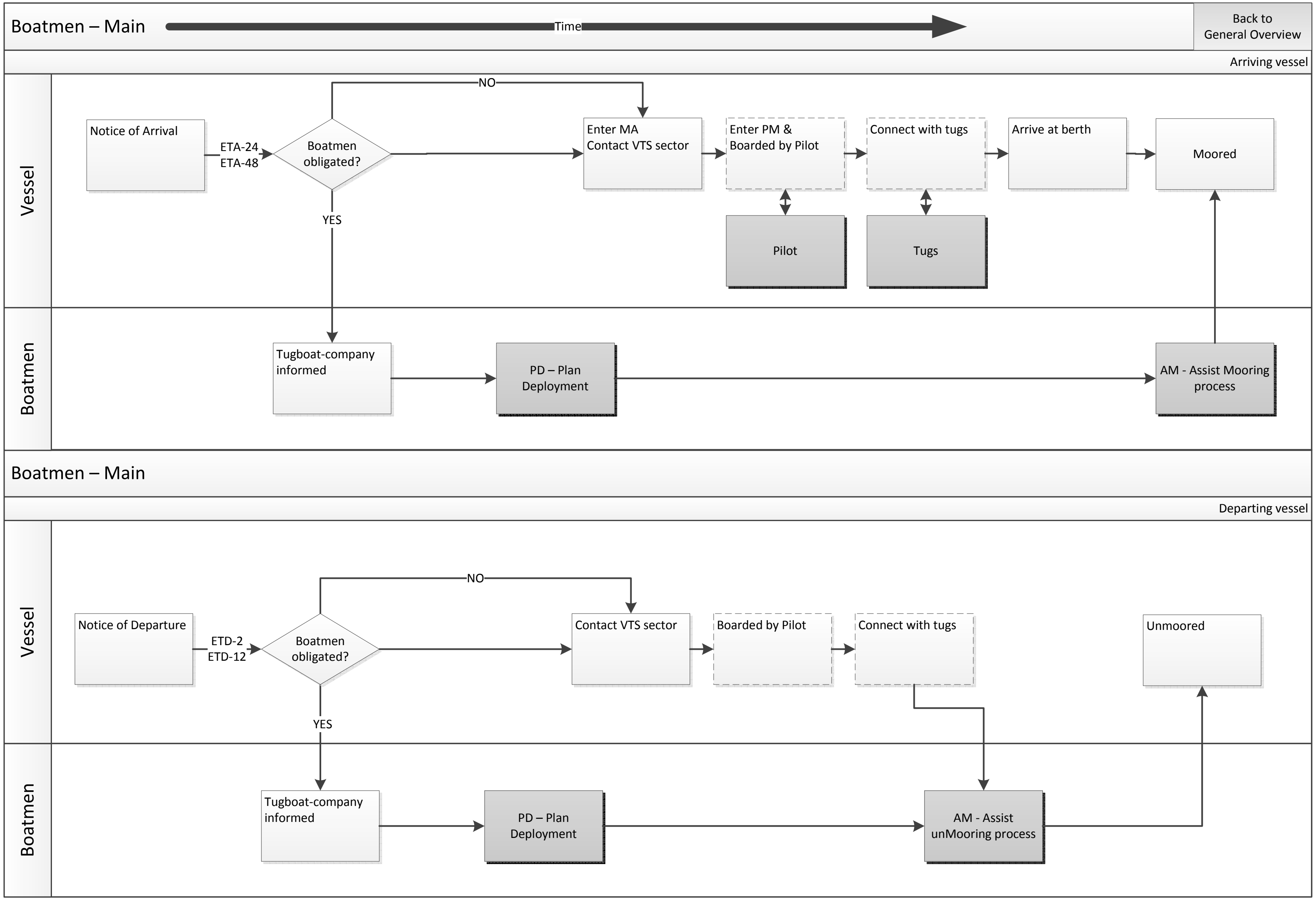

Figure H.13: Boatmen-organisation - General overview

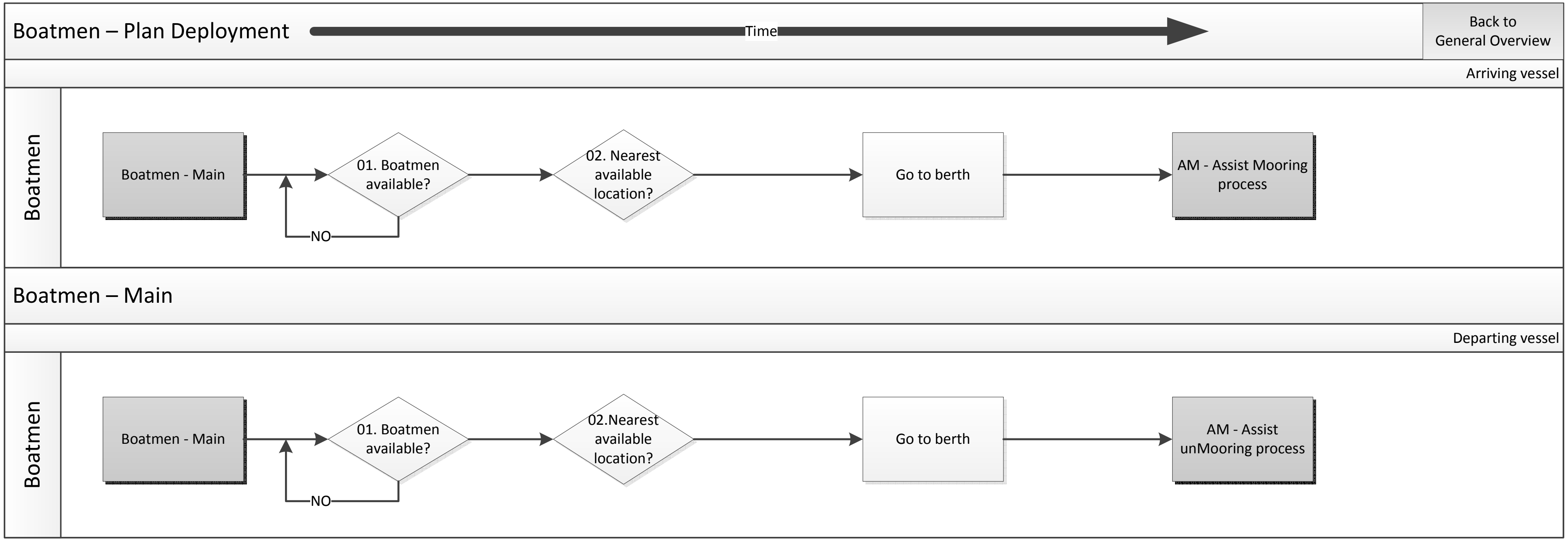

Figure H.14: Boatmen-organisation - Plan deployment

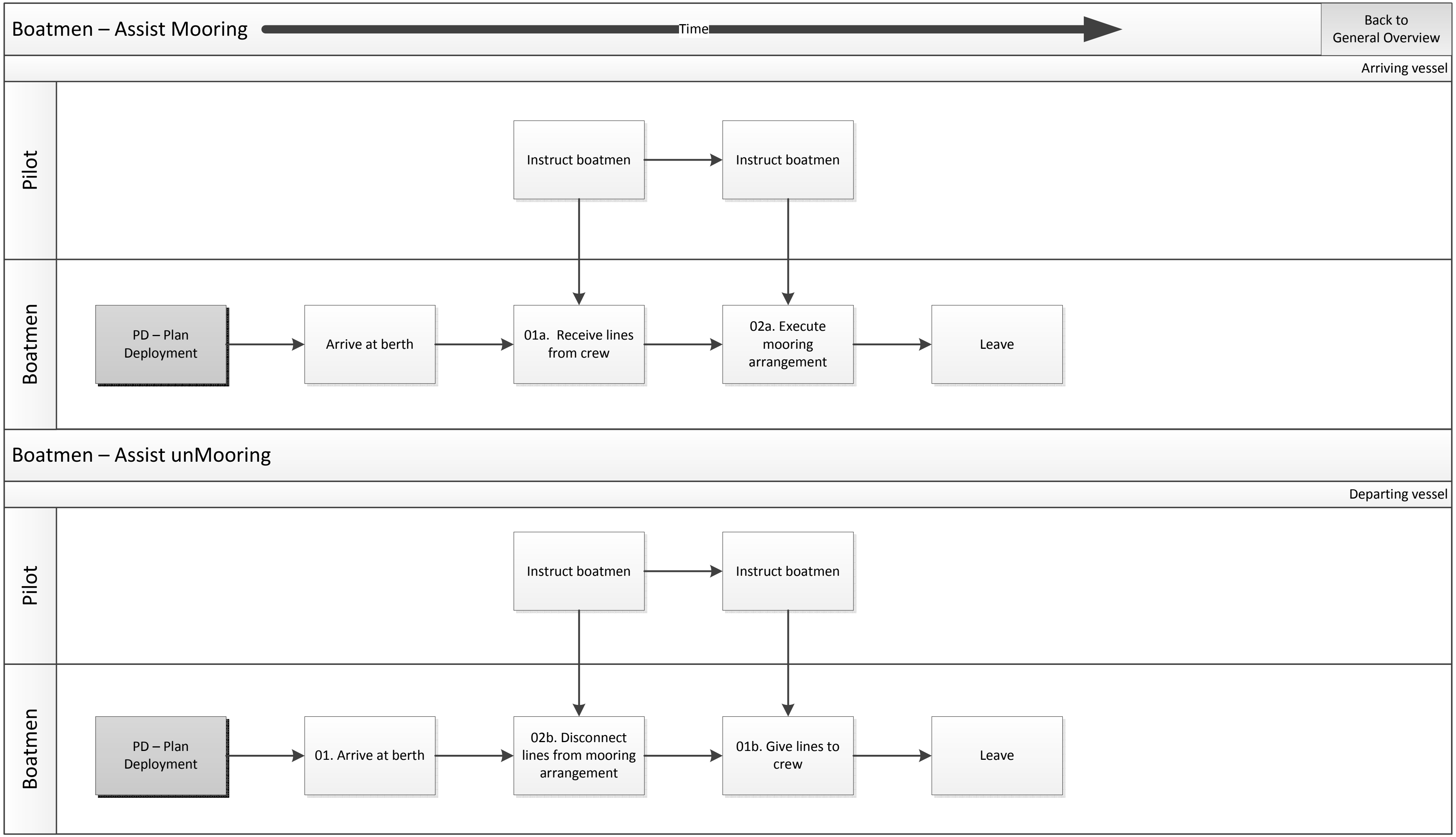

Figure H.15: Boatmen-organisation - Assist (un)mooring

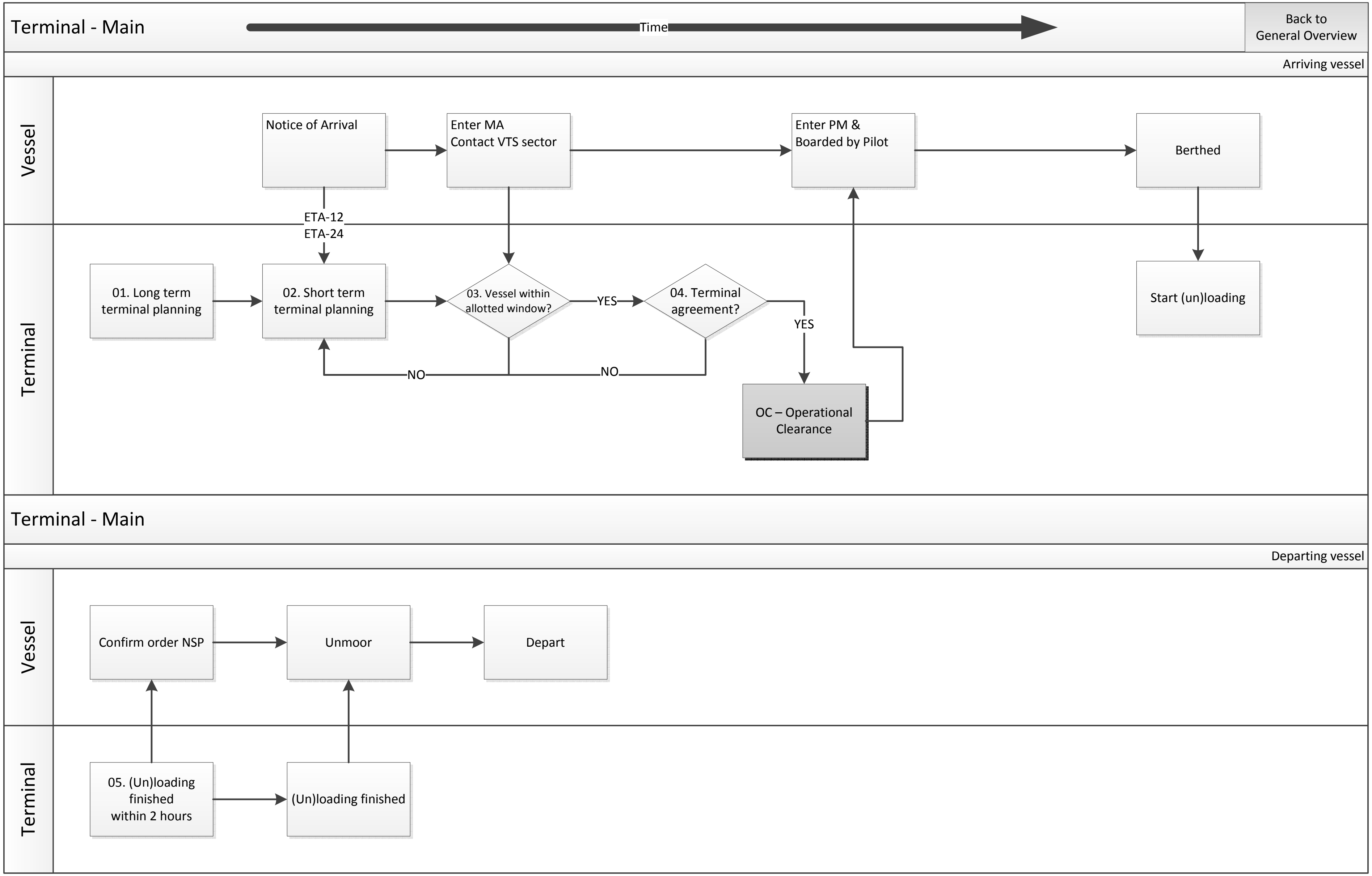

Figure H.16: Terminal processes

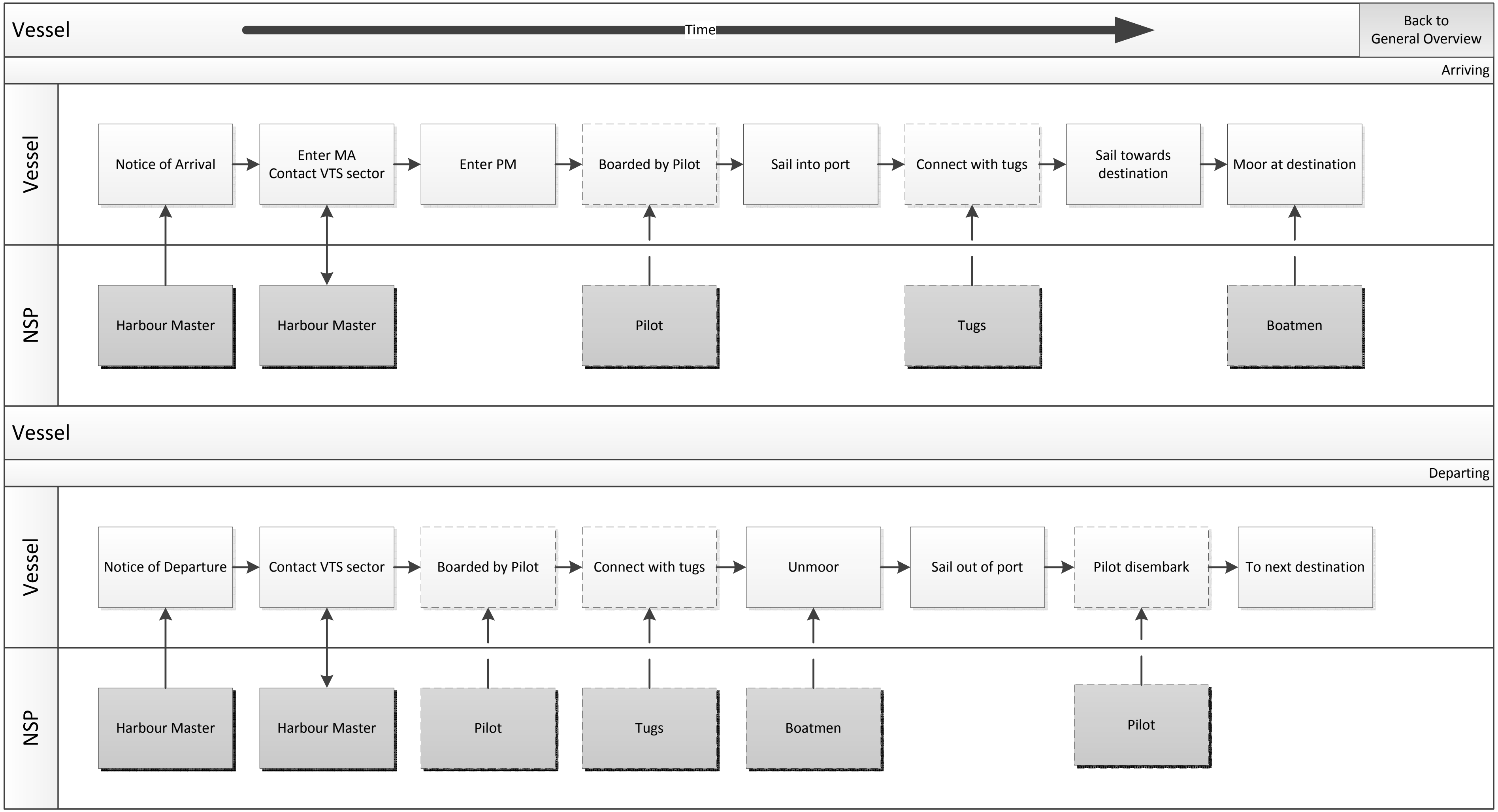

Figure H.17: Vessel processes