Digitization of Vessel Traffic Management in port areas

Gaining insight into VHF-communications and research into solutions for further reduction

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By

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Preface

In front of you lies my master thesis, which concludes eight very pleasant years at the Delft University of Technology. These eight years are characterized by valuable experiences, both inside and outside my studies. By means of this preface I would like to reflect on those years and thank the people who made this possible.

I grew up close to Rotterdam and I have come into contact with the Port of Rotterdam already from an early age. Later, through a side job on a container terminal, I was able to experience this world with my own eyes. Especially the huge vessels in combination with the big infrastructural projects appealed to me. Next to that, the atmosphere and no-nonsense mentality in the port suits me well, or how we say it in Rotterdam: the "*niet lullen maar poetsen*" mentality. For that reason, I chose the Ports & Waterways track in the master Hydraulic Engineering. I am glad that, by means of this thesis, I have been given the opportunity to contribute to the development of the Port of Rotterdam.

The journey of writing my master thesis started over a year ago. Working on this thesis went very different from the way I had expected. Due to the Covid-19 pandemic, I had to work from home from week two onwards and unfortunately this is still the scenario at the moment of writing this preface. Of course, this is unfortunate, however I have to admit that I never had the feeling that I would be delayed as a result. Therefore, a big compliment goes to the Rotterdam Port Authority and its employees, which ensured that the transition to working from home has been seamless. Special thanks go to Marcel Oosterbaan for providing me access to the VTS-centre to perform my analyses. A special acknowledgement goes to my daily supervisor Harmen van Dorsser: I am very grateful for the extensive support in the entire process of writing my thesis. All the phone calls, meetings, walks, coffee breaks and Turkish pizzas, in combination with your attendant enthusiasm and positivity, have always helped me to overcome the days I was stuck. When the pandemic measures do permit, we will definitely go out for a beer!

Furthermore, I would like to thank my graduation committee from the TU Delft. First, I would like to thank Mr. van Koningsveld for chairing the committee and for his valuable feedback during the entire process. The same goes towards the other members of my graduation committee, Mr. Bolt and W. Daamen, for guiding me during this process and always providing me with relevant feedback. I would also like to thank Fedor Baart for helping me during the setup of my models in python. Finally, I would like to thank David Woudenberg, for providing the radar images of the MSC Factofour.

The last word goes to my family and friends. First, to my fellow roommates Davey and Bas, who always provided me with some fresh advice and more importantly, helped me to not think too much about my thesis from time to time as well. Another note goes to the friends I've met over the years, the friends from my hometown, the boys from my football team, the friends from Civil Engineering and the people I've met in South Africa: What a great party we made of it! My last word goes towards my parents, Frank and Ellen: I can't be grateful enough for the unconditional support over the years.

S.J. Allersma
Rotterdam, March 2020

Abstract

High vessel traffic densities, restricted water areas, and low manoeuvrability are common factors that form constraints for the navigating vessels in port areas. While navigating through these areas, vessels get assisted by the Vessel Traffic Service (VTS). VTS operators (VTSO) are monitoring the vessels in ports and provide the navigating skippers with the required information to ensure the safety and efficiency of the vessel traffic in the port. Information is communicated using very high frequency (VHF) radios on the corresponding VHF-channels of the sectors. In busy sectors in the port, these VHF-channels are very crowded, which results in unclear situations and high workloads for the VTSOs. The Rotterdam Port Authority is currently investigating measures to reduce VHF-traffic.

To define effective measures, it is required to understand by which factors the VHF-communications are triggered. In this thesis, a quantitative method has been developed to investigate whether VHF-communications are caused by certain properties of a fairway system. The method is based on analysing VHF-traffic and identify factors that lead to an increase in these communications. The main component is digitizing the VHF-communications, which is achieved by converting spoken VHF-audio bands to text, then dividing this text into different conversations and finally classifying each phrase according to place, time and content. Subsequently, the spatial and temporal characteristics of the VHF-communications are linked to spatial and temporal characteristics of a property of the fairway system, to analyse whether the occurrence of a particular form of VHF-communication is related to the occurrence of that particular property of the waterway system. The method can be applied to investigate the individual influence of several fairway properties, but in this research the focus is on analysing to what extent the fairway property "blocked view" leads to the development of VHF-communications. To investigate whether VHF-communications are related to the occurrence of visual obstructions, a method is developed to estimate the visibility for varying locations and vessel parameters.

To map the visibility of vessels of different locations, a model has been set up to determine the visibility around a chosen observation point. The model is based on the viewshed-analysis, which is used to determine the visible and invisible areas around a chosen observation point. Using this viewshed analysis, the visibility around an observation point is determined based on digital elevation information of the surrounding environment and this visibility is dependent on the locations and elevations of the observation- and target point and the detection range. The output of the model consists of a viewshed in which the visible and invisible, as seen from the observer location, are indicated. The visibility of a location is expressed in the form of a "blockage factor" (BF), which defines the percentage of invisible waterways in the vicinity of the observation point. The output of the model has been validated using real radar images.

One hour of VHF communication has been analysed to digitize the VHF traffic. During this hour 81 individual conversations occurred, in which a total of 573 different communications have been transmitted. The transmitted messages can be divided into five main forms of communication: Announcements, Traffic Images, Manoeuvres, Intentions and Other. Announcements are communications in which a skipper clarifies his/her position and destination. This differs from the communication form Intentions, where intentions are shared after a request from another skipper or VTSO. In Traffic Images, the locations and destinations of other vessels are discussed, also known as targets. The communication form Manoeuvres concerns all communications regarding the arrangement of passages. Finally, under Others, all communication which is not intended for traffic management is categorized. This holds for example for personal conversations between skippers or when skippers arrange to switch over to another VHF-channel to keep the main VHF-channel of the sector free the other participants. When focusing on the quantities of the messages, one can conclude that traffic images have been shared in the majority of conversations, which often occurred in combination with an announcement and/or an arrangement of a manoeuvre.

The model to determine the visibility is used to analyse the behaviour of the BF for several varying conditions. The visibility is varying extensively over the main fairway, for which an oscillating behaviour appeared with BFs between 0-70%. Low BFs occurred at the seaside of the main fairway and high BFs occurred close to the city centre and at the beginning of the Oude Maas. In the sector Botlek, the BFs are varying between 10-95%, with high values deep inside the harbour basins. Next to that, it can be concluded that the visibility of an observing vessel is dependent on the antenna height and detection range of the radar and the air draft of targets. The BF is in general decreasing for increasing antenna heights and target air draft. For some sectors, this difference is small, however, considerable differences occur at the sector Maassluis, which is due to the presence of the adjacent Landtong dike and Calandkanaal. Lower BFs arises for smaller detection ranges. Finally, a simplified research has shown that moored vessels at berths could have a significant influence on visibility. This especially holds for berths for tanker vessels, which are positioned more perpendicular and more away from the quays for safety reasons.

The results of the digitized VHF-data and the model to determine the visibility are combined to verify whether the occurrence of VHF-communications is related to a lack of visibility. In this analysis, the focus is on communications regarding traffic images because in this form of communication an overview of the locations of target vessels is given. The following hypothesis is tested:

"At locations with higher blockage factors arises more VHF-traffic regarding objects which are not visible for the observing vessel."

For each communicated traffic image, the corresponding visibility of the involved participants is analysed. This analysis addresses two individual aspects: first, the blockage factors of the locations of the observing vessels, towards which traffic images have been communicated, have been determined. In this way, it is verified whether traffic images are communicated to vessels located on locations where relatively higher BFs arise or not. Next, the mutual visibility of the targets is determined. In this way, it has been analysed to what extent the addressed targets in traffic images have been visible for the observing vessel. The visibility in traffic images has been analysed by creating viewsheds for all the observing locations which has been defined in the VHF-analysis. In this way, it has been determined whether the occurrence of VHF traffic is related to the occurrence of a lack of visibility.

The visibility of 79 individual traffic images has been analysed in the sector Botlek. A total of 143 targets were communicated in these 79 traffic images. Of these 143 targets, 83 (58%) of the addressed targets has been visible for the observing vessel, indicating that the locations of both visible and invisible targets are communicated. From this, it can be concluded that VHF-communications are not necessarily regarding objects that are not visible. The locations of the observing vessels to which these traffic images are communicated are widely spread over the main waterway and central channels leading to the harbour basins. The associated BFs of these locations vary between 15-80%, indicating that traffic images are communicated to locations with low and high visibility. When the distribution of the BFs of the observing vessel locations is compared to the distribution of the average BF of the sector, it can be concluded that there is not occurring more VHF-traffic at locations with higher BFs. Based on the outcomes of this analysis the formulated hypothesis needs to be rejected.

The developed method in this research has been successful in determining what percentage of VTS messages can be linked to a blocked visibility. The method to determine that objectively works, however blockage does not appear to be a trigger for VTS-communications. Full visibility creates 42% more insight in locations of targets, however, information regarding intentions is still missing. This information is required to determine the targets with which a future encounter can be expected. Verifying in what way the intentions of vessels can be made accessible, and a way how this information can be implemented in an information system, are recommendations as input for follow-up studies.

Acronyms

1st Pet	1st Petroleumhaven
3rd Pet	3rd Petroleumhaven
A	Announcement
AHN	Algemeen Hoogtebestand Nederland
AIS	Automatic Identification System
BF	Blockage Factor
DEM	Digital Elevation Model
DH	Delta Hotel
DSM	Digital Surface Model
DTM	Digital Terrain Model
GDAL	Geospatial Data Abstraction Library
GIS	Geographical Information System
HCC	Harbour Coordination Centre
I	Intention
IALA	International Association of Lighthouse Authorities
IMO	International Maritime Organization
INS	Information Service
KB	"Kattenbak"
KS-test	Kolmogorov-Smirnov Test
NAP	Normaal Amsterdams Peil
M	Manoeuvre
MOT	Maasvlaakte Oil Terminal
MTI	Moving Target Indication
NAS	Navigational Advice and Assistance Service
QGIS	Quantum Geographic Information System
RBA	Right-hand board angle
SEI	Safety Environmental Index
THMD	The Harbour Master's Division
TI	Traffic Image
TOS	Traffic Organization Service
VHF	Very High Frequency
VTS	Vessel Traffic Service
VTSO	Vessel Traffic Service Operator
WP	Welplaathaven

Table of contents

1. Introduction

In this chapter the subject of this thesis is introduced. First an overview of the context is given. The objective, approach and scope are defined with the formulation of the research questions and hypothesis. Lastly, the structure of the report is described containing a brief overview of the content of the individual chapters.

1.1. Context

The main objective of sea shipping is the transportation of a certain type of goods from a port of origin towards a port of destination. To achieve this goal, vessels need to reach the corresponding berths in the ports, where the (un)loading takes place. The port of Rotterdam is one of the biggest ports in the world. In 2019, there were about 30,000 sea-going and 100,000 inland vessels sailing into or out of the port. All these vessels together transported a throughput of 469.4 million metric tons through the port and this makes the port of Rotterdam the largest port in Europe and the 10th largest port in the world (Port of Rotterdam, 2021). High vessel traffic densities, restricted water areas, and low manoeuvrability are common factors that form constraints for the navigating vessels in port areas. While navigating through these areas, vessels often get assisted by external organizations to ensure a safe and efficient port-call event. Examples of these services are the assistance of tugboats, pilots, and linesmen (Nautical Service Providers) and the Vessel Traffic Service (VTS).

In the port of Rotterdam, the VTS is monitored from two traffic control stations, one in the sector Botlek and another one at Hoek van Holland. On these stations, VTS operators are positioned who can track all incoming and outgoing vessels based on radar and AIS-data. Each port sector has its own VTS operator (VTSO) and the communication towards the vessels will be maintained by use of Very High Frequency (VHF) radios. The VTS is providing three different types of services: Information service (INS), traffic organization service (TOS), and navigational advice and assistance (NAS). The INS is providing general information publicly and enables sharing of intentions between vessels. The TOS provides information about the availability of certain resources like "space" and "time" and assists vessels with their strategical planning. In case a ship is not able to sail safe, the NAS provides information to assist skippers of the navigating vessels in their tactical decisions.

Especially in busy port sectors, high vessel densities arise. Due to the high vessel intensities, the corresponding VHF-channels are often very crowded, which results in high workloads for the VTSOs. The Rotterdam Port Authority is currently investigating measures to reduce the high amounts of VHF-traffic. In here the possibilities of a digital transformation of the VTS are investigated, in which is focused on full object detection and visibility. In the majority of occurring VHF-communications information regarding positions of other vessels is communicated. By realizing full object detection and visibility, all participating vessels are mutual detectable with which is expected to reduce VHF-traffic regarding traffic images. This reduction is required to reduce the workloads of VTSOs. Next to that, the situational awareness of the participating skippers will be increased, which is beneficial for the safety and efficiency of the vessel traffic in the port areas. Full object detection can be realized by sharing shore-based radar data, which is currently available for VTSOs, with the navigating skippers.

1.2. Research Objective

To define effective measures to reduce VHF-traffic, it is necessary to gain a better insight in the factors by which VHF-communications are triggered. The objective of this research is to investigate whether VHF-communications are triggered by fairway properties. To analyse this, a method will be developed to digitize VHF-communications in order to relate types of messages with properties of the fairway system. This will be done by linking spatial and temporal characteristics of VHF-communications to spatial and temporal characteristics of the fairway system, to analyse whether the occurrence of a certain type of VHF-communication is related to the occurrence of a particular fairway property.

1.2.1. Approach

To be able to link VHF-communications to properties of a fairway system, both the spatial and temporal characteristics of the VHF-communications and properties of a fairway system have to be defined first. This is done by means of a VHF-analysis and a fairway-system-analysis. In the VHF-analysis, VHF-communications are digitized and classified according to content, time and space. This results in a clear overview of the communicated messages, the involved participants and the locations and moments from where these messages have been transmitted. The VHF-analysis is the main component of the method and the results can be used to analyse the influence of several fairway properties. Subsequently, the spatial and temporal characteristics of a considered fairway property are defined in the fairway-system-analysis. This is done by identifying factors on which a considered property is depended and analysing how this dependency is varying in space and time. Finally, the results of both analyses are compared to verify whether the occurrence of a certain type of VHF-communication is related to the occurrence of a certain property of a fairway system. See figure 1-1 for an overview of the structure of the method.

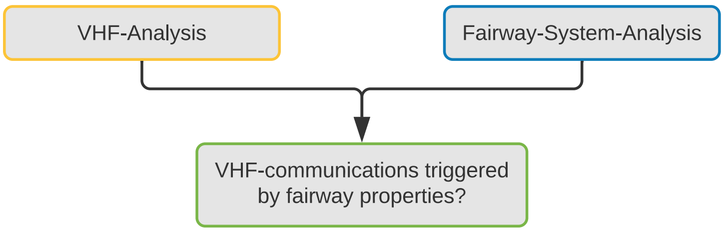

Figure 1-1 General methodology overview.

1.2.2. Scope

Fairway properties are components by which a fairway system can be defined. These properties can be categorized in four main categories: layout-, hydrostatical-, meteorological- and traffic-related properties. Under layout related properties, the dimensions of cross-sections are addressed as well as the alignment of the cross-section over the length over the channel. This involves the channel dimensions such as width, depth, bank alignment and bank clearance and the presence of curves and intersections along the alignment of the channel. Within the hydrostatic category, all parameters which are related to the fluid that is flowing through the waterway are classified. This involves the flow discharge, tides, currents, wave heights, water levels, water temperature and salinity. The meteorological parameters consist out of all parameters pertaining to the atmosphere in the surrounding environment of the channel, such as wind, temperature, visibility and atmospheric pressure. Finally, under traffic related properties, all properties regarding the navigating vessels are addressed such as vessel types, dimensions and intensities.

The general method as illustrated in figure 1-1 can be applied to analyse the influence of multiple waterway properties on VHF-communications, but in this thesis the focus is on analysing to what extent the waterway property “visibility” is likely to trigger VHF-communications. There is chosen to analyse the visibility because this is in line with an ongoing research into the feasibility of the digital transformation of VTS, which is currently carried out by the Rotterdam Port Authority. One of the principles on which this digital transformation is based is the realization of full object detection and visibility, with which is aimed to reduce the amount of occurring VHF-communications. This principle is based on the hypothesis that VHF-communications are a caused by a lack of mutual visibility of objects. A lack of mutual visibility can be caused by the presence of buildings, infrastructures, afforestation and other vessels on the fairway, which are blocking the line of sight. To verify whether VHF-communications are triggered by a lack of visibility, the spatial and temporal characteristics of visibility have to be identified and analysed first, before they can be linked to the substantive, spatial and temporal characteristics of the VHF-messages.

1.2.3. Research questions

The combination of the research objective and the formulated scope regarding the considered fairway property is translated in the following main research question:

To what extent are VHF-communications triggered by a blocked visibility for the vessel radar?

In here the following hypothesis will be tested:

At locations with significant higher blockage factors arises significant more VHF-traffic regarding objects which are not visible for the observing vessel.

To test this hypothesis and provide an answer to the main research question, several sub-questions are defined which have to be answered first:

1. *In what way can VHF-communications be digitized to classify the communications according to content, space and time?*
2. *What are the substantive, spatial and temporal characteristics of the digitized VHF-communications?*
3. *What method can be used to determine the visibility of vessel radars?*
4. *How does the visibility of vessel radars behave for varying locations, vessel parameters and obstructions?*
5. *To what extent is the occurrence of a certain type of VHF-communication related to the occurrence of blocked visibility for the vessel radar?*

1.3. Thesis structure

This thesis consists of four different parts and ten different chapters and the addition of the appendix:

- **Chapter 1: Introduction**
  In this chapter an introduction to the research is presented. In here, the role of VTS in the vessel traffic management of port of Rotterdam is discussed as well as the provided VTS-services. Next to this, the scope, main- and sub research questions, hypothesis and thesis structure are addressed.

- **Part I: Literature review.** The first part of this research contains a literature study, in which is focused on the VTS- and VHF-procedures in the port of Rotterdam, technical aspects of a maritime radar and a way to visualize the visibility of a maritime radar.

  - **Chapter 2: Vessel Traffic Service**
    In the second chapter, a brief overview of the procedure of the vessel traffic service in the port of Rotterdam is given. In here the role of VTS in the organization is addressed, the area of operation and the provided services. Subsequently, guidelines for VHF-communication are discussed as well as the additional provisions for sea going vessels.

  - **Chapter 3: Maritime radars**
    In chapter three the basic principles of a maritime radar are discussed, to gain a better insight in the visibility onboard of vessels. In here the target detection mechanism of a radar is addressed, as well as indicating factors that cause blind radar zones. Subsequently, the basic principles and practical applications of the viewshed-analysis are discussed, which is a method to determine the visibility around an observer point.

- **Part II: Method and Materials.** In the second part the applied methods and used materials are addressed. In here the overall methodology is discussed as well as the model set-up, implementation and internal validation of the model to determine the visibility.

    - **Chapter 4: Methodology**
      Chapter four addresses the applied methods which have been used. This is done for the VHF-analysis, the Visibility-analysis and the combined analysis in which the results of the first two analyses are combined.

    - **Chapter 5: Implementation & Internal Validation**
      In chapter five the model set up for the visibility analysis is addressed. This discusses what considerations are made to develop a model to estimate the visibility of vessels. Eventually, the validation of the visibility model using real radar images is presented in this chapter as well.

- **Part III: Results**. Part three focuses on the results which have been obtained through the VHF-analysis, Visibility-analysis and the analysis into the visibility during the occurred VHF-communications.

    - **Chapter 6: VHF-Analysis**
      The results of the VHF-analysis are presented in chapter six. In here the occurred types of communications, the involved participants and the vessel positions are analysed.

    - **Chapter 7: Visibility-Analysis**
      In chapter seven, the results of the visibility-analysis will be discussed. The blockage factor behaviour is analysed for various port locations of the main fairway and within the sector Botlek. Subsequently, the influence of varying vessel parameters is analysed thereafter. Finally, the Blockage Factor behaviour of dynamic obstruction are investigated as well.

    - **Chapter 8: Visibility in Traffic Images**
      In chapter eight, the results of the VHF-analysis and Visibility-analysis are combined to analyse the visibility of involved participants in the communication type traffic images. This is done by determining the corresponding blockage factors of the locations on which observing vessels are located and whether the communicated targets are visible/invisible for the observing vessel in question.

- **Part IV: Concluding remarks.** Part four contains the discussion, conclusions and recommendations regarding the conducted research

    - **Chapter 9: Discussion**
      Over the length of the research different simplifications and assumptions have been made. In chapter nine these assumptions are summarized, and the accuracy of the model results is discussed. Next to that, additional model applications are presented.

    - **Chapter 10: Conclusions & Recommendations**
      Chapter ten forms the final chapter of this research, in which an answer to the main research question is provided and recommendations for future work.

- **Part V: Appendix.** The appendices supporting the research are added as part V


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I. Literature Review

2. Vessel Traffic Service

In this chapter the vessel traffic service (VTS) is discussed. In here the role of the VTS in the vessel traffic management domain is discussed, as well as the area of operation and the provided services within VTS. Thereafter, the procedure and guidelines for VHF-communication are discussed to provide a better understanding on what kind of information is shared by which involved participants. Eventually, the mandatory reporting duties for sea going vessels are elaborated.

2.1. VTS in Vessel Traffic Management

In the international guidelines for vessel traffic services, as defined by the International Maritime Organization (IMO), the VTS is defined as follows:

“A service implemented by a competent authority designed to improve the safety and efficiency of vessel traffic and protect the environment. The service should have the capability to interact with the traffic and the to respond with to the traffic situations developing in the VTS area.”

The main objective of VTS is to improve the safety and efficiency of navigation, the safety of life at sea and the protection of the marine environment and/or the adjacent shore area, worksites and offshore installations from possible adverse effects of maritime traffic. The benefits of implementing a VTS are that it allows identification and monitoring of vessels, strategic planning of vessel movements and provision of navigational information and assistance. It can also assist in the prevention of pollution and coordination of pollution response. The efficiency of a VTS will depend on the reliability and continuity of communications and on the ability to provide good and unambiguous information. The quality of accident prevention measures will depend on the system's capability of detecting a developing dangerous situation and on the ability to give timely warning of such dangers (IMO 1997).

In the port of Rotterdam, the Vessel Traffic Service is part of the Harbour Master’s Division (THMD), a department of the Rotterdam Port Authority that is responsible for vessel traffic management. In the VTS, the vessel traffic is monitored from two traffic control stations, one in Hook of Holland and one in the Botlek. On these stations Vessel Traffic Service Operators (VTSO) are positioned who can track all incoming and outgoing vessels based on radar- and AIS-data. Based on this information the VTSO are providing continuous information regarding the current situation of the marine traffic in the surrounding environment. Each port sector has its own VTS operator and the communication towards the skippers of the navigating vessels will be maintained by use of a Very High Frequency (VHF) Radio. The VTS supervises both the seagoing- and inland vessels in the port.

The main objective of the Harbour Master’s Division (THMD) is the handling of vessel traffic as safe, secure, sustainable and efficient as possible through the port aiming to boost the competitive position of the port of Rotterdam. To achieve this objective, the division is providing several other services next to the VTS (Port of Rotterdam, 2020a):

- **Harbour Coordination Centre:** The Harbour Coordination Centre (HCC) is controlling the planning and access of all vessels navigating in the port of Rotterdam.
- **Harbour patrol boats:** The Rotterdam Port Authority’s fleet, consisting out of several vessels, is responsible for enforcement and inspection on the waters in the port. The patrol boats will guide vessels if necessary and assisting services will be provided in case of emergency.
- **Inspection:** To reach the objective of a safe, sustainable and secure port, various safety standards have been defined. These standards are defined globally or by the Harbour Master itself in the form of the Safety Environmental Index (SEI). THMD’s inspectors check whether vessels meet these regulations and measures will be taken in case of unsafe or incorrect conditions. Next to this, systematic checks are carried out as well to make sure that agents/companies comply with statutory administrative reporting obligations.

- **Port Health Authority:** The Harbour Master's Division is contributing to the Port Health Authority. This Authority guides and advises vessels in case of epidemics on board.
- **Port Security:** Despite the yearly increasing numbers of visiting vessels and the corresponding complexity, the Harbour Master ensures that the level of safety in the Port is maintained at the right level.

2.2. Area of Operation

VTS is applied in a so called VTS-area. The definition of a VTS-area as defined by the international guidelines for vessel traffic service: *"The delineated, formally declared service area of the VTS. A VTS-area may be subdivided in sub-areas and sectors."* (IALA, 2012). In the port of Rotterdam, the VTS-area is reaching from the seaside on the west of the port towards several kilometres upstream of the city centre of Rotterdam. In here two sub-regions are defined in which several individual port sectors have been defined. These sub-regions are the Sea area and the Inner area. See figure 2-1 for a general overview of the port of Rotterdam and the different sub-regions and sub-sectors (Port of Rotterdam, 2020b)

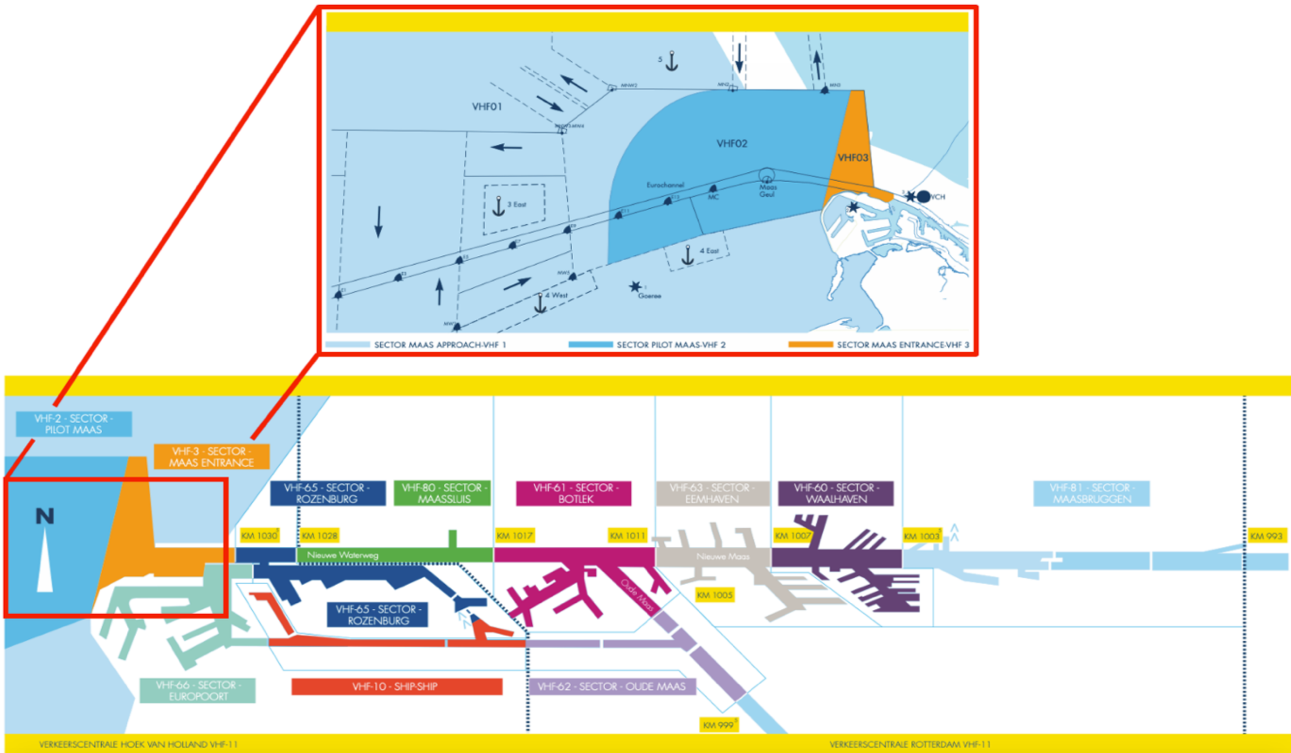

Figure 2-1. Area of operation. Top: Approach area. Bottom: inland fairway section with individual port sectors. (Port of Rotterdam, 2020b)

2.2.1. The Sea area

The area at sea consists out of the port approach region and is located in the North Sea. This port approach area is subdivided in three subsectors: Sector Maas Approach, Sector Pilot Maas and Sector Maas Entrance. The anchor area can be found in the Sector Maas Approach. This area is the area where vessels are waiting before navigating into the port. Vessels are waiting at the anchor area if the administrative- or operational clearance is not given yet, when the intended berth is still occupied or in case of economic reasons. The pilots embark the vessels in the sector Pilot Maas through a vessel or a helicopter. Vessels meet the tugboats in the sector Maas Entrance, from where it will be assisted on its journey towards the quay.

2.2.2. The Inner area

The inner area covers all main fairways and side channels within the operational areas of the Rotterdam Port Authority: the Nieuwe Waterweg, the Calandkanaal, the Beerkanaal, het

Yangtzekanaal, the Nieuwe Maas upon kilometer 993.0 and the Oude Maas upon kilometer 999.5. The inner area is subdivided in nine individual subsectors: Sector Europoort, Sector Rozenburg, Sector Maassluis, Sector Botlek, Sector Oude Maas, Sector Eemhaven, Sector Waalhaven and. Sector Maasbruggen. See figure 2-1 for an overview.

2.3. Provided services

The provided services by VTS can be divided into three groups: 1) Information services (INS), 2) Traffic organization services (TOS) and 3) Navigational assistance services (NAS). An INS can be seen as the fundamental type of service within the VTS. The INS is providing general information publicly and enables sharing of intentions between vessels. In case the VTS authority is organizing and managing the traffic within its VTS area as part of its function, the TOS is often provided as well. The TOS provides information about availability of certain resources like “space" and "time" and assists vessels with their strategical planning. In case a ship is not able to sail safe, the NAS provides information to assist vessels in their tactical decisions (IALA, 2012)

2.3.1. Information services (INS)

The main objective of the INS is the provision of timely and relevant information, which is based on factors that may could influence the vessel’s movement within the area of interest. An INS concerns the maintaining of a traffic image and allows the interaction with the present traffic and gives a response to the development of traffic situations. These services are provided in order assist the decision-making on-board and should be delivered when this information is deemed necessary by the VTS operator or when it is requested by the ship itself. The INS include information regarding:

- Navigational situations such as traffic and route information
  - The position, identity, intention and movement of other vessels
  - Limited manoeuvrability that may impose restrictions on the navigation of other vessels or any other potential hazards
- Navigational warnings
  - Dangerous wrecks
  - Diving warnings
  - Vessels not under command
- Meteorology and hydrography
  - Among others, information regarding wind, visibility, waves, tides currents and swells
- Other
  - Pilot or tug requests
  - Cargo information

The INS should be provided in case this is deemed to be necessary by the VTSO, information is requested by the navigating skippers of the vessels or at fixed times in case general information has to be shared with the entire sector. The INS is provided on the VHF radio channel.

2.3.2. Traffic organization services (TOS)

The objective of this service is to ensure that the movements of ships will be regulated on a safe and efficient manner. It is one of the core tasks of the VTS to prevent the development of dangerous traffic situations in the VTS sector. It concerns the planning of traffic/vessel movements in times of high traffic density. In here, the TOS is responsible for the separation of the traffic in space, time and or distance. Some occasions for which the TOS has to be provided:

- A forward planning and prioritization of vessel movements is required to prevent congestion and/or dangerous situations
- Special types of transport or vessels with polluting or hazardous cargo, which could affect the organization of the other traffic needs to be organized
- The allocation of space and time have to be organized

- Special routes have to be followed
- Speed limits have to be observed
- A VTSO considers to it be necessary to interact and coordinate with the vessel traffic in case a potential situation is observed to develop
- Etc.

Several examples of information which can be provided in a TOS are elaborated below:
- Waterway management
  - Organizing the traffic concerning vessel dimensions in comparison to fairway restrictions
  - Establish and organize ship safety zones in case of particular operations
  - Slot management to allocate vessels in a time window
- Traffic clearance
  - Lock and bridge passage planning
  - Giving authorization under conditional circumstances to a vessel when
    - Entering the VTS area
    - Departing from a berth in the VTS area
- Anchorage
  - Organizing the movements to/from an anchorage area
  - Anchorage position assignment

Again, the TOS is provided using the VHF-radio. The information is shared in case this is deemed to be necessary by the VTSO.

2.3.3. Navigational assistance services (NAS)

The final service provided by VTS involves support to the navigational safety of the vessel by providing timely and essential navigational information to assist in the decision-making on-board. The service is especially important in case of difficult navigational or meteorological circumstances or in the case of deficiencies or defects. Next to that, the service can be seen as an important addition to the provision of other non-VTS services such as pilotage, linesman or tugboat services. The VTS operators have to be trained appropriately to be able to provide navigational assistance services in case situations occur that compromises navigational safety. Unsafe situations may develop when a vessel is deviating from its passage plan, when a ship is at risk of grounding or collision and when a ship is unsure of its route or position.

Examples of information in NAS:
- Request and identification
  - Requests for ship identification such as position, course and ground speed
  - Status of equipment on board of vessels
- Navigational information
  - Provide range and bearing from fixed objects and fairway waypoints
  - Proximity to navigational hazards
- Advice/Instructions
  - Advice to alter speed or course
  - Advice to stay away from area/position
- Warning
  - Diverging of recommended track towards dangerous areas
  - Vessel not under command
  - Diving operations

The NAS should be provided when this is deemed to be necessary by the VTSO or when it is requested by the navigating skipper of the vessel. The first scenario arises when a VTSO observes the development for which a hazardous situation and deemed necessary to assist the skipper of the navigation vessel. The second scenario may occur in circumstances such as navigational unfamiliarity or in case of equipment failure on board. The communication of NAS should be as quick as possible to save time and increase the chances of the prevention of the potentially dangerous situation. The communicated information should be communicated clearly, unambiguous and understood by both parties. In messages in a NAS should always be addressed with the name of the vessel in question, so there is no doubt towards which participant the corresponding information is directed. It might be useful to switch over to a separate VHF-radio frequency to prevent to get interrupted by other communications on the main channel of the section.

2.3.4. Revision of guidelines

The provided VTS services as discussed in this section are based on the Guideline 1089 - Provision of VTS – INS, TOS and NAS, which is defined by IALA and dating from December 2012 (IALA 2012). Currently, IALA is developing a revision of these guidelines to clarify the position on the “Provision of Vessel traffic Services” and removing the misconceptions that currently exist on Types of Service. In many respects, the current version of Guideline 1089 is still valid, but the updated revision will remove the confusion over Types of Service being optional and establishes these services as capabilities of any VTS. This holds that the provided VTS services INS, TOS and NAS, as defined in the current guideline, will still be provided but expressed differently. In the revised guidelines these VTS services are defined by 1) The provision of timely and relevant information on factors that may influence the vessel’s movements and assist on-board decision-making, 2) The monitoring and management of ship traffic to ensure the safety and efficiency of ship movements and 3) The responding to developing unsafe situations. The revision issue is pending for adoption at IMO. When the revision is adopted by IMO, there is aimed to include the amendments to the IMO resolution A.857 – Guidelines for Vessel Traffic Services at the end of 2021 (IALA 2020). Because it is still unclear whether the proposed revisions will be adopted in a new resolution, in this thesis is adhered to the current guidelines as defined in 2012.

2.4. VHF communication

Any vessels in the nautical control area of the port of Rotterdam must listen to the correct VHF sector channel. Vessels can use the VHF channels to communicate with the two traffic centres in the port of Rotterdam. All the sea and inland shipping vessels as well as the pleasure craft which is equipped with a VHF installation are obligated to:

- Listen to the VHF channel of the sector in which they are navigating during their trip.
- Participate in the VHF communication if necessary and provide the requested information at the request of the VTSO
- Report only in case they are about to execute a special manoeuvre, such as crossing the waterway, entering or leaving a port and any other action that deviates from the usual traffic pattern, including incidents.

Guidelines have been defined to keep the VHF communication as formal and relevant as possible.

Language

On the sea area sectors Maas Approach, Pilot Maas and Maasmond the primary radio language is English, and Dutch is used as secondary language. For the inner area sectors the main primary language is Dutch, but the English and German language is used as well.

Radio discipline

The VHF channel is only intended for communication regarding the safe navigation or the regulation of the marine traffic. Mutual arrangements between navigating skippers regarding navigation can be arranged between the participating skippers directly or by interference of the VTSO. Under all circumstances strict conversation discipline must be maintained, to which the VTS operator can give directions if necessary. In case skippers want to discuss something in more depth they are advised to switch to another frequency to keep the VHF-channel of the sector free for other purposes.

International basic principles are:

- When the VTSO ends his/her message with “OVER” a response is required/desired from the corresponding navigating skipper in question.
- When the VTSO ends his/her message with “OUT” no response is required/desired from the corresponding navigating skipper in question.

Message markers

To contribute to the radio discipline and to prevent overloading of the VHF channels in the VTS sectors, the VTSO can use the internationally established “Message markers” when communicating with the vessels. All this to keep communication short, formal and clear for all waterway users. After a call is made, the intended communicated information is preceded by a message indicator to emphasize the intention of the message. These indicators can be used by all traffic participants on the VTS-VHF channels. In total 8 different message indicators are defined and the occasion when they are used is quite straightforward:

- Information (For messages regarding observed facts)
- Question (For messages in which a question is asked)
- Answer (For messages in which an answer is provided)
- Intention (For messages regarding intentions or plans)
- Warning (For messages regarding a warning of a certain danger)
- Request (For messages in which an action is requested)
- Advice (For messages in which advices/recommendations are shared)
- Instruction (For messages in which traffic instructions are shared)

Shipping announcement

When communicating with the vessels, the VTS operator can send out a shipping message. This shipping message can be a good addition to quickly reach a large group of vessels in a certain area and/or sector. By making use of a shipping message, communication to individual vessels can be limited. The shipping message can be used by the VTS operator in special circumstances such as maintenance activities, messages regarding visibility or regarding obstructions and incidents, etc.

2.5. Additional provisions for sea-going vessels

For sea going vessels additional provisions are established in which mandatory reports have to be made before these types of vessels are allowed to continue with the desired voyage. These mandatory reports can be divided into three categories

- Mandatory reporting on arrival in the VTS area
- Mandatory reporting in the VTS area
- Mandatory reporting for preparation for departure or shifting movement

Sea going vessels are obligated to report upon arrival in the VTS-area. The VTS area can be entered in the sectors Maas Aanloop, Oude Maas and Maasbruggen. The report must contain information regarding the Name of the Vessel, the call sign, current position, desired destination, draught and other special circumstances.

When sea going vessels are navigating through the port and different port sectors, mandatory reporting is required when a VTS area is left, when the unmooring is commenced and in case a special manoeuvre is executed. Special manoeuvres are the crossing of a fairway, entering or leaving a harbour, overtaking other vessels and any other actions that deviates from the usual voyage plan. The report should contain information regarding the name of the vessel, desired destination and other special circumstances. Prior to the departure another report must be made, in which information regarding the name of the vessel, desired destination, draught and other special circumstances is shared.

2.6. Conclusion

In this chapter the main principles of the vessel traffic service and VHF communications are discussed. The main objective of VTS is to improve the safety and efficiency of navigation, the safety of life at sea and the protection of the marine environment and/or the adjacent shore area, worksites and offshore installations from possible adverse effects of maritime traffic. The VTS service is provided by VTS operators which are tracking and monitoring all the participating vessels in a particular VTS-sector using radar and AIS-data. Information is exchanged publicly using Very High Frequency radios (VHF-radio) on the corresponding VHF-channels of the VTS-sectors. The provided services by VTS can be divided into three groups: 1. Information services (INS), 2. Traffic organization services (TOS) and 3. Navigational assistance services (NAS). An INS can be seen as the fundamental type of service within the VTS. The INS is providing general information publicly and enables sharing of intentions between vessels. In case the VTS authority is organizing and managing the traffic within its VTS area as part of its function, the TOS is often provided as well. The TOS provides information about availability of certain resources like “space" and "time" and assists vessels with their strategical planning. In case a ship is not able to sail safe, the NAS provides information to assist vessels in their tactical decisions.

To keep the communications on the VTS-channel formal and relevant, skippers of the navigating vessels have to adhere to prescribed guidelines for VHF-communications. These guidelines consist out of the obligation to listen to the correct VTS channel, participate in VHF-communications if necessary and report in case a special manoeuvre is executed. Next to that, regulations regarding languages, radio discipline and message markers have been defined in order to increase the efficiency of the communications. For sea going vessels, additional provisions are defined concerning mandatory reporting in case of an arrival in a new VTS area, an arrival in a new VTS sector and in case a departing or shifting movement is about to be executed.

3. Maritime radars

To determine whether VHF-traffic is triggered by blocked visibility for a vessel radar, a better understanding of the detection principle of the maritime radar is required. In this chapter, the technical background of maritime radars is addressed. First a brief introduction regarding the history of radars is discussed. Subsequently, the basic principles of radars are addressed, such as echo principle, the estimation of ranges and bearings of targets and in which way the obtained data is presented to the navigating skipper. Thereafter, the phenomenon of blind radar spots will be addressed, in which is discussed by what factors these blind areas are caused. Finally, a method to determine the visible areas and blind spots around a chosen observer point is discussed in the last section.

3.1. Introduction

The maritime radar is one of the most important components of navigational equipment which is equipped on board of almost every vessel. The radar display presents critical information to the navigation officer and forms the focus for the presentation of other navigational data, which makes it of major importance on the bridge of a vessel. Together with the nautical charts, the maritime radar provides the main displays for marine navigation into an increasingly integrated navigational world. The main objective of the maritime radar is to detect targets, such as other vessels and land objects, in the surrounding environment. It returns bearings and distances from an observer point towards these detected targets, which can be used for collision avoidance and/or other navigational purposes.

The word RADAR is an acronym for Radio Detection and Ranging. The theory has first been introduced by the scientist Heinrich Hertz in 1886. Hertz was a German physicist who demonstrated that radio waves could be reflected by metal objects. After this finding, it still took about 50 years before the radar technology was introduced into the marine domain. During the 1930s, there was a lot of simultaneous but independent research into radar techniques carried out in several countries among which: The United States, The Soviet Union Great Britain, France, Germany and The Netherlands. These developments led to the first application of the radar technique on a warship in 1937. This introduction and the development in the following years led to the widespread usage of maritime radars during the Second World War. Eventually, the maritime radar made its appearance towards the merchant shipping industry from about the end of the Second World War.

Although the maritime radar, as introduced to the merchant shipping industry in the 1940s, is differing remarkedly from the currently used maritime radars, the basic principles have been the same. These basic principles hold that the current radars still offering distance and bearing to the detected targets. The major differences arise in the appearance, size, accuracy and versatility of the newer radar systems. In here new functions are added such as the moving target indication (MTI), collision avoidance systems and route planning tools (Bole et al. 2013).

3.2. Basic principles

3.2.1. The Echo Principle

As described in the introduction, the main objective of a maritime radar is to detect targets in the surrounding environment of an observer point. With the observer point is referred to the observing vessel, on which the maritime radar is equipped. In the marine domain targets usually consists out of other vessels, buoys and land obstacles. With the observer point is referred to the position of the own vessel, on which the corresponding radar is equipped. A maritime radar consists out of an antenna, a switch, a transmitter and a receiver. See figure 3-1. Targets can be identified by the transmission and reception of radio wave energy in the form of pulses. The transmission and reception of these pulses is both done via the antenna of the radar. The switch alternately connects the transmitter and receiver to the shared antenna on a high frequency, which makes the radar able to transmit and receive signals almost instantly. When a radio energy pulse is transmitted by the antenna and it hits an object, a subsequent energy pulse is reflected back. This reflected energy pulse by an object is called the echo. This echo will travel back in the opposite direction of the transmitted energy pulse and eventually be received by the antenna again.

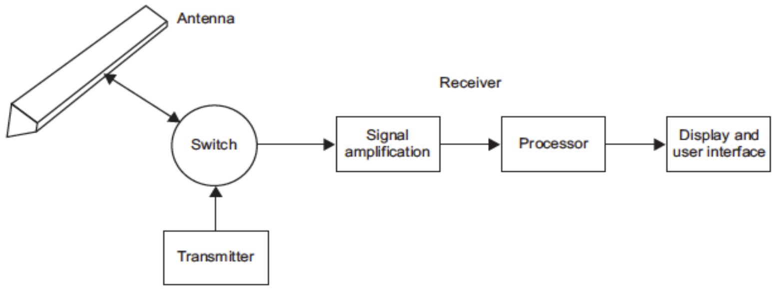

Figure 3-1. The basic radar system. (Bole et al. 2013)

To cover the entire surrounding of the observer point, the maritime radar is rotating in the horizontal plane. The antenna completes a full rotation in about 2 seconds. This means that the transmitted radar pulses consecutively cover all directions over 360 degrees at each rotation of the antenna. Each radar pulse is transmitted in between a certain horizontal beam width limit. These limited beam widths are called azimuth cells and the cell width is normally smaller than two degrees. By creating these small beam widths, the antenna will only receive the equivalent echo pulses which are returning from within the angular limits of the beam width. This ensures that the antenna will not be picking up any other unwanted noise from other directions and therefore increase its ability to detect the echoes from the targets. The speed at which the radio energy pulses are travelling is about one million times larger than the speed at which sound is travelling. Because of the high travel speeds of the radar pulses, the antenna is receiving the echoes from the transmitted pulses before the antenna has noticeably rotated. This holds that the radar image, which is presented on a screen on the bridge of the vessel, is updated with every rotation of the antenna.

3.2.2. Range of objects

When the radio energy pulses are transmitted and eventually received back by the antenna again, the data needs to be processed to obtain the range and bearing of the detected targets. In navigation, the range of an object is equal to the distance between the target and the observer point. The range can easily be calculated if the speed of the pulse is known. This speed depends on the medium through which the pulse is travelling. Within the Earth’s atmosphere, the speed at which the pulses are travelling is equal to the speed of light, which is 299.792.458 m/s. For simplicity, it is assumed to be equal to 300 meters per millisecond. Using this value for the travel speed, it is possible to define the range of objects by a simple general relationship between the travelled distance and the required time needed to travel this distance. The travelled distance by the pulse is called D and is equal to the sum of the combined distances travelled by the transmitted pulse and the returning echo. See figure 3-2. This means that D is equal to two times the range. The target range becomes then:

$$R = \frac{1}{2} * D \tag{3-1}$$

$$D = c * T \tag{3-2}$$

$$R = \frac{(c * T)}{2} = \frac{(300 * T)}{2} = 150 * T \tag{3-3}$$

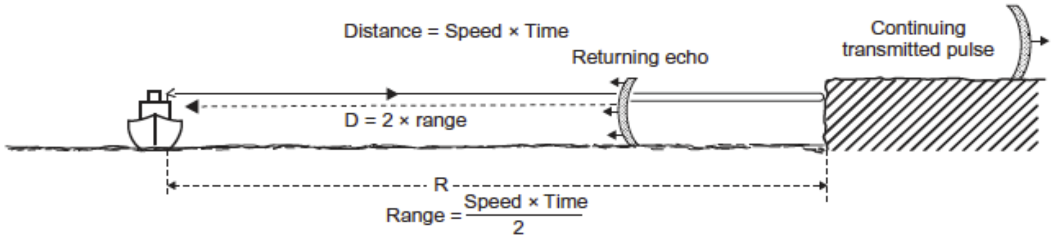

Figure 3-2. The estimation of object ranges. (Bole et al. 2013)

3.2.3. Bearing of objects

Next to estimating the range of objects, estimating the bearing of objects is another observable quantity of the maritime radar. From the position of the radar antenna in relation to the direction of the fore ship at the moment of receipt of the echo (right-hand board angle RBA), the receiver can determine the direction in which the object is located with relation to the fore ship. By linking a compass to the radar installation, the compass bearing of the object can be calculated as follows:

$$Compass\ bearing = Compass\ heading + RBA \qquad (3\text{-}4)$$

3.2.4. Presentation

Finally, when the ranges and bearings of the targets are known, the data has to be presented to the user in a convenient way. This is done by creating a plan view of the surrounding area, allowing the user to get a quick but informative overview of the surrounding environment. This is done by converting the received echoes, which are coming from the various azimuth cells, together to create a circle-based map with the observer point in the centre of the circle. In the current used radar displays, the presented output can be combined with nautical charts and/or AIS data. This will give extra information to the observed radar images.

3.3. Blind radar zones

As described in the previous subsection, a maritime radar detects targets by transmitting energy pulses and receiving the subsequent echoes. Blind zones occur when the radio energy pulses are intercepted by objects and by the maximum and minimum detection ranges for which these pulses can reach.

3.3.1. Maximum radar detection range

Maritime radars can detect targets as long as the antenna is able to transmit and receive energy pulses towards and from surrounding objects. This is following the line-of-sight principle, in which two observers are able to see each other if an undistorted straight line can be drawn between these two observer points. In case this line of sight is not intercepted by any obstacles it can basically be seen as a tangent of the Earth, in which the intersection points of this tangent and the Earth's surface are called the horizon. The horizon is the point or line that is dividing all visible directions into 2 groups, the lines that intersect with the Earth's surface and the lines that don't intersect with the Earth's surface. The position of the horizon is depending on the observer height and the curvature of the Earth. Targets, which are located below the tangent of the line of sight and behind the horizon of the observer cannot be detected. See figure 3-3.

Figure 3-3 - The radar horizon. (Bole et al. 2013)

For maritime radars in practice, the line-of-sight principle should be slightly adjusted because the atmospheric conditions cause that the transmitted radar pulses tend to bend slightly downward towards the earth surface. The theoretical maximum detection range of a maritime radar can be calculated using the observer and target heights and the formula below. In here it is assumed that standard atmospheric conditions are present, sufficiently powerful radar pulses are transmitted and received and that these pulses are not affected by any weather conditions (FURUNO, n.d.).

$$R_d = 2.2 * \left(\sqrt{Z_o} + \sqrt{Z_t}\right)\ [nm] \qquad (3\text{-}5)$$

3.3.2. Minimum radar detection range

As described earlier, targets are detected through the transmission and receiving of radar beams. At the time such a beam is being transmitted, the antenna cannot receive echoes coming back from the objects. The rear end of the transmitted radar pulses will clear the transmitter of the antenna after the beginning of the time period, with an expired time equal to the duration of one pulse length. This exact moment coincidences with the arrival of reflected echoes coming from a particular reflecting objects or surfaces, which are positioned at a distance of one-half pulse length away from the observing antenna. The theoretical minimum radar detection range can be determined by computing the covered distance by the radar pulses in one-half length of the transmitted pulse. See also figure 3-4a.

In practice this theoretical minimum of the radar detection range cannot be achieved because of two principal reasons. 1) The vertical beam width, which is defined by the lower and upper vertical limits of the transmitted beams. Targets which are navigating below the vertical beam limit of the maritime radar cannot be detected by the maritime radar. This is illustrated in figure 3-4b. 2) Because of the superstructure of the observing vessel. In the case the maritime radar signals are blocked by the shape of the vessel or the superstructures on top of the vessel, close by navigating targets or objects may not be detected. See figure 3-4c. Summarizing, the phenomena that results in the lowest detection range is normative and determines the minimum detection range. See also the next section regarding the blind radar spots caused by external obstacles.

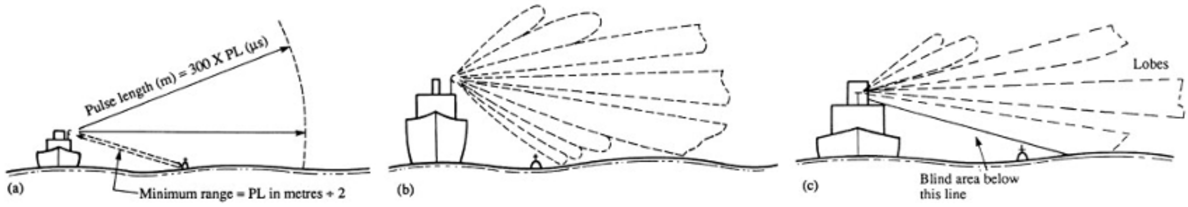

Figure 3-4. The minimum detection ranges of a radar and constraining factors. A) Theoretical minimum detection range. B) Minimum detection range for vertical beam limit. C) Minimum detection range as a consequence of vessel's superstructure. (Bole et al. 2013)

3.3.3. External obstacles

Next to the blind spots which are located beyond the maximum and minimum detection range of the maritime radar, blind spots can occur within this detection range as well. These areas are caused by the blockage of the transmitted pulses. This blockage is caused by obstacles, from which the pulses are reflected back as echoes. Since the transmitted pulses are reflected back, targets behind these obstacles cannot be detected and therefore these areas are forming blind spots for the maritime radar. This is illustrated in figure 3-5. The blockage by (external) obstacles can be categorized in two groups. The first group are obstacles which are present in the surrounding environment of the observer point. Examples of these obstacles are mountains, infrastructures, terminal equipment, forests and other vessels. A division can be made in static- and dynamic obstacles. Static obstacles are fixed objects which are continuously present, such as properties, infrastructures and forests. Dynamic obstacles are objects that are only partially present, such as vessels moored at berths or stacks of goods on the terminal. The obstacles of the first group are mainly present in ports, on inland waterways or in waterway sections close to the coastline, although the blind spots caused by other vessels can also occur at sea.

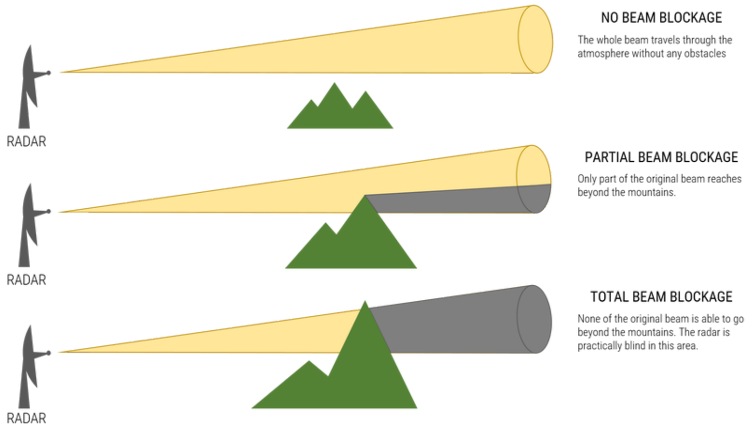

Figure 3-5. No-, partial- and total beam blockage. (Johnson, 2016)

The second group of obstacles which form blind spots for the maritime radar are obstacles which are positioned on- or are part of the layout structure of the vessel, from which the radar is observing the targets. Examples of these obstacles are masts, funnels, cargo and the vessel layout itself. As a consequence, blind and shadow zones can occur for the maritime radar. See figure 3-6. Shadow zones are zones where the radar pulses are partially obstructed. The radar pulses bend to a certain degree around the obstacle by diffraction, which enables the radar to have some performance in these sectors. The results of this are that the maritime radar is able to detect some targets in these areas at times. This is different with blind zones, in which no targets can be defined at all. The dimension of the antenna and the obstacle and the distance range at which the obstacle is located determine the angular width of the zone and if these areas can be classified as a blind- or shadow sector.

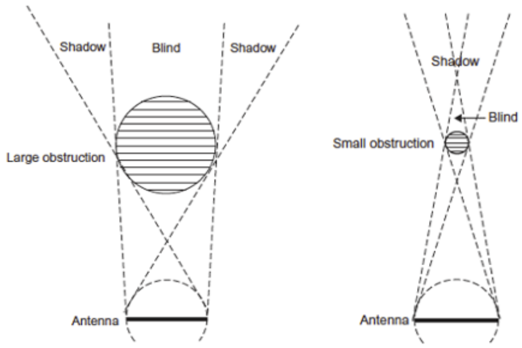

Figure 3-6. Blind- and shadow radar zones. (Bole et al. 2013)

3.4. Viewshed-Analysis

3.4.1. Overview

In the previous sections the detection principle of a maritime radar has been discussed as well as the formation of blind radar zones. In this section a method to determine the visible and invisible areas is addressed. The general method to determine whether areas around a chosen observer point are visible or invisible is called the viewshed-analysis. A viewshed analysis is a representative method for spatial analysis that identifies the visibility of every point on a terrain surface from any observer point and then marks the viewsheds on a raster image (Stucky, 1998). Viewshed-analysis have been applied to a wide range of purposes including urban environmental planning (lake et al., 1998 & lake et al., 1998), analysing the impact of wind turbines (Kidner et al., 1999), planning of watchtowers for monitoring forest fires (Bao et al., 2015) and to design power transmission pipelines (Fontani, 2017).

In terms of the transmission of radar waves, the viewshed-analysis can be used to determine the locations from where a transmitted radar pulse can be received from a particular transmitter point. This results in a communication viewshed or "commshed", which is indicating the coverage area of the transmitter point (Bostian et al., 2002). Several studies showed that the viewshed-analysis is a proper method to determine radar beam propagation and coverage. Dodd performed a study in which the viewshed-analysis is validated with respect to the prediction of reception areas of radar waves for optimizing a telecommunication system. The results showed that the viewshed-analysis can be used to determine the areas on which the radar beams can be received and therefore can be used as a major component in determining the profitability of establishing a cellular system (Dodd, 2001). In another study into radar beam coverage of weather radars, Shipley demonstrated that Geographic Information Systems provide an excellent tool to "estimate the effects of terrain and manmade obstacles on radar beam propagation, and their resulting impact on radar coverage over regions of interest." (Shipley et al., 2005).

With respect to the marine shipping domain, viewshed-analyses have been executed in several studies at the port of Szczecin in Poland. The port is located on an inland fairway area and because of the meandering fairway geometry and the presence of various types of barriers such as bridges, buildings, terminal equipment and vegetation, the planning of a proper VTS radar/sensor network was experienced as difficult. To determine the optimized locations for VTS-stations, radars/sensors and cameras, the viewshed-analysis have been applied. The results showed that by means the viewshed analysis the radar coverage areas as well as the radar shadows can be identified, which can be used as a component to support the overall radar-sensor planning for the VTS-monitoring system. By means of several examples it can be concluded that the use of spatial analyses in the environment of the GIS software packages contributes to the idealized localization of VTS-stations and radar/sensors which increases the overall effectiveness of the VTS-monitoring system (Łubczonek 2008), (Łubczonek et al., 2011) and (Łubczonek 2012)

3.4.2. Principle

With a viewshed-analysis is referred to the process in which the visibility of areas is identified as seen from a chosen observer point. This is done using the line-of-sight method, in which is verified whether a straight line between two points can be established. If the line is not obstructed by the elevations of the considered terrain, the points are mutually visible. Whether a line of sight can be formed between a chosen observer point and a target pixel is dependent on the location and offset of the observer point, the location and offset of the target point, the detection range and the elevation and surface profile of the considered terrain (Petrasova et al., 2018). Information regarding elevations of a particular terrain is presented by a Digital Elevation Model (DEM). A DEM is a raster file of n x m pixels, for which elevation information is stored on every pixel within the raster. With the offset of the observer and target points is referred to the height above the ground or DEM, for example the height of an antenna.

For each target pixel with location (x,y) and elevation z is verified whether the line of sight between the observer point and the target pixel intersects with the elevation of the terrain. This is done by comparing the terrain elevation on every individual pixel, which is covered by the line of sight, with the elevation of the line of sight at that pixel. In case the terrain elevation on at least one of these considered pixels is higher than the elevation of the line of sight, the line is distorted. This means that the target pixel will be invisible as seen from the chosen observer point. The other way around, target pixels for which this line of sight is undistorted will be visible as seen for the chosen observer point. See figure 3-7.

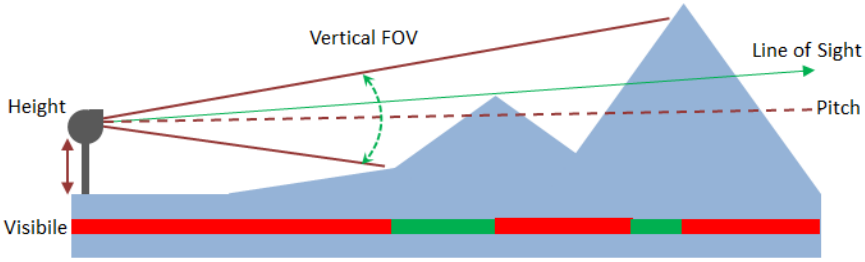

Figure 3-7 Line-of-Sight method in 2D domain. Green pixels are visible, red pixels are invisible. (Schafer, 2017)

The output of a viewshed analysis is a raster file in which for every pixel within the detection range a value regarding the visibility is assigned. The general way to define visible and invisible pixels is by means of a binary raster file in which the visible pixels are assigned with a 1 and the invisible areas are assigned with a zero. Another output form is to assign the required offset to make the particular pixel visible as seen from the observer point. In case the targets are visible a value of 0 is assigned, since no extra offset is required to make the pixel visible. The output raster file can be made visualized by a GIS program for example, for which a plan view with the visible and invisible areas as seen from the observer point can be obtained. An overview of the visualization of a viewshed is presented in figure 3-8. The green areas indicate the visible areas, and the red areas indicate the invisible areas.

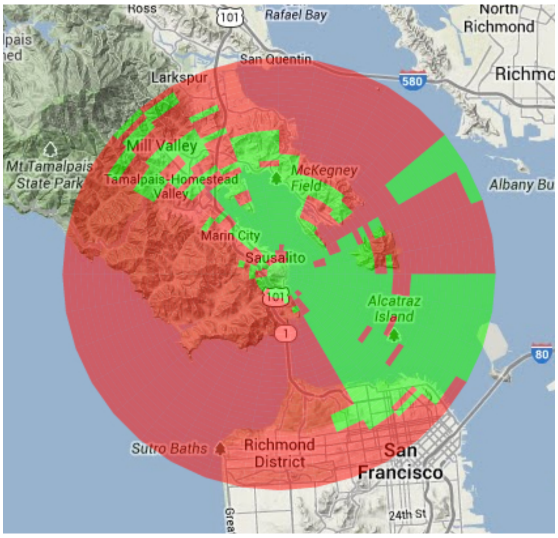

Figure 3-8 Overview of a viewshed. Green areas are visible, red areas are invisible. (Clark, 2013)

3.5. Conclusion

In this chapter the basic principles of the detection mechanism of a maritime radar have been discussed. A maritime radar consists out of an antenna, a switch, a transmitter and a receiver and the main objective of the radar is to detect targets in the surrounding environment of an observer point. Targets are identified by the echo principle, in which energy pulses have been transmitted and reflected back by obstacles in the surrounding environment of the observer point. When the radio energy pulses are transmitted and eventually received back by the antenna again, the data is processed to obtain the ranges and bearings of the detected targets. The detection principle of a maritime radar is based on the line-of-sight method, which states that two points are mutually visible for each other in case an undistorted line can be drawn between the two points.

Blind radar zones arise when the line of sight cannot be maintained between two points and these blind zones are caused by three main categories: 1) Maximum detection range, 2) Minimum detection range and 3) External objects. The maximum detection range is reached at the location where the line of sight intersects with the curvature of the Earth, also referred as the radar horizon. The location of the radar horizon is dependent on the observer height of the radar and the height of the target. With the minimum detection range is referred to the blind zones which arise very close to the observing vessel. These areas are dependent on the vertical beam limit in which the pulses are transmitted and/or the blockage of radar pulses by the structure of the observing vessel and/or by equipment/goods on top of this structure. Finally, blind areas can also occur as a consequence of beam blockage caused by external objects. Examples of these obstacles are mountains, infrastructures, terminal equipment, forests, other vessels and obstacles which are positioned on- or are part of the layout structure of the observing vessel. Depending on the target height of the obstacles, targets located on these blind areas might not be detected by the maritime radar.

In the last section of this chapter, the viewshed analysis is discussed, which is a method to determine the visibility around a chosen observer point. The viewshed analysis is based on the line of sine principle and by using a digital elevation model (DEM), the visible and invisible areas can be determined. This method will later be used to analyse the visibility of different locations and to verify how this visibility is behaving for different input parameters such as observer height, target height and detection ranges.

II. Method & Materials

4. Methodology

This thesis analyses whether VHF-communications are triggered by properties of the waterway system. To verify this, a quantitative method has been developed, in which spatial and temporal characteristics of VHF-communications are compared to spatial and temporal characteristics of fairway properties. This general method was briefly introduced in the introduction and this method can be applied to analyse the influence of multiple waterway properties on VHF-communications. As discussed in the introduction, in this thesis the focus is on analysing to what extent visibility is likely to trigger VHF-communications. To be able to execute this comparison, the spatial and temporal characteristics of the VHF-communications and the spatial and temporal characteristics of the fairway property "visibility" have to be defined first. This is done by a VHF-analysis and Visibility-Analysis. When the characteristics are defined, the characteristics are compared to analyse *whether the occurrence of a particular form of VHF-communication is related to the occurrence of blocked visibility. An overview of the strategy of this method is presented in figure 4-1. In this chapter the methodologies for executing the individual and combined analyses will be addressed. The methodology for the VHF-analysis can be found in section 4.1. In section 4.2, the visibility-analysis is discussed. Finally, the outputs of both analyses will be combined to verify whether VHF-communications are triggered by a lack of visibility, the methodology for this analysis is presented in section 4.3.*

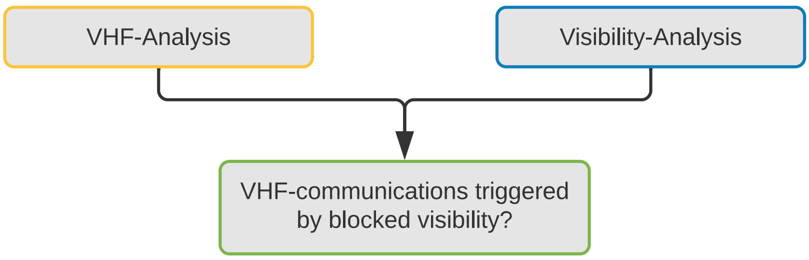

Figure 4-1 General methodology overview.

4.1. VHF-Analysis

The objective of the VHF-analysis is to create a clear digitized overview of the occurred VHF-communications, in which for each communicated message the substantive, temporal and spatial characteristics are addressed, which can be used for the execution of further analyses. To analyse the VHF-communications, historical VHF-data has been used. This historical VHF-data is internally available at the VTS centre of the Rotterdam Port Authority, where VHF-tapes as well as the associated radar and AIS-data of every port sector in the port of Rotterdam are stored. The VHF-data can be replayed using a replay function at the back-up desks at the VTS-centre, which is mainly used for training/feedback sessions for VTSO or for insurance related purposes in case of accidents. For the purpose of this study the replay function has been used to analyse the VHF-communications.

The VHF-analysis consists out of three main parts: Selection of the VHF-dataset, the digitization of the occurring VHF-communication and a subsequent analysis of the obtained digitized data. In the digitization process, the spoken VHF-communications are transferred into text and classified according to content, time and space. When the VHF communications have been digitized, it has been analysed what kind of communications occurred, which participants were involved and from where and when these messages have been transmitted. Based on this overview a better understanding of the occurring VHF-communications is obtained, which is used to identify waterway properties that are likely to trigger VHF-communications. An overview of the methodology of the VHF-analysis can be found in figure 4-2.

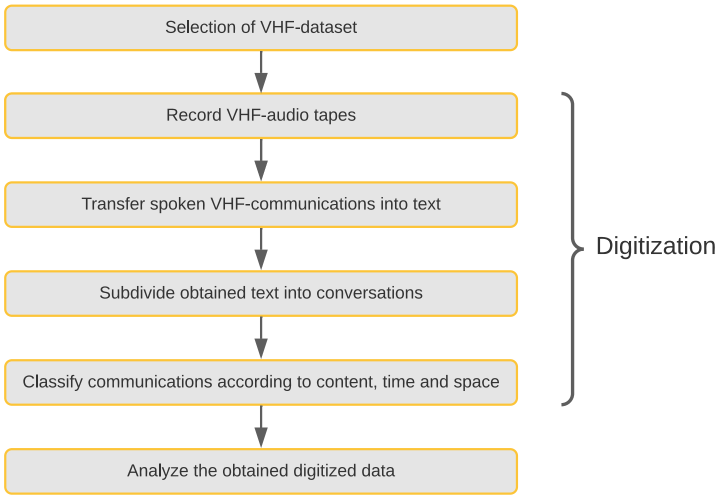

Figure 4-2 VHF-Analysis methodology.

4.1.1. Selection of VHF-dataset

To select a suitable VHF-dataset which will be used for the VHF-analysis, two criteria will be considered. First, the VHF-data should come from a sector which is prone to the formation of blind radar spots. In this way, it can be verified whether VHF-traffic is triggered by a lack of visibility. The first criterion is related to the considered fairway property which is investigated. In case a different fairway property is considered, one might define other another criterion. Secondly, the number of VHF-communications of the VHF-tape should provide sufficient input data to execute the analyses. Therefore, a tape with relatively more VHF-traffic is desirable.

Considering these criteria, there is chosen to use VHF-data of the sector Botlek for the VHF-analysis. First, in the sector Botlek are high structures onshore on the terminal areas present, which are likely to create blind spots for the maritime radar. Next to that, the layout of the sector is interesting as well. The sector is located in the centre of the port and characterized by a big intersection, which splits the Nieuwe Waterweg into the Nieuwe Maas and Oude Maas. Because of the centrally located spot of the sector in the port, the sector is categorized by a high amount of passing inland and sea going vessels in all directions. Furthermore, three major harbour areas are located in the sector: The Botlek, the 1st Petroleumhaven and the 3rd Petroleumhaven, in which in total 13 harbour basins can be found. These harbour basins are connected by central channels to the main fairways of the sector. This creates a sector in which a high number of adjacent fairway branches are present, which are likely to induce encounters between the vessels passing through the sector and the vessels coming out of these harbour basins. The combination of the expected occurrence of blind radar zones and the high number of expected encounters makes the sector suitable for the analysis regarding the layout criteria.

Secondly, the sector Botlek is also suitable for the analysis because in this sector relatively more VHF-communications arise in comparing to other sectors. To further meet the second criteria, a timeframe of a crowded sector will be analysed, which provides even more VHF-data as input for the analysis.

4.1.2. Digitization of VHF-communications

The digitization of VHF-data consists out of four subsequent steps, in which spoken VHF-communications has been transferred into text and classified based on content, time and space. In the first step of the digitization process, the VHF-audio files have been recorded. Subsequently, the recorded audio files have been transferred into text. Initially, it was thought to use specific speech-to-text software programs to transfer the spoken audio files into text, however no appropriate program has been found to execute this process for VHF-communications. Several speech-to-text programs have been tested; however, the results were unsuccessful. Disturbances on the VHF-channel, a variety in used languages, multiple speakers at the same time and a high speaking rate are factors that made the output texts unusable. Because the transformation of the audio files into text cannot be executed using an automized program, an alternative strategy has been developed in which the spoken VHF-communications will be typed out. This is done by listening back the VHF-audio file and typing out the spoken communication word by word, whereafter a raw text of the VHF-communications is obtained.

After the raw text is obtained, the text has been subdivided into individual conversations. This is done to create a better structured overview of the communications, which is beneficial for the classification of content and the involved participants in the next step. Individual conversations can be identified by searching for quiet phrases on the VHF-tape, in which no audio is recorded, or by recognizing the message marker “OUT”, which indicates that no further response is required, and the conversation has ended. When the individual conversations have been identified, each transmitted message in the conversations has been classified according to content, space and time. Within content the involved participants and the communication types have been addressed. The involved participants consist out of the transmitter and receiver of the message as well as the participants where have been communicated about in that particular message. The classification of the communication types is based on the internationally prescribed guidelines and regulations for VHF and VTS. Finally, the temporal and spatial components of the messages have been identified. Within the temporal component of a message, the transmission times and durations of messages are addressed, where under the spatial component the locations of the involved participants are identified. The locations of the involved participants can be identified by making use of the associated radar and AIS-data of that moment.

4.1.3. Analysis of digitized data

When the VHF-communications have been digitized, the obtained data will be analysed to gain a better insight in the occurred communications. This is done by summing up all the individual conversations and identifying the substantive, spatial and temporal characteristics of the considered VHF-communications. First it will be verified what types of communication occurred, in which quantities these communication types are present and whether certain categories can be identified. Next to that, it will be verified whether certain patterns can be recognized. In this way it can be analysed which communication types occur the most and whether certain circumstances are likely to trigger these communications. The identification of the communications categories is required to verify later whether a certain type of communication is likely to be triggered by a lack of visibility, when the spatial and temporal characteristics of the VHF-communications are linked to the spatial and temporal characteristics of the fairway property “visibility”. Next to that, gaining insight in the occurring VHF-communication types and the quantities in which these types occur is relevant to identify which potential measures will be most effective in reducing the VHF-traffic.

Subsequently, the involved participants of the communications are identified. In this analysis a general overview will be obtained in which can be verified what number of VHF-messages have been transmitted by which kind of participants. In here a distinguishing will be made in communications between skippers and VTSO and skippers mutually. When combining this analysis with the analysis regarding the types of communications, it can be verified which type of communication is communicated between which participants and to what extent the VTSO is participating in the conversations.

Finally, the locations of the observing vessels are analysed to verify towards which positions VHF-traffic is occurring. This will firstly be done for the individual communication types separately, to identify whether a certain type of communication is communicated to particular locations with respect to the layout of the sector. Thereafter, all observing vessel locations are combined to analyse whether certain hotspot locations can be recognized, where relatively higher amounts of VHF-traffic are communicated to. The identification of the observing vessel locations is required to obtain a better understanding where VHF-communications arise, and these locations provide the input for the visibility analysis to later verify whether a lack of visibility is likely to induce certain VHF-communications at particular positions.

4.2. Visibility-Analysis

First a model is developed to determine the rate of blockage of maritime radar signals. This is done by the visibility-analysis, in which the visibility around an individual observer location is determined and expressed by a blockage factor. When the model is set up, the outputs will be compared with real radar images, to validate whether the predicted visibility by the model is a valid representation of the visibility of a real maritime radar. These radar images are coming from the vessel Factofour, an inland container vessel which is currently operating. When the results of the verification are assumed to be valid, the visibility-analysis will be used to determine the BF behaviour for multiple locations and several scenarios. In here the BF behaviour is analysed for varying port locations, varying observer and target parameters, such as antenna height, detection range and target height, and static and dynamic obstruction scenarios. Static obstructions are fixed objects which are continuously present, such as properties, infrastructures and forests. Dynamic obstructions are objects that are only partially present, such as vessels moored at berths. When these varying conditions are analysed, the BF behaviour and dependency throughout the port is known. An overview of the strategy of this method, including the subsequent steps, is presented in figure 4-3.

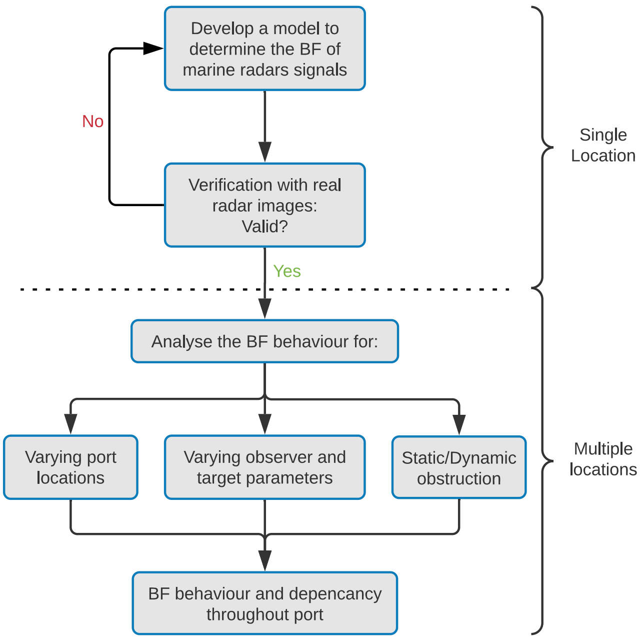

Figure 4-3. Visibility Analysis structure.

4.2.1. Visibility-Analysis

To estimate the obstruction of maritime radar signals, a model has been developed to determine the visible and invisible areas around a chosen observer point. This is done by means of a visibility-analysis. To get an overview of the rate of blockage of the maritime radar signals for a particular location, the visibility is expressed by a blockage factor (BF). The BF is defined as the total invisible fairway area within a circle around a chosen observer point ($A_{FW,C,Invisible}$), divided by the total fairway area in that circle ($A_{FW,C}$). This indicates which fairway areas are invisible from the chosen observer point, within the selected detection range. In formula form:

$$BF = \frac{A_{FW,C,Invisible}}{A_{FW,C}} * 100\ \% \qquad (4\text{-}1)$$

In the visibility-analysis, the blockage factor is determined by two sub-analyses, a viewshed-analysis and a subsequent area-analysis. See figure 4-4 for an overview of the model methodology. Firstly, a viewshed-analysis is carried out to determine the visible and invisible areas around a chosen observer point. This is done based on a Digital Elevation Model (DEM) of the area of interest and several input parameters for the observer point, curvature coefficient and output mode. The observer parameters consist out of coordinates of the observing location, the antenna height and detection the detection range. The output of the viewshed analysis is a viewshed in which the required elevation for each pixel in the surrounding environment are addressed, which are required to be visible for the maritime radar.

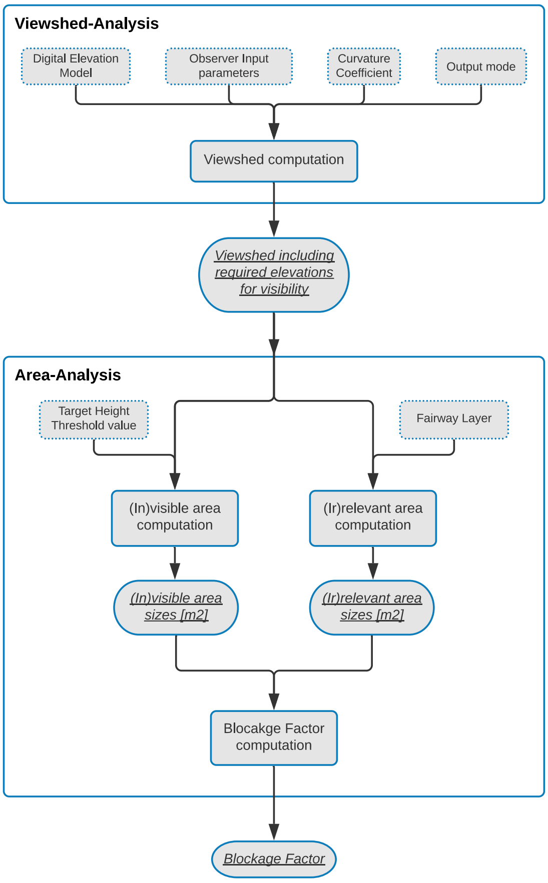

Figure 4-4. Visibility-Analysis methodology

The output of the viewshed-analysis forms the input for the area-analysis. In the area-analysis, the output viewshed is subdivided into different areas categorized by visibility and relevance. Based on a target threshold height the viewshed is divided into two regions, namely the areas for which target vessels upon the target threshold height are visible and the areas for which target vessels upon the target threshold height are not visible. This is done in the (In)visible area computation. The output of the (In)visible area computation are the sizes of the corresponding visible and invisble areas. Secondly, the viewshed is divided in relevant and irrelevant areas. Relevant areas are areas on which the targets of interest can be detected. In the marine shipping domain, targets of interest consist out of other vessels, buoys and other obstacles, which are positioned on the fairways in the surrounding environment. Therefore, relevant areas are defined by regions positioned on the fairway and irrelevant areas are defined by regions with are not located on the fairway areas, such as regions ashore. The distinguishing between relevant and irrelevant areas is executed in the (Ir)relevant area computation, based on the input of a fairway layer. In this computation the sizes of the (Ir)relevant areas are computed, which forms the output of this computation.

Finally, when the output viewshed from the viewshed-analysis is divided in visible and invisible areas as well as relevant and irrelevant areas, the blockage factor can be calculated by combining the outputs of these computations. This results in a blockage factor for a particular location as defined in the set-up of the viewshed-analysis.

The model methodology, -documentation and -set up of the visibility analysis can be found in chapter five. In here is briefly expressed what steps are taken to execute the analysis, as well as a example viewshed computation for a single location in the sector Botlek. The verification with real radar images is explained in section 5.3.

4.2.2. Blockage Factor Behaviour

In the previous section, the visibility of a single observer point has been defined by the visibility-analysis. The next step is to analyse the behaviour of this blockage factor for varying input parameters. This is done by running the visibility-analysis for varying input parameters for the observer point, observing- and target vessel parameters and dynamic obstructions.

4.2.2.1. Varying port locations

The BF behaviour for varying locations in the port is determined by running the visibility-analysis model for multiple locations in the port. This is done by creating multiple observers point coordinates throughout the port and run the model for every single location. The observer point coordinates are created by drawing lines on the fairway sections of the port and define points with equal mutual distancing on these lines. This is done in the Geo Information Software QGIS (QGIS, 2021). For each point on the line, the corresponding coordinates are extracted and used as input for the visibility-analysis model. For every location, the corresponding blockage factor will be compared with the BFs other locations and in this way the behaviour of the BF can be analysed for different locations in the port.

4.2.2.2. Varying observer and target parameters

Next to varying port locations, the BF behaviour for varying input parameters for the observing- and target vessels will be analysed as well. The input parameters for the observing vessel are consisting out of the antenna height and the detection range. The input parameter for the target vessels is defined by the air draft. For each individual parameter, the BF-analysis model will be run for varying values of the considered input parameter and the corresponding BFs will be determined. In this way the BF-behaviour can be analysed for varying antenna heights, detection ranges and target air drafts. This analysis is combined with the varying location analysis to verify what the differences in BF dependency are for different sections in the port.

4.2.2.3. Dynamic obstruction

Finally, the influence of dynamic obstructions on the blockage factor is determined as well. Dynamic obstructions are obstructions caused by objects that are only partially present. There are several types of dynamic obstructions, but in this thesis is focused on the influence of vessels which are moored at berths. To determine the influence of moored vessels on the BF, a modified DEM file has been used. In this DEM file, the presence of moored vessels has been included. The visibility-analysis is then carried with this modified DEM file.

4.3. Comparing of Characteristics

When both the characteristics of the VHF-communications and the considered fairway property "visibility" are defined, it can be verified whether the occurrence of a certain type of VHF-communication is triggered by a lack of visibility. This has been analysed by combining the results of the VHF-Analysis and the visibility-analysis, in which the spatial and temporal characteristics will be compared. The objective of this analysis is to formulate an answer to the formulated hypothesis:

On locations with higher rates of blocked visibility occurs more VHF-communications regarding objects that are not visible.

In this analysis will be focused on the VHF-communications regarding traffic images because in this form of communication an overview of the locations of target vessels will be presented for which an encounter with the observing vessel is expected. To analyse whether a lack of visibility is likely to trigger communications regarding traffic images, for each communicated traffic image the visibility is determined and analysed. In here is focused on two aspects: 1) The rate of blockage of the locations of the observing vessels towards which traffic have been communicated and 2) The mutual visibility of the observing vessel and the involved targets vessels about which have been communicated in a particular traffic image. By computing the rate of blockage of the observing vessel locations it can be verified whether traffic images are communicated towards locations with significant higher blockage factors or not. By determining the mutual visibility of the involved participants, it can be verified whether the communicated targets in a traffic image have been visible for the observing vessels. When both visibility aspects have been analysed, an answer can be given to the hypothesis.

4.3.1. Observing vessel visibility

To determine the rate of blockage of the locations on which the observing vessels have been located during the moment a traffic image is communicated, information regarding the positions of the observing vessels is required and the model to determine the visibility of a particular location. The observing vessel locations have been defined in the VHF-analysis and the visibility around a chosen observer point can be determined by means of the visibility-analysis. For each observing vessel location, the corresponding blockage factor is determined by means of the visibility-analysis. In this way an overview of all observing vessel locations during traffic images is obtained. This overview is used to analyse whether traffic images have been communicated to observing vessels which are positioned on locations with significant higher blockage factors or not. This is done by comparing the blockage factors of the observing vessel locations with the average blockage factors of the surrounding environment.

4.3.2. Mutual target visibility

The mutual visibility of the communicated targets in traffic images is determined by adding information regarding the positions of targets vessels to the computation of the visibility of a single observing vessel location, as defined in the previous section. Information regarding the positions of target vessels has been defined in the VHF-analysis. For each communicated traffic image, it will be verified whether the communicated targets have been visible for the observing vessel or not. This can be determined by analysing whether the target locations coincide with visible or invisible areas, as defined by the visibility analysis. Logically, target locations which coincide with visible areas are visible for the observing vessel and target’s locations which coincided with invisible areas are invisible for the observing vessel.

4.4. Conclusion

In this chapter the methodology is discussed which will be used to give an answer to the main research question. In this thesis will be investigated to what extent VHF-communications are triggered by a blocked visibility for the maritime radar. In order to verify this main research question, a method is developed in which spatial and temporal characteristics of the VHF-communication are compared to spatial and temporal characteristics of the fairway property “visibility”, to investigate whether the occurrence of a particular type of VHF-communication is related to the occurrence of a blocked visibility. To do so, the spatial and temporal characteristics of the VHF-communications as well as the spatial and temporal characteristics of the fairway property “visibility” have to be defined first. This will be done by a VHF-Analysis and a Visibility-Analysis.

The VHF-analysis consists out of two parts: 1) Digitization of the VHF-communications and a subsequent 2) Analysis of the obtained digitized data. In the first part, the spoken VHF-communications will be transferred into text and classified according to content, space and time. This will be done by recording VHF-audio tapes, type out the messages word by word, subdivide the obtained text into individual conversations and classify each communication based on communication type and involved participants. Subsequently, the locations of the vessels of the involved participants will be identified by using historical radar and AIS-data. In the second part, the substantive, spatial and temporal characteristics of the VHF-communications are identified. This is done by analysing the obtained digitized data and identify the occurred types of communications, the involved participants per type of communication and the corresponding locations of the participants. When the involved participants and corresponding vessel locations during each form of communication are known, it can later be verified whether the communicated targets have been visible for each other and whether visibility is likely to trigger VHF-communications.

Secondly the visibility is analysed in the visibility-analysis. Likewise, the VHF-Analysis, the Visibility-Analysis consists out of two parts as well. First a model will be set up to determine the visibility around a chosen observer point. The visibility is expressed by a blockage factor, which is defined as the total invisible fairway area within a circle around a chosen observer point, divided by the total fairway area in that circle. The blockage factor is determined using a model in which a viewshed-analysis and a subsequent area-analysis are executed. The blockage factor is the output of the analysis and can be visualized by means of a corresponding viewshed, in which the locations visible and invisible locations around the chosen observer point are indicated. The output viewshed will be validated with real radar images and there will be verified whether the visible areas as determined by the model coincide with visible areas as seen on the real maritime radar images. When the model is validated and approved it will be used to analyse BF behaviour for different conditions. In here the BF behaviour is analysed for varying port locations, varying observer and target parameters, such as antenna height, detection range and target height, and static and dynamic obstruction scenarios. Static obstructions are fixed objects which are continuously present, such as properties, infrastructures and forests. Dynamic obstructions are objects that are only partially present, such as vessels moored at berths. When these varying conditions are analysed, the BF behaviour and dependency throughout the port is known.

Finally, when the substantive, spatial and temporal characteristics of the VHF-communications as well as the spatial and temporal characteristics of the fairway property “visibility” are identified, there can be verified whether the occurrence of a certain type of VHF-communication is related to the occurrence of a blocked visibility. This will be done by comparing the outcomes of the VHF- and Visibility-Analysis and investigate the visibility during the VHF-communication type traffic images. For each communicated traffic image, it will be verified whether the communicated targets have been visible for the observing vessel and what the BF is for the location of the observing vessel. This will be analysed by running the visibility analysis for each of the observing vessel locations and verify what the corresponding BFs are. When the corresponding viewsheds of the BFs are visualized, it can be verified whether targets have been visible for the observing vessel. If traffic images are communicated towards locations with higher BFs and if the addressed targets in the traffic images are not visible for the observing vessel it can be concluded that visibility is likely to have an influence on the occurrence of VHF-communication regarding traffic images

5. Implementation & Internal Validation

In this chapter the model implementation and internal validation for the visibility-analysis are elaborated. In here the main principles of the viewshed- and area-analysis are discussed, as well as the definition of the input parameters. This involves the set-up of the Digital Elevation Model (DEM), the definition of the vessel parameters and the desired output mode of the model. An example viewshed, in which the visible and invisible areas around a chosen observer point are determined, is provided to get an overview of the model outputs. This example viewshed is used to validate the model, which is discussed in the last section of this chapter. The validation is performed by comparing the output viewshed with real radar images and verifying whether the (in)visible areas as determined by the model coincide with (in)visible areas as seen by a maritime radar.

5.1. Viewshed-analysis

5.1.1. Model Documentation

As described in section 5.3.2., the viewshed-analysis is a proper method to estimate the degree of obstruction of the maritime radar signals. The viewshed analysis can be computed by making use of one of the many geographical information system (GIS) programs such as ArcGIS, GRASS GIS, QGIS and Google Earth Pro or by using translatory libraries such as GDAL and GRASS. In general, these software packages execute the viewshed-analysis based on the line-of-sight principle, however differences arise in the applied methods for analysing the line-of-sights. Especially for files with large detection ranges, high level of accuracies and small pixel sizes, the viewshed analysis can be a time-consuming process. Therefore, various algorithms have been developed in order decrease the processing time. Proposed strategies are for example the local viewshed (Wang et al., 1996), fuzzy viewshed (Ogbum 2006), square ring (Franklin & Ray, 1994), and reference plane (Wang et al., 2000) approaches.

In this study the viewshed-analysis will be calculated by making use of the Geospatial Data Abstraction Library (GDAL) documentation, in combination with the programming language Python (Python Software Foundation, n.d.). GDAL is a translator library for raster and vector geospatial data formats and provides a variety of command line utilities for data translation and processing (GDAL/ORG, 2020). There is chosen for the GDAL software because of multiple reasons. First, the GDAL software can be downloaded freely online and can be used without the requirement of a particular licence or authorization. The software is updated frequently which makes it a reliable source. Next to that, the software is supported by the programming languages *C*, *C++, Python* and *Java*, which are currently the most used programming languages as indicated by the TIOBE index (TIOBE, 2020). By means of these programming environments, the processes can be linked and atomized. This holds that the viewshed computation, as well as the computation of the (in)visible- and (ir)relevant areas and therewith the BF can be determined by one single code/command and all the required output/input data files are kept within the same program environment. This makes the process quicker and more effective than the case when multiple executions have to be carried out in different programs, in which an exchange of data files is required. Finally, because the software is open accessible and supported by the main programming languages, this modelling study is suitable for further research. This is in line with the FAIR-principles, which states that scientific data should be Findable, Accessible, Interoperable and Reusable, to make scientific data suitable for re-use under clearly described conditions (GO FAIR, The underlying theory for performing the viewshed analysis by means of the GDAL viewshed documentation is based on the Reference Plane Algorithm (Wang et al., 2000). In this algorithm, viewsheds are computed based on gridded Digital Elevation Models (DEM). In contrast to other viewshed analysis theories, this theory is generating viewsheds based on reference planes, rather than executing the line-of-sight analysis for every bearing in a 360-degree circle around an observer point, which is a time-consuming process. In Wang's method, the line-of-sight principle is performed in eight main bearings directions only, starting from the North and with mutual distances of 45 degrees. The visibility of the pixels which are located on the areas in between these bearings are computed by a reference plane and auxiliary grid. In comparing with the traditional sightline-based algorithms, the reference plane method calculates the viewshed in much less computation time. The GDAL viewshed analysis creates a viewshed based on a DEM and some input parameters for the observing point. In the model set up, in which these input variables are addressed, is elaborated below, as well as the output data file.

5.1.2. Model set-up

5.1.2.1. Digital Elevation Model

The key input parameter for the GDAL viewshed analysis is a digital elevation model (DEM) of the location for which a viewshed-analysis is desired. Based on this elevation model the visible and invisible areas will be determined. For this research, the desired areas of interest are the areas in which the port of Rotterdam is located, as well as the surrounding environments. For the entire area of the Netherlands, various types of digital elevation models are composed and made publicly accessible in the form of "Het Algemeen Hoogtebestand Nederland" (AHN, n.d.). AHN can basically be seen as the digital elevation model for the entire country. Using laser technology, 3D elevation information has been collected from helicopters and airplanes. This resulted in a detailed set of different elevation models in which the ground level of every square meter in the Netherlands is known upon an accuracy of five centimetres. Next to information about ground level elevations, information about the elevation of buildings, vegetation and infrastructures is available as well. The elevation models are widely used by organizations such as water boards, provinces and Rijkswaterstaat for among others water and flood management and dike maintenances.

Through the visibility-analysis the rate of blockage of maritime radar signals will be determined based on two scenarios': the visibility based on static obstructions and the visibility based on static + dynamic obstructions. Static obstructions are fixed objects which are continuously present, such as properties, infrastructures and forests. Dynamic obstructions are objects that are only partially present, such as vessels moored at berths. To obtain the desired digital elevation model for executing the viewshed analysis for both the static and dynamic obstruction scenario, some intermediate steps have to be carried out:

1. Selection of type of dataset and level of accuracy
2. Merge fairway layer
3. Merge berthing layer (for dynamic obstruction)

This eventually results in two DEM files, one DEM file to estimate the blockage factor caused by static objects, which is obtained after the first two steps, and another DEM file to estimate the blockage factor caused by dynamic objects, which is obtained after the merging of the berthing layer on top of the DEM file for the static obstructions. In the sections below the intermediate steps are addressed in more detail.

1. Selection of type of dataset and level of accuracy

As described above, the digital elevation models as developed by AHN are available in different datasets which differ in output file type, elevation information and level of accuracy. To select the most suitable set for the viewshed analysis, some criteria have been established. The criteria are: 1) The DEM file has to be in raster output format. This requirement is based on model requirements of the GDAL viewshed package, which creates a viewshed based on a raster DEM input file. 2) The DEM file has to provide information regarding both the ground level elevations as well as the elevations of the objects on top of the ground level. Since the visibility of the maritime radar is determined at inland fairways, the elevations of superstructures on top of the ground are expected to have a significant influence on the visibility in these areas and therefore cannot be neglected. 3) The DEM file has to be of sufficient accuracy. 4) The DEM file should be as up to date as possible.

AHN is providing elevation models based on two output files, raster and point clouds. Based on criteria 1, there is chosen to use the raster files. The raster files are divided into two categories, Digital Surface Model (DSM) and Digital Terrain Model (DTM). In the DTM information regarding the elevation of the surface level is provided. In the DSM file the elevations of the surface level as well as the elevations of objects on top of the ground level, such as buildings, vegetation and infrastructures are presented. Therefore, there is chosen to use the DSM raster files. In here is chosen to use the AHN3 DSM files, since these files are collected most recently and are most up to date, which most meets the last criteria.

Finally, the level of accuracy of the AHN3 DSM files has to be considered. The AHN3 DSM files are available in two different accuracy levels: DSM 0.5 m and DSM 5 m, which are having pixel sizes of 0.5 x 0.5 meters and 5 x 5 meters respectively. Because of the smaller pixel size, the DSM 0.5 m file is more accurate/detailed than the DSM 5 m file. A consequence of this higher level of accuracy is that the size of the DSM 0.5 m files is way larger than the size of the DSM 5 m files. This will also increase the required computation time to perform particular calculations with the DEM as input. To decide whether the DSM 0.5 m or DSM 5 m dataset should be used for the viewshed analyses, a comparison of the two datasets is made based on the computation time and deviation of output results. This is done while performing viewshed analyses and corresponding blockage factor calculations for different locations for both the DSM 0.5 m and DSM 5 m files. The picked test locations are located in the sector Botlek, see figure 5-1 for an exact overview of the test locations.

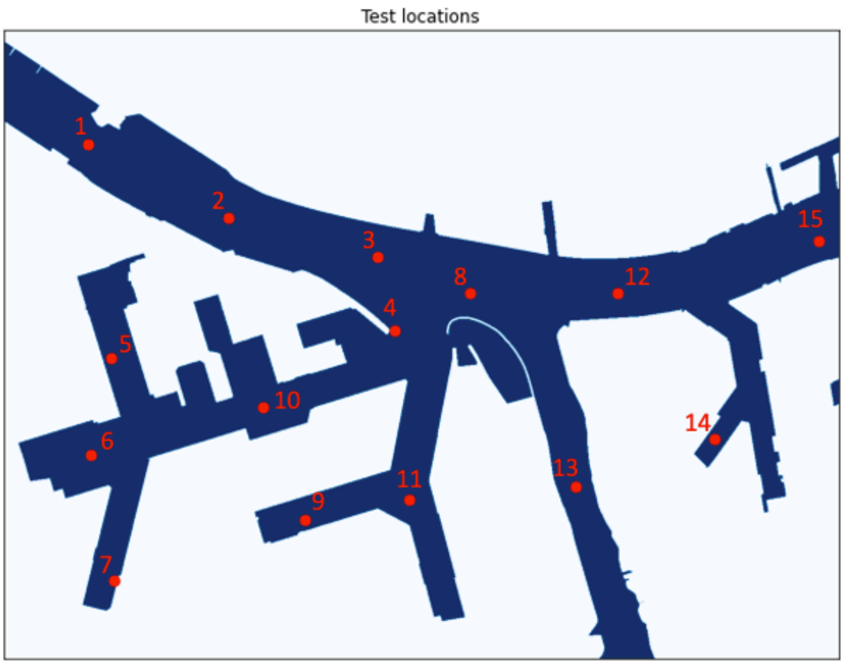

Figure 5-1. Test locations for accuracy verification.

As can be seen in figure 5-2a, the computation time of the DSM 0.5 m file is significantly longer in comparing with the computation time for the DSM 5 m file. The average computation time for the DSM 0.5 m file is 6.87 seconds, where a DSM 5 m file only takes 0.079 seconds. Although the significant difference in computation time, this difference is not recognizable in the output results. The average difference in output results is only in the order of 0 – 3%, which can be seen in figure 5-2b. Next to that, multiple viewshed analysis have to be executed to get a detailed overview of the blockage rates of several locations in the port, which will also cause longer computation times. This will be executed as a batch process in which up to 200 individual viewshed analyses have to be carried out for a particular sector. Considering this and the relatively small differences in the output results, the DSM 5 m dataset is assumed as detailed enough to execute the viewshed analyses. The test is only carried out for the sector Botlek, but it is assumed that these small differences can also be expected in other port sectors. Therefore, the DSM 5 m files will be used to describe the elevations throughout the full port of Rotterdam.

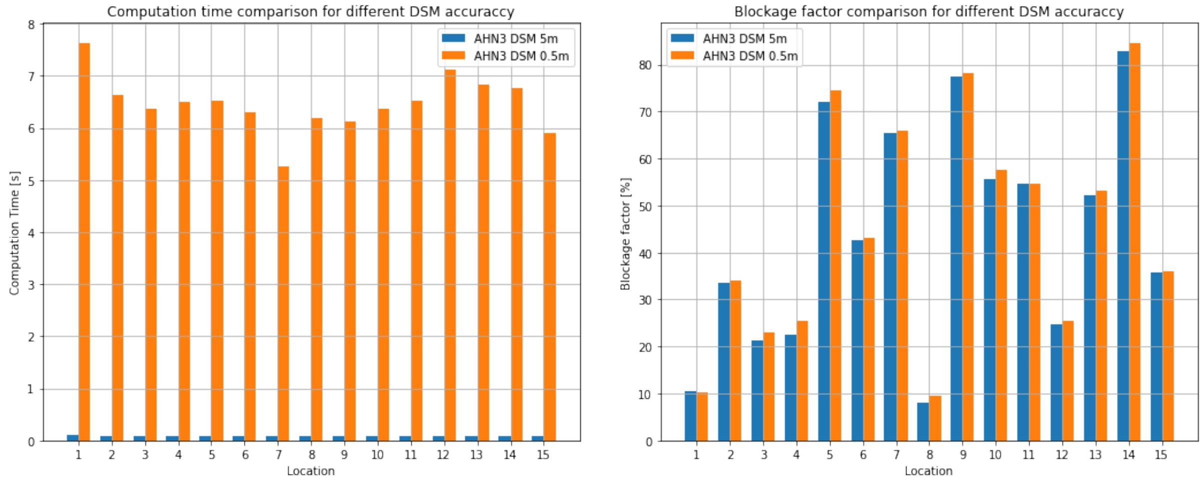

Figure 5-2. Results of accuracy verification. Left graph: Computation time comparison. Right: Blockage factor comparison.

2. Merge Fairway layer

The AHN3 DSM files describe all elevations of pixels except those which are classified as “water”. This holds that all pixels laying on the main fairway, side channels and harbour basins are classified with the “no data” value. To eliminate these “no data” pixels, a layer in which the fairway regions of the port of Rotterdam is included is merged on the DEM of the full port. This vector layer is gathered intern at the Rotterdam Port Authority. Since the fairway layer is categorized as a vector layer, it is transformed in a raster layer to merge it with the DEM file of the full port, which is a raster layer as well. Again, this will be done by the program QGIS, in which the “Rasterize (vector to raster)” tool is used of the “GDAL” package from the “Processing Toolbox”. The transformation from vector to raster makes it possible to assign pixel values to the fairway layer as well.

To assign a representative value for the water level, the limit values of the tides are considered. In the port of Rotterdam, the difference between high and low tides can reach upon 2 meters. In here is focused on the limit values for low tides, as these lower water levels will induce more maritime radar blockage than high water levels and are therefore normative. Information regarding the limits of tides and other hydraulic properties of Dutch rivers is measured and made open accessible by Rijkswaterstaat (Rijkswaterstaat, n.d.). Concerning the port of Rotterdam, information is gathered through 8 measurement stations throughout the port, on which continuously measurements are carried out. Due to the elongated shape of the port, the height of the tide differs over the different measurement stations of harbour. The values of the low tide are ranging between 1.0 m NAP on the westside of the harbour (at the seaside) and -0.6 m on the east side (at the city side) (Rijkswaterstaat, n.d.). There is chosen to assign a pixel value of -0.8 m to pixels which are located on the water areas because this is the average value of low tide limits for the different measurement stations.

As described earlier, the AHN3 DSM files are not assigning values to pixels which are located on water. However, the pixels of locations where vessels were navigating during the exact moment the measurements were taken are assigned with an elevation, though. The fairway layer is representing the full water area of the port of Rotterdam. After the fairway layer is merged over the DEM of the full port, all the measured elevations such as the navigating- and moored vessels and berthing infrastructures are removed from the AHN3 DSM 5 model. This results in a full port DEM file for which all fairway areas are assigned with the same pixel value of -0.8 meters. See figure 5-3a. Because all the dynamic influences of navigating- and moored vessels are removed, this DEM model can be used for analysing the influence of the static obstacles on the obstruction of maritime radar signals. Static obstacles are fixed objects which are not moving in time, such as buildings, vegetation and infrastructures.

3. **Merge Berthing layer**

In the previous two steps the DEM input file for the viewshed analysis for static obstructions is determined. To obtain the DEM input file to determine the blockage rate of maritime radar signals as a consequence of the static + dynamic obstructions, an extra layer is added and merged to the DEM file for the static obstruction, as defined by the previous steps. Dynamic obstacles are objects that are not fixed and will move from time to time. An example of a dynamic obstacle is a vessel moored at a berth. To analyse the influence of dynamic obstruction, moored vessels will be simulated on an adjusted DEM input file. This is done by merging a layer with information about berthing the location of berthing places. Like the fairway layer, the berthing place layer is a vector layer as well and therefore needs to be transformed into a raster layer before it can be merged to the DEM file. The same process is followed as with the fairway layer. To simulate the presence of moored vessels, elevations of 20 meters will be assigned to the surface areas of the berths, which creates box shaped obstacles. See figure 5-3b. Although the shape of a vessel is deviating strongly from the shape of a box in practice, the side of a vessel can be recognized as a vertical plane by a maritime radar. Vessels can moor in different ways to the quay (quay at port or at starboard) and will move up- and downwards because of the tide. Therefore, it is assumed that a box shaped model is applicable. Especially because the aim of this part of the analysis is to identify the locations for which the influence of dynamic obstacles is significant. Which means that there is aimed on dynamic obstacles that will definitely block radar signals.

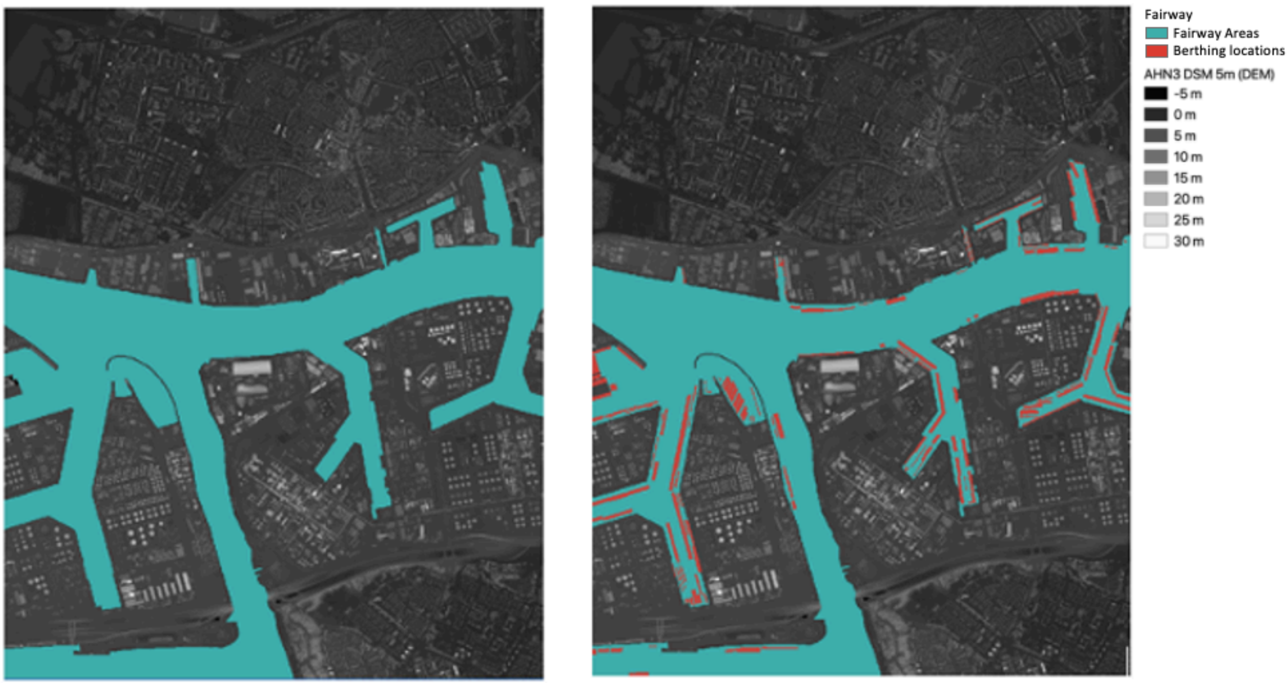

Figure 5-3 DEM Files for viewshed-analysis. Left) Static DEM, Right) Dynamic DEM.

5.1.2.2. Observer input parameters

The observer input parameters are related to the X and Y position-, the height above the surface and the maximum distance of from the observer to compute visibility. Since the visibility of a maritime radar is simulated by means of the viewshed, the observer input parameters are related to the maritime radar of the vessel. For the X and Y coordinates the projected coordinate system for the Netherlands is used, also referred as: EPSG:28992 - Amersfoort (EPSG, 2005). With the height above the surface is referred to the elevation at which the antenna of the radar is mounted. This is equal to the vertical distance between the antenna and the water surface. With the maximum distance is referred to the set detection range of the radar, for which the radar is able to detect targets in the surrounding environment. This detection range is equal to the radius of a circle around the observer point, by which the detection circle is defined.

5.1.2.3. Curvature Coefficient

When the visibility between two points is calculated, for example by the line-of-sight method or by a viewshed analysis, a curvature coefficient has to be implemented. This coefficient considers the influence of the curvature and refraction. The magnitude of the curvature coefficient is dependent on the wavelength and varies for different atmospheric conditions. The coefficient can be determined by the following formula:

$$C_{curvature} = 1 - C_{refraction} \quad (5\text{-}1)$$

For radio waves, the refraction coefficient is in the order of 0.25 – 0.325 (GDAL, 2018). For this research, a refraction coefficient of 0.3 is assumed to be valid. This holds that the curvature coefficient is equal to 0.7 and this value will be used for all computations regarding viewsheds. The influence of this parameter is more significant when the line of sight between two points becomes larger. In this research there is focused on determining the visibility of maritime radars on inland fairways, for which viewsheds with a detection range up to 2500 meters are determined. So, the influence of the curvature coefficient will not be that significant on the final results of the radar visibility. This would change in case the model will be used for determining the visibility for larger distances, for example for vessels navigating on more open water areas like the sea or the ocean.

5.1.2.4. Output mode

For the viewshed analysis the output mode “DEM” is used, instead of the default output mode “VISIBLE”. This is done because the DEM output mode returns more information than the VISIBLE output mode. The VISIBLE output mode returns only pre-set values which indicate whether a pixel is visible or invisible. So, for example, a pixel value of 1 represents a visible pixel and a pixel with a value of 0 represents an invisible pixel. In the DEM output mode, the value assigned to the pixel is equal to the minimum additional elevation on top of the DEM elevation model file, which is required to make that pixel visible as looking from the chosen observer point. This is beneficial because the same output dataset can be used to analyse the visibility of targets with different antenna heights, instead of performing multiple simulations for different target antenna heights separately.

When running the model, the target detection height is set to zero. This returns an output file with data about the minimum elevations ($E_{min,vis}$) on top of the DEM input file, which are required to make a particular pixel visible from the observer point.

5.1.3. Viewshed computation

When all input parameters are defined, the viewshed analysis can be performed. As described above, the desired output is a raster file with the required elevations for pixels to be visible as seen from the observer point. To get an idea what such an output file looks like, an example viewshed analysis is carried out for a single location in the sector Botlek in the port of Rotterdam. See table 6-1 for the input parameters and figure 5-4 for the output.

This visibility is expressed by the minimum additional elevation on top of the DEM elevation model file, which is required to make that pixel visible as looking from the chosen observer point. The different colours indicate different ranges of required elevations. In the dark green areas targets upon a height of 10 meters are visible, whereas in the dark red areas a target height of higher than 40 meters is required, to be visible for the chosen observer point. This output file forms the input file for the area-analysis in which a distinguishing will be made between (in)visible and (ir)relevant areas before the blockage factor can be estimated. This is addressed in the next section.

Table 5-1 Input parameters viewshed computation

Input parameter	Value	Unit
DEM input file	Static	-
X-coordinate	81687	m
Y-coordinate	433933	m
Antenna Height	11.2	m
Detection range	1500	m
Curvature Coefficient	0.7	-
Output mode	DEM	-

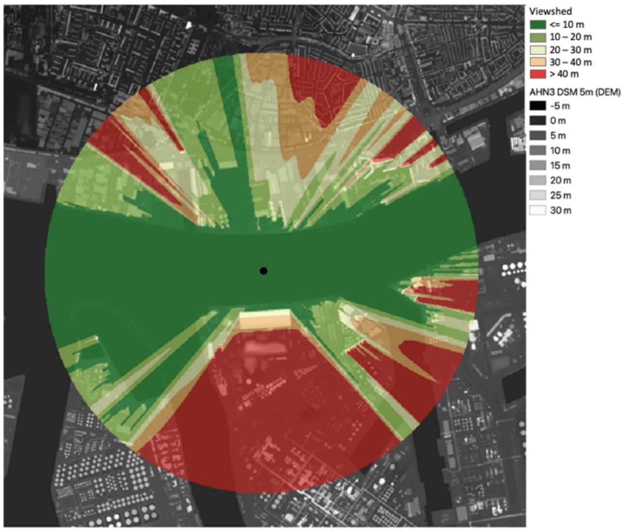

Figure 5-4 Output of the viewshed-analysis for DEM output mode

5.2. Area-Analysis

The Area-analysis is the second part of the SLV-analysis, in which the output of the viewshed-analysis is further processed to determine the blockage factor. This is done by subdividing the viewshed output file in relevant and irrelevant areas as well as visible and invisible areas. This is done in the (In)visible and (Ir)relevant area computations, which will be addressed in the sections below. In here the example viewshed from the previous section is used again.

5.2.1. (In)visible area computation

In the (in)visible area computation, the output viewshed of coming from the viewshed-analysis is subdivided in visible and invisible areas. This is done by comparing the required elevations to be visible with a threshold input variable for the target height. The condition is simple, if the required elevation of a particular pixel is lower or equal to the threshold value for the target height, than the pixel is visible. Otherwise, the pixel is invisible. This indicates the areas on which target with a target height upon the threshold value for the target height are visible or not. When following the viewshed example as shown in section 5.1.3 and setting the threshold value for the target height equal to 10 meters, the visible and invisible areas are defined as presented in figure 5-5.

The green areas in figure 5-5 indicates the areas on which targets with a target height upon the target height threshold value of 10 meters are visible as seen from the observer point. The red areas indicate the areas on which these targets cannot be detected. Finally, this model is transferred into a binary grid V, in which the visible areas are assigned with a 1 and the invisible areas are assigned with a 0.

5.2.2. (Ir)relevant area computation

The execution of the (Ir)relevant area computation is likewise the execution of the (in)visible area computation. Again, the output viewshed of the viewshed analysis is taken as input and in this computation a distinguishing is made between relevant and irrelevant areas. Relevant areas are areas on which the targets of interest can be detected, within the set-up detection range. In the marine shipping domain, targets of interest consist out of other vessels, buoys and other obstacles, which are positioned on the fairways in the surrounding environment. Therefore, relevant areas are defined by the regions within the detection range which positioned on the fairway and irrelevant areas are defined by regions which are within the detection range but are not located on the fairway areas, such as regions ashore.

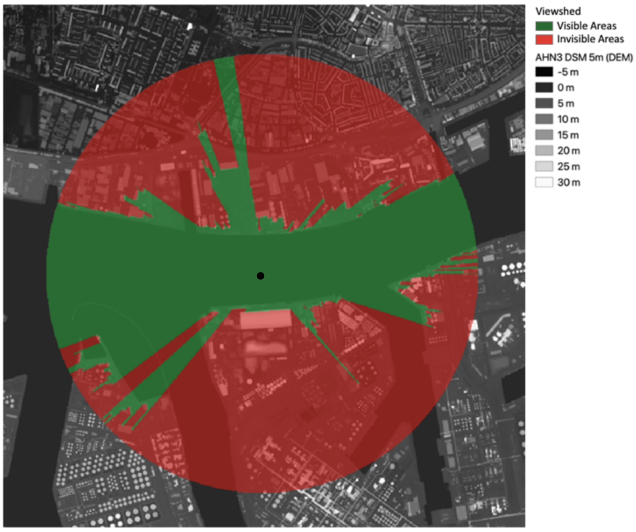

Figure 5-6 Output of the (in)visible area computation. Green areas indicate the visible areas, red areas indicate the invisible areas.

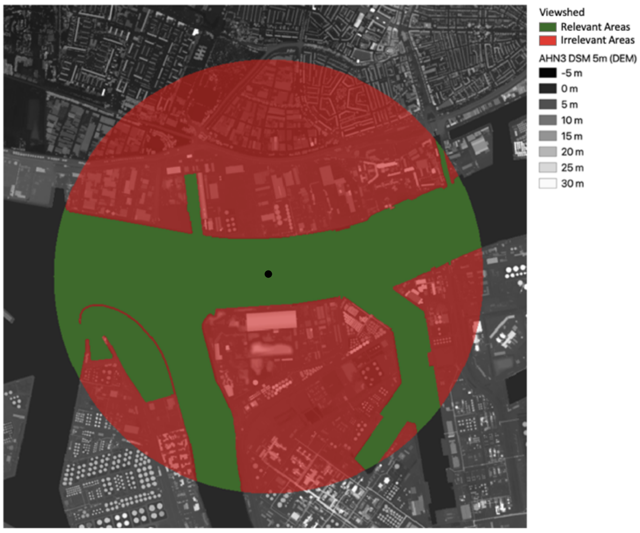

Figure 5-5 Output of the (ir)relevant area computation. Green areas indicate the relevant areas, red areas indicate the irrelevant areas

The identification of relevant and irrelevant areas is done by comparing the pixels of the viewshed output file with a fairway layer. This is the same layer which have been merged on the DEM file in the viewshed analysis. As well as in the (in)visible area computation, a binary grid is formed for the (ir)relevant area computation as well. In here, the relevant areas are assigned with a 1 and the irrelevant areas are assigned with a 0. The binary grid of the (ir)relevant computation is categorized as R. See figure 5-6 for the visualization of the output of the (ir)relevant area computation.

5.2.3. Blockage factor computation

Finally, when the visible and invisible areas and the relevant and irrelevant areas are identified, the blockage factor can be computed. The BF is the output of the area-analysis and therewith the output of the total visibility analysis as well. With this factor, an idea of the visibility of the surrounding environment around a particular observer point is determined, which is expressed in the rate blockage of the relevant areas. The BF is defined as the total invisible fairway area within a circle around a chosen observer point ($A_{R,I}$), divided by the total fairway area in that circle (A_R). This indicates which relevant areas on the fairway are invisible from the chosen observer point, within the selected detection range. In formula form:

$$BF = \frac{A_{R,I}}{A_R} * 100\ \% \tag{5-2}$$

$A_{R,I}$ is determined by making use of the binary grid output files V and R, which are computed in the (in)visible and (ir)relevant area computations. For pixel P_i, with coordinates x_i and y_i, which is laying within the detection range, is checked whether the pixel is invisible and whether it is positioned on a relevant area. This is done by verifying the condition whether P_i is assigned with a 0 in the binary grid file V and assigned with a 1 in the binary grid file R. The total area is defined by summing up all pixels for which this condition holds and multiply this amount with the area of a single pixel. As described earlier, the pixels in the AHN3 DSM DEM files are having a size of 5x5 meters. In formula form:

$$A_{R,I} = \left(\sum_{i=0}^{n} P_{i,(V=0\ AND\ R=1)} \right) * A_p \tag{5-3}$$

The total area of the relevant areas is calculated by taking the sum all the pixels for which the condition R = 1 holds and this sum is multiplied by the area of a pixel.

$$A_R = \left(\sum_{i=0}^{n} P_{i,(R=1)} \right) * A_p \tag{5-4}$$

When merging equation for $A_{R,I}$ and A_R into the equation for BF, the blockage factor can be calculated:

$$BF = \frac{\left(\sum_{i=0}^{n} P_{i,(V=0\ AND\ R=1)}\right) * A_p}{\left(\sum_{i=0}^{n} P_{i,(R=1)}\right) * A_p} * 100\% \tag{5-5}$$

For the visibility-analysis example, as presented in the previous sections, the total surface of the relevant areas within the detection range around the chosen observer location (A_R) is equal to:

$$A_R = 104610 * 5^2 = 2.615\ [km^2]$$

The total surface of the relevant areas which are not visible as seen from the chosen observer point is equal to:

$$A_{R,I} = 25211 * 5^2 = 0.630\ [km^2]$$

This leads to a BF of:

$$BF = \frac{0.630\ [km^2]}{2.615\ [km^2]} * 100\ \% = \ 24.10\ [\%]$$

This blockage factor indicates that 24.10% of the fairway areas around the chosen observer location is not visible from that particular position. See figure 5-7 for a visualization of the outcomes. As can be seen in figure, the detection circle consists out of the areas ashore and areas located on the fairway, for which the latter has been subdivided in visible and invisible areas as seen from the chosen observer point. Table 5-2 presents an overview of the total number of pixels of each individual area category within the detection circle, as determined by the viewshed-model. The total surface area of each of these areas is computed by multiplying the number of pixels with the size of a single pixel. The areas as determined by the viewshed-model are compared with the true size of the detection circle. This is done by adding up all individual surface areas as determined by the viewshed model and compare to the true size of the detection circle. The true area size of the detection circle is computed using the chosen detection range, which is equal to the radius of the circle:

$$A_{Circle} = \pi * r^2 \tag{5-6}$$

$$A_{Circle} = \pi * 1500^2 = 7.069\ [km^2]$$

As can be seen in the table, the absolute difference between the area of the detection circle as determined by the model and the true size of the detection circle are differing only 1158.471 square meters. On a total surface area of 7.069 square kilometres this difference is in the order of only 0.01% and very small. From this, it can be concluded that the areas calculated by the model are quite accurate in comparing with the true sizes of the detection circle. In the next section, it will be verified whether the locations of the visible and invisible areas, as calculated by the model, are coinciding with visible and invisible areas as seen by a maritime radar.

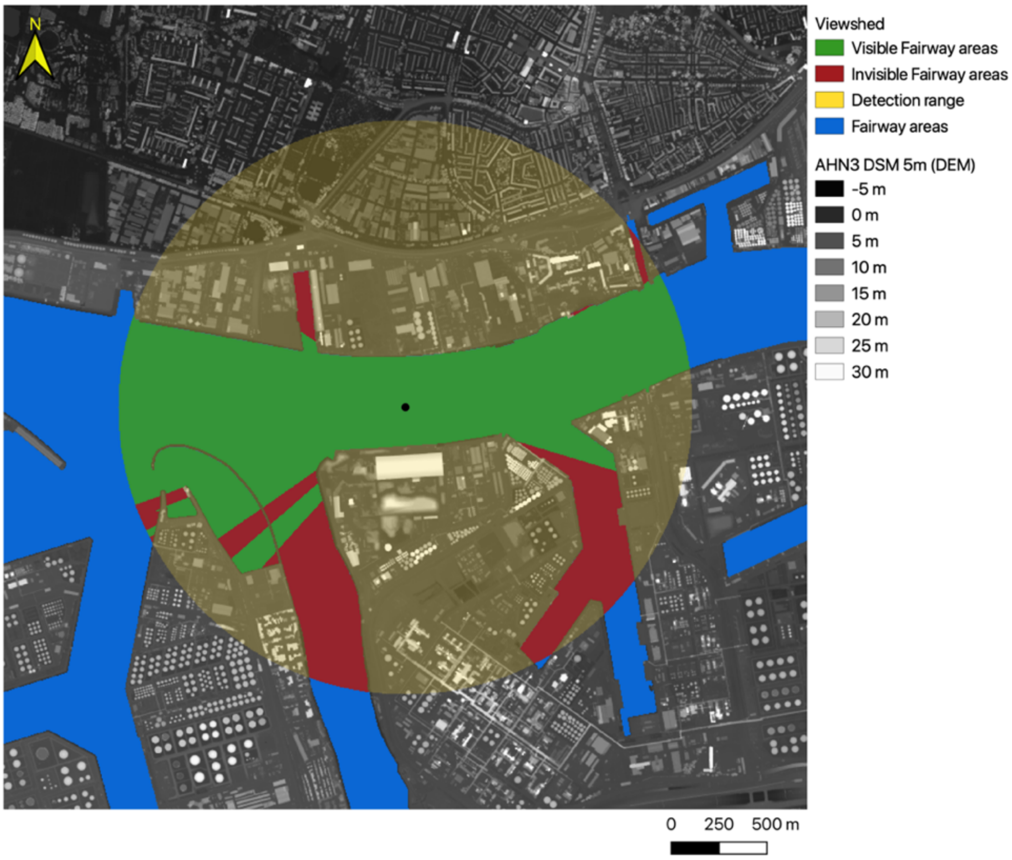

Figure 5-7. Output of the visibility-analysis

Table 5-2 - Surface areas of individual areas within the detection circle.

Area Category	[#] of Pixels	[%] of Detection circle	[%] of Fairway	Area [km2]	True Area [km2]	Absolute Difference [m2]
Invisible FW	25211	8.918	24.100	0.630	-	-
Visible FW	79399	28.086	75.900	1.985	-	-
Fairway	104610	37.004	100	2.615	-	-
Ashore	178087	62.996	**-**	4.452	-	-
Detection circle	282697	100	**-**	**7.067**	**7.069**	**1158.471**

5.3. Verification with real radar images

5.3.1. Setup

To verify whether the visibility-analysis model outputs are a valid representation of the detection mechanism of a maritime radar, the model output results are compared with radar images coming from a real maritime radar. In the comparison is verified whether the detected targets by the maritime radar coincide with the visible and invisible areas as determined by the visibility-analysis. The radar images are coming from the vessel MSC Factofour and are provided by Shipping Technology, which installed measuring equipment such as sensors on the vessel to do research into developing systems for autonomous shipping. The MSC Factofour is an inland container vessel which is currently operating and mainly transporting containers from Rotterdam to Antwerp and vice versa (Shipping Factory, n.d.). See figure 5-8 for an overview of the vessel and table 6-2 for some basic parameters.

Figure 5-8 The MSC Factofour (Xomnia B.V., n.d.)

Vessel parameter	Value	Unit
Length	135.0	m
Width	17.1	m
Draught	4.0	m
Tonnage	6438	ton
Max. containers	498 (5 layers)	-
Antenna height	11.2	m
Detection range	2250	m

Table 5-3 Basic Vessel parameters MSC Factofour

The radar images of the MSC Factofour are describing the detection of objects in the surrounding environment of the vessel while it was navigating through the port of Rotterdam. This is presented by white "dots" on a black background. See figure 5-9 for an overview. To compare the visibility outputs with real radar images, the visibility-analysis is carried for the exact same conditions as under which the radar images are obtained. The exact position of the vessel during the radar image in figure 5-9 is at the height of the intersection in the sector Botlek, just upstream on the river Oude Maas. This holds that the position, antenna height and detection range of the MSC Factofour are used as input values for the visibility-analysis. This results in a viewshed which defines the visible and invisible areas as seen by the radar of the MSC Factofour.

Figure 5-9. Real radar image coming from the MSC Factofour

The viewshed is subdivided in three sectors: green, red and orange and these areas are related to the threshold value for the target height. The green areas represent the locations on which targets can be detected for every value of the target threshold height. This means that for these locations the radar horizon coincides with the surface level of the fairway and all targets regardless of their air draft can be detected. The red areas represent the locations on which only targets can be detected with an air draft higher than 25 meters. Based on the corresponding historical AIS-data, it is verified that no vessels with such an air draft where present in the surrounding environment of the MSC Factofour, so no targets are expected to be detected by the maritime radar in these red areas. The orange areas indicate the intermediate locations where targets upon 25-meter air draft can be detected, however a certain target threshold value is required to make them visible. This holds that a certain target can be detected in case it has an air draft higher than the threshold value for the target height.

To compare the viewshed with real radar images, the viewshed is merged on top of the radar images. The colour range of the radar images has been reversed to clarify the different sectors as determined by the visibility analysis. By means of historical AIS data is verified which targets were present in the surrounding environment of the MSC Factofour. Together with the radar images and the viewshed analysis, it is verified whether the present targets have been detected by the maritime radar and in which area these detected targets were located. If the model predictions are valid, it is expected that all targets vessels which are indicated by the historical AIS data and coincide with the green areas of the visibility analysis, will be detected by the maritime radar. Next to that, it is expected that no targets vessels will be detected by the maritime radar on locations which coincide with the red areas as determined by the visibility-analysis. Finally, for the targets located on the orange areas some more in-depth analyses have to be carried into the air draft of the vessels and the required air draft of the locations, to verify whether the targets are visible or not. An overview the combined output of the radar images and the viewshed-output can be seen in figures 5-10 – 5-13, as well as an overview of the present targets as defined by the historical AIS-data.

5.3.2. Results

Green areas

As can be seen in figure 5-11, the green areas arise at the river Oude Maas, downstream of the intersection at the Nieuwe Waterweg and at the Geulhaven. On these areas multiple targets were present, which have been indicated by the green circles in figure 5-11. All of these have been detected by the maritime radar, as can be seen by the dots which have been highlighted by the green circles in figure 5-11. This is in line with the expectations because the green areas are the locations upon which targets can be identified without a minimum height for the air draft, so every target should be visible for the maritime radar.

Red Areas

As can be seen in figure 5-12, red areas arise at the 1st Petroleumhaven, 3rd Petroleumhaven, Welplaathaven and at the fairway section on the east side of the detection zone. Especially in the harbours many targets were present, as is indicated by the dotted lines in the figure 5-12, in which the historical AIS-data is presented. Although these targets were present, the maritime radar could not detect any of these targets. This is shown in figure 5-12, in which only some single dots are detected by the radar in these zones, but with these single dots no clear vessels can be identified. This is in line with the expectations because through the visibility analysis it was determined that only vessels higher than 25 meters could be detected on these areas. Because no such vessels were present, no clear targets vessels have been detected by the maritime radar.

Orange areas

As can be seen in figure 5-13, the orange areas are the transitions zones between the green and the red areas. These orange areas arise at the central channels of the 3rd Petroleumhaven and Botlek harbour basins. At the time the MSC Factofour was navigating through the port of Rotterdam, several targets were present on the locations of these orange areas. This is shown in figure 5-13. Only some of the targets in the orange area has been detected by the maritime radar. The detected targets are *Ramform Titan, Fairplay 21, Stolt Innovation* and *Zijpe*, which are indicated with the solid circles in figure 5-13. The dashed circles indicate the targets that have been present but have not been detected by the maritime radar. The undetected vessels are *Bernard Senior 2, NCC Sudair, Trans Exeter, Janjo, Kedia* and the vessels at the beginning of the Geulhaven.

A possible clarification why some targets in the orange areas were detected by the maritime radar and others not, is that the detected targets vessels did meet the threshold value for the air draft at their locations and the undetected targets did not meet this requirement. In contrast to the verification of the target detection on the green and red areas, the verification for the orange areas is more subjective. This because the air draft of vessels is dependent on multiple factors which make it complicated to verify whether the criteria for the threshold value is met by the target vessels. Since the detection of the targets in the red and green areas was pretty accurate predicted by the viewshed model, it is assumed that this holds for the orange regions as well. Therefore, it is assumed that the blockage of the maritime radar signals, as defined by the model can be used for further calculations.

Figure 5-10 . Verification of model with real radar images

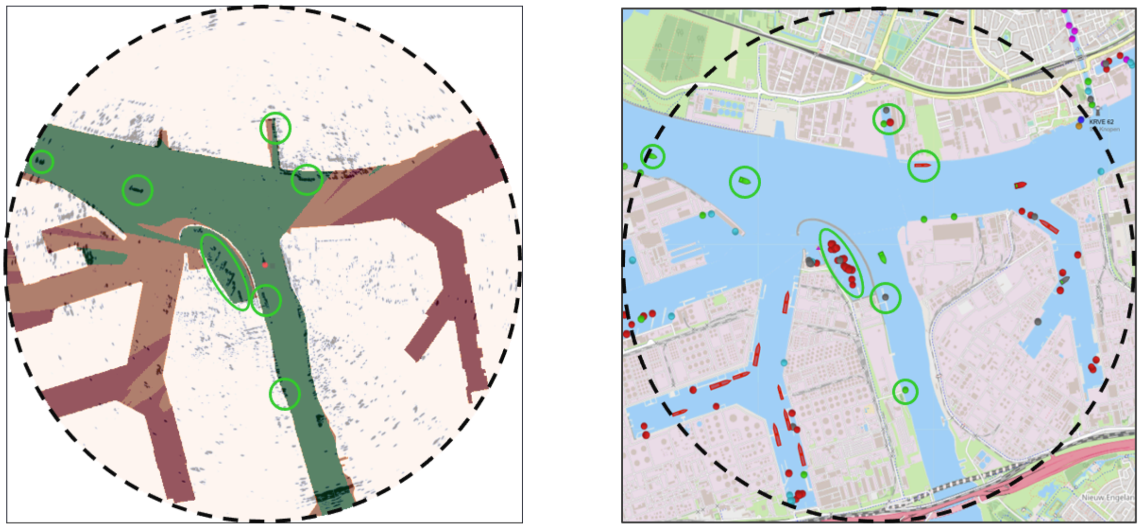

Figure 5-11 Verification of target detection without a required value for the air draft. Solid circles represent detected targets, dotted circles represent undetected targets.

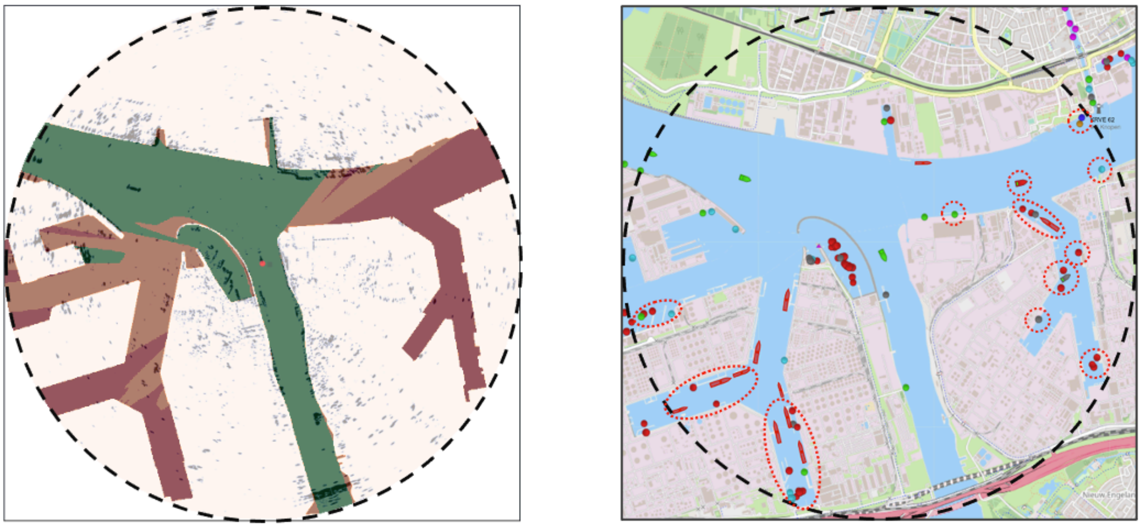

Figure 5-12 Verification of target detection for targets with an air draft > 25m. Solid circles represent detected targets; dotted circles represent undetected targets.

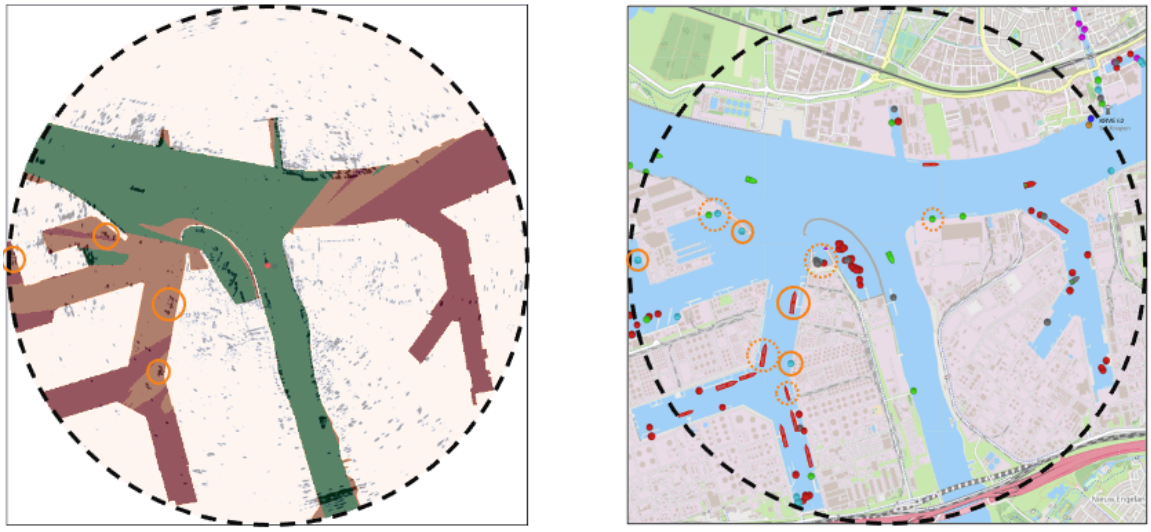

Figure 5-13 Verification of target detection on areas which are dependent on the threshold value for the air draft. Solid circles represent detected targets; dotted circles represent undetected targets.

5.4. Conclusion

In this chapter an answer is given to the following sub question:

What method can be used to determine the visibility of vessel radars?

The visibility as seen by a vessel radar is depending on the location of the observing vessel, the height and the detection range of the equipped radar and the position and air draft of the targets in the surrounding environment. To determine the visibility, a model has been developed with which the visibility around a chosen observer point can be determined. This is done by means of the visibility-analysis, in which the visibility is expressed by a blockage factor (BF). The BF is defined as the total invisible fairway area within the detection range around a chosen observer point ($A_{FW,C,Invisible}$), divided by the total fairway area in that detection range ($A_{FW,C}$).

$$BF = \frac{A_{FW,C,Invisible}}{A_{FW,C}} * 100\%$$

The BF is computed by means of a viewshed-analysis and a subsequent area-analysis. In the viewshed-analysis the required pixel elevations are determined, which are required to make that pixel visible as seen from the chosen observer point. This is done following the line-of-sight method, based on a Digital Elevation Model (DEM), and input parameters regarding the location, antenna height and detection range. The output of the viewshed-analysis forms the input for the area-analysis, in which the viewshed is subdivided in visible and invisible areas and relevant and irrelevant areas. Relevant areas are defined by the areas which are positioned on the fairway. When the (in)visible and (ir)relevant areas have been defined, the BF can be computed, which forms the output of the visibility-analysis. The model outputs of the visibility analysis have been validated with real radar images coming from the vessel MSC Factofour.

III. Results

6. VHF-Analysis

In this chapter, the results of the VHF-analysis are presented. In here the types of communications and involved participants that have been addressed in the conversations are discussed. Subsequently, the corresponding observing vessel locations are identified for the main types of communication. It was found that most communications are occurring at tactical hotspot locations, therefore these locations are analysed in depth as well.

6.1. Digitization of VHF-communications

In section 4.1 a method has been addressed with which the VHF-communications can be digitized. The individual steps in this process have been executed to digitize a set of VHF-data for the sector Botlek. There is chosen to use VHF-audio of the sector Botlek, since this is a sector in which generally a lot of VHF-communications arise. To obtain sufficient input data, the timeframe of a crowded sector is analysed. The VHF-data is dating from September 29th. In total one hour of VHF-data is digitized. An overview of the transmitted communications, the involved participants, the durations of the conversations and the addressed communication types is presented in Appendix A.

6.2. Digitized data-analysis

6.2.1. Communication types

When focusing in more detail on the types of information that has been communicated in the individual conversations, it can be concluded that a total of five main types of information can be distinguished:

1. Announcements (Mandatory reporting)
2. Traffic Images (INS)
3. Manoeuvre (TOS)
4. Intentions
5. Others

Within announcements all communications regarding the locations and intentions of observing vessels are addressed. Announcements are only made by the participating skippers and are intended to inform the VTSO. In section 5.4 the mandatory reporting duties of navigating skippers has been addressed. These mandatory reporting duties are done by making an announcement. Under traffic images all the communications regarding the locations and intentions of target vessels are addressed. Contrary to announcements, traffic images are only communicated by the VTSO and are intended to inform the skipper of the observing vessel in question. The provision of traffic images falls under to the information services (INS) of the VTS. The category Manoeuvre consists out of all communication regarding arrangements of passages of future encounters. Communications regarding manoeuvres can arise between skippers mutually or by an intervention of the VTSO. The arrangement of passages falls under the Traffic Organization services of the VTS.

The category Intentions covers all the individual communications regarding plans, intentions and destinations of the participating vessels, which have been communicated without information regarding the location of the corresponding vessels. This category differs from the announcements and traffic images categories since in these forms of communication the intentions of a vessel are shared as an addition on the current positions of the vessel. Within Intentions, the intentions of targets are directly requested by other participants. The intentions of participating vessels can be requested by VTSO, to contribute to the provision of the INS, TOS or NAS services of the VTS, or by other participating skippers. Finally, under Others, all communication which is not intended for traffic management is categorized. This holds for example for personal conversations between skippers or when skippers make an arrangement to switch over to another VHF-channel to keep the main VHF-channel of the sector free the other participants.

In the majority of the individual conversations, multiple types of information are shared. This can be seen in the following conversation between a VTSO and the skippers of the vessels *Fiona* and *Renata*, as presented in table 6-1. The numbers indicate the position of the transmitted message in the sequence of the full analysed VHF-tape, as expressed in appendix B.

Table 6-1 VHF-conversation between VTSO, Fiona & Renata, including the types of communication.

29/09/2020 – 12:37:37 – 12:38:19 | Conversation 12 | VTSO, Fiona & Renata		
#	***Transmitted message***	***Type***
70.	Sector Botlek, Fiona out.	Announcement
71.	Fiona, sector Botlek over.	Announcement
72.	Departing at Vopak North and then towards the Scheurkade.	Announcement
73.	The Fiona, that is understood. Vessels navigating downstream the central channel, 500 meters within the mouth, heading towards de Oude Maas, upstream navigating vessel at the Scheurkade, 1000 meters below the mouth of the Botlek, which is also heading towards de Oude Maas, over.	Traffic Image
74.	Yes, then I would like to do starboard-starboard with that one that is going to the Oude Maas, then I stay at the wrong shoreside.	Manoeuvre
75.	Yes, you are already crossing now, right? Yes, that is okay. The Renata, there is another small vessel coming out of the central channel towards the Scheurkade, which stays very close to the shore dam and navigates starboard-starboard with you, okay?	Manoeuvre
76.	Yes, clearly.	Manoeuvre

One can see that the skipper of the Fiona starts the conversation through an announcement, in which he shares his intentions with the VTSO. As described in section 2.1.4, vessels are required to make an announcement when they are about to execute a special manoeuvre. As a response, the VTSO operator answers with information about the traffic image in the surrounding environment of the Fiona. In his turn the skipper of the Fiona is replying on the communicated traffic images and clarifies that he would like to make an arrangement for a passage with one of the addressed targets, in this case the Renata. Subsequently, the VTSO is communicating the passage request of the Fiona with the skipper of the Renata and he responses that he agrees on the proposed passage arrangement of the Fiona, which makes an end to the conversation. In this conversation three different types of communication can be distinguished: Announcement, Traffic Image and Manoeuvre. The first three messages (70, 71 and 72) are regarding an Announcement, the fourth message (73) is regarding a Traffic image and the final three messages (74, 75 and 76) are regarding the arrangement of a manoeuvre.

As can be seen in table 6-1, the traffic image for the Fiona consists out of information of the position as well as the intentions of two target vessels. This is usefull for the skipper of the observing vessels because when the position and destinations of the targets are known, future encounters can be identified more carefully, for which eventually manoeuvers can be arranged in order to create safe and efficient passages with the other vessels. For every case in which a traffic image has been shared it is verified whether next to the positions also intentions of the targets vessels has been shared. For the majority of the communicated targets, with 122 times, the current location as well as the destination have been shared. Moreover, often when no intention has been shared, it was due to the fact that this intended destination of a target was not known by the VTSO yet. A common response of a VTSO could be: “Vessel X is coming out of channel Y, not heard yet”, which points out that the VTSO would share these intentions if these were known. So, it can be concluded that for basically every communicated target in a traffic image the intentions of the targets will be shared, as far as these destinations are known by the VTSO.

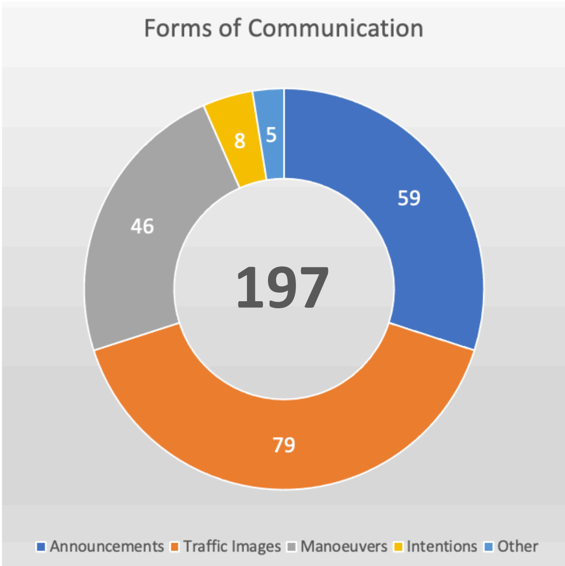

Figure 6-1 Distribution of forms of communications.

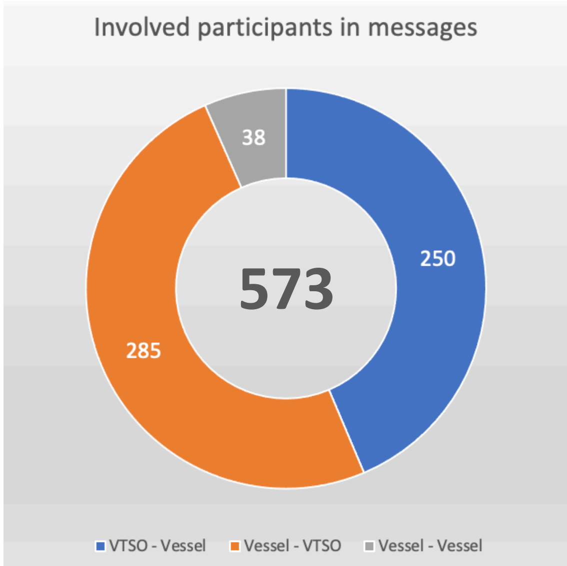

Figure 6-2 Involved participants in VHF-communications

When combining all the types of communication which occurred in the 81 conversations, it can be concluded that a total 197 individual types of communications has been communicated between the participants. As can be seen in figure 6-1, the majority of these communications was regarding an Announcement, a Traffic Image or the arrangement of a manoeuvre. It is found that these forms of communication are related to each other, since traffic images are often communicated after an announcement has been made and manoeuvres are often communicated after a traffic image has been shared. Prior to 59/79 communications in which a traffic image has been shared, an announcement has been made by the observing vessel of the traffic image. Next to that, prior to 40/46 communications regarding the arrangement of a manoeuvre, a traffic image has been shared in which the targets are addressed for which an arrangement for a manoeuvre is made.

6.2.2. Involved Participants

The involved participants of the messages consist out of the transmitter and the receiver of the messages as well as the targets which are addressed in the messages. Messages can be transmitted or received by either the VTSO or the skipper of the participating vessels. This creates three possible communication scenarios: VTSO to skipper, skipper to VTSO and skipper to skipper. In total 573 messages have been transmitted, an overview of the way these messages are distributed over the communication scenarios is illustrated in figure 6-2. In this figure is shown that the majority of the messages has been transmitted by skippers and that most of these transmitted messages by the skippers has been orientated to the VTSO. Only 38 of the 573 transmitted messages were between skippers mutually. It can be concluded that skippers obtain most of the required information from the VTSO. This can be confirmed when the involved participants in each conversation are analysed. In the majority of the conversations, with 75/81 occurrences, a VTSO has been included. Most of these 75 conversations was between the VTSO and only one other skipper, which holds for 48/75 conversations. In 20 conversations two skippers were included and only in 7 conversations 3 or more skippers were involved.

Next to the transmitter and receiver of messages, the addressed targets in the messages have been analysed as well. For each communication form except for announcements, the targets have been assigned. Through an announcement skippers inform the VTSO about their location and intentions, in which no targets are addressed. In the communication forms Manoeuvre and Intention 1 target is addressed and in traffic images the number of targets is varying depending on the situation. As described in the previous section, a total of 79 traffic images have been shared with participating vessels. When combining all the targets in these traffic images, a total of 143 targets have been shared with the observing vessels in question. The way in which these 143 targets have been shared per traffic image is presented in figure 6-3. As can be seen, the range of number of target vessels per traffic image is ranging from zero (in case no targets were present) up to 5 targets. On average 1.89 targets are communicated per information regarding traffic images, which can be found by dividing the total number of targets by the total number of traffic images.

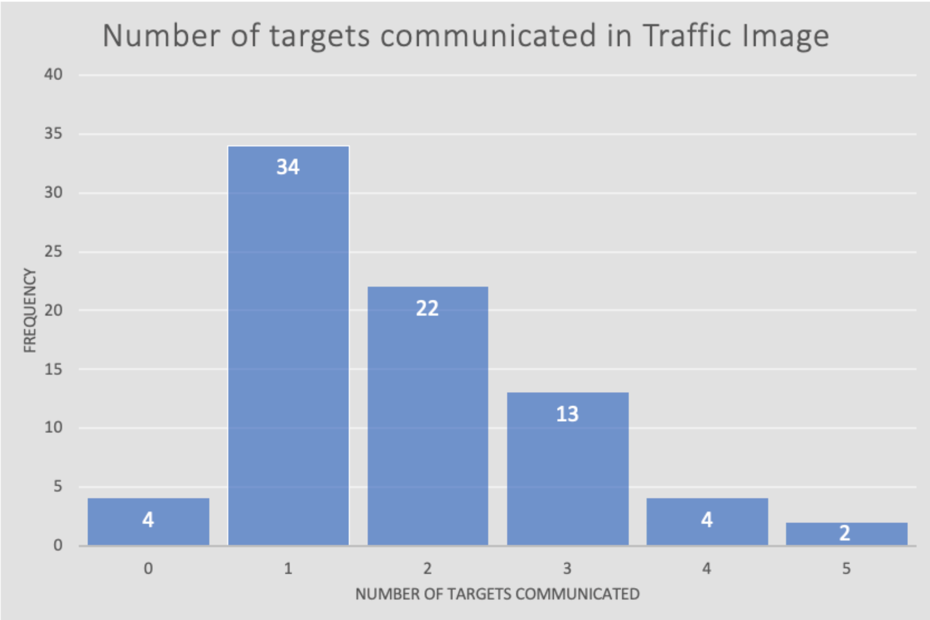

Figure 6-3 Number of addressed targets in traffic images

The number of targets that are communicated during information regarding traffic images is relatively low in comparing to the total number of navigating vessels in the sector. In some cases, only 1 target is communicated in a traffic image, where upon 10 navigating vessels were present in the sector. The reason why the number of communicated targets is lower than the number of vessels present in the sector is that a VTSO is trying to keep the message as short and relevant as possible. This holds that only the locations of relevant targets are communicated in a traffic image. Relevant targets are targets which are likely to create a future encounter with the observing vessel. Whether a target can be classified as a relevant target is therefore dependent on the current location, course, intended destination and course speeds of both the observing and target vessel(s). Because these variables are different for each scenario a general procedure cannot be followed and each scenario will be different.

6.2.3. Vessel Positions

The locations of the observing vessels from/towards where VHF-communications occurred are presented in figure 6-4 and 6-5. This is first done for the individual forms of communications, to get a clear overview where the observing vessels were located at the moment of a particular form of communication. The green dots indicate the locations from where announcements have been made by the participating skippers. It can be concluded that announcements have been made on the main fairways, on the central channels towards the harbour basins and within the harbour basins as well. The distribution of the locations from where announcements have been made is wide and reaches until the borders of the sector, however no announcements have been made in the centre of the main intersection of the sector. One can see that the majority of the announcements are made on the right-hand side of the fairway, when navigating into the direction of the main intersection. This can be related to the mandatory reporting duty of vessels when a special manoeuvre is about to be executed.

The distribution of the locations of the vessels towards which traffic images have been communicated is identical to the distribution of the announcements. The locations of the observing vessels during traffic images are indicated by white dots. In contrary to the announcements, traffic images have also been communicated to vessels which were positioned in the centre of the main intersection. Again, the right-hand side pattern on the fairway can be distinguished, however traffic images have been communicated at both sides of the fairway section which located on the east side of the intersection. This can be related to the presence the 1st Petroleumhaven, which is merging to the main fairway in that area.

In the lower-left figure, all the observing vessel locations during arrangements of manoeuvres are indicated by the red dots. One can see that most of the manoeuvres are arranged on the main fairways and around the mouths of the harbour basins of the Botlek, the 1st- and the 3rd Petroleumhaven. This can be explained by the fact that most of the vessels are navigating on the main fairways and therefore relatively more encounters will occur on the main fairway or at locations close by. Finally, the locations of the vessels from where intentions are requested are indicated by the orange dots in the lower right figure of figure 6-4. The intentions which have been requested by the VTSO are left out since the VTSO is positioned ashore and no observing vessel location can be identified for these communications. No real patterns can be recognized to verify in which occasions intentions are requested.

When combining all the locations of the observing vessels of the individual communication types in one figure, one can see that multiple communications have occurred at the same location. This result is expected because it has already been addressed that multiple forms of communication occur within the same conversation in which the same participants are involved. This has been demonstrated in the example conversation of the Fiona and the Renata, in which the Renata has been the observing vessel for the announcement, traffic image and manoeuvre type of communication. This is illustrated in figure 7-5.

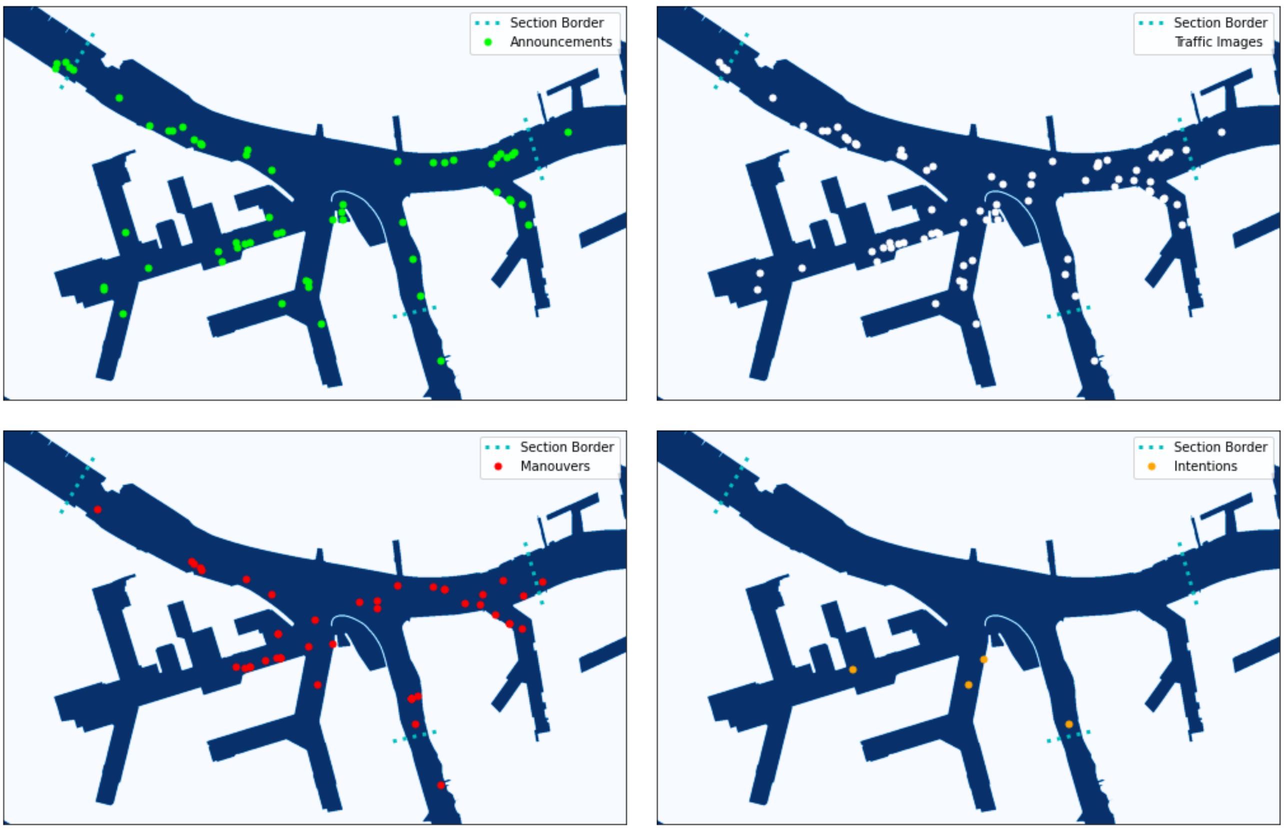

Figure 6-4 Observing vessel locations during VHF communications.

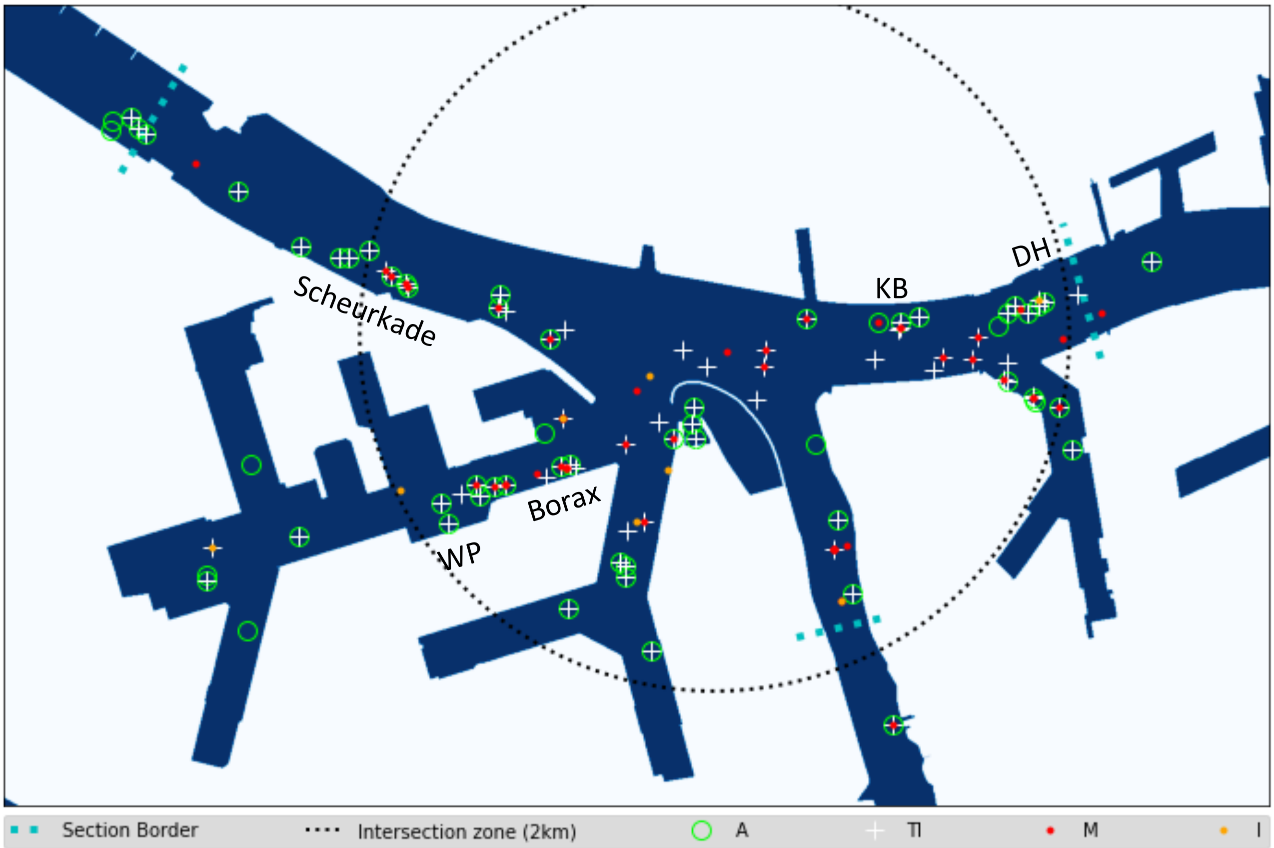

Figure 6-5 Observing vessel locations of all forms of communications combined.

6.2.4. Tactical hotspot areas

Although the distribution of the locations of the observing vessels is widely spread over the sector, still some hotspot locations can be distinguished. In these areas the density of observing vessels is higher in comparing to other areas within the sector. This is illustrated in figure 6-6, in which a heatmap is presented of all observing vessel locations towards where VHF-communication is communicated. For every pixel, the number of observing vessel locations are determined within a circle with a radius of 250 m around that particular pixel. For the upstream navigating vessels coming from the side sea of the sector, the hotspot area is located at the height of the *Scheurkade*. Another hotspot area can be found at the height of the *Delta Hotel (DH)/Kattenbak (KB),* where announcements have been made by skippers coming from the city side. For the vessels leaving the harbour basins of the Botlek, a hotspot can be distinguished at the height of the *Welplaathaven (WP)/Borax*, which is just before the mouth of the Botlek. For vessels entering or leaving the 1st Petroleumhaven, a hot spot arises at the mouth of this harbour basin, indicated with "1P". Locations with smaller observing vessel densities arise at the Geulhaven, entrance channel of the 3rd Petroleumhaven and at the Oude Maas. See figure 6-6 for an overview of the locations of the hotspot locations. One can conclude that the hotspot areas are all located within a distance of 2 km of the central point of the intersection of the Nieuwe Maas, Oude Maas, Scheur and mouth Botlek.

Since most of the announcements are made on these hotspot locations, it seems like the skippers wait until they reach these tactical points around the intersection before they are making an announcement and receiving the required information to enter this intersection. This can be confirmed when is looked in more detail into the communications towards observing vessels which are not located on these hotspot areas. For each of these vessels it is verified whether another traffic image is shared eventually and what the corresponding location was of the vessel in question. This is firstly done for the vessels which made an announcement on non-hotspot locations but didn't receive any information regarding traffic images as a response. The results are shown in figure 6-7, in which the locations of the observing vessels at the time of the first announcement and the locations of the vessels at the time the traffic image is shared eventually are plotted. The locations where the initial announcement has been made are indicated with an “A” and the locations towards where a traffic image is shared eventually is indicated with a “T”. The colours represent the different vessels considered.

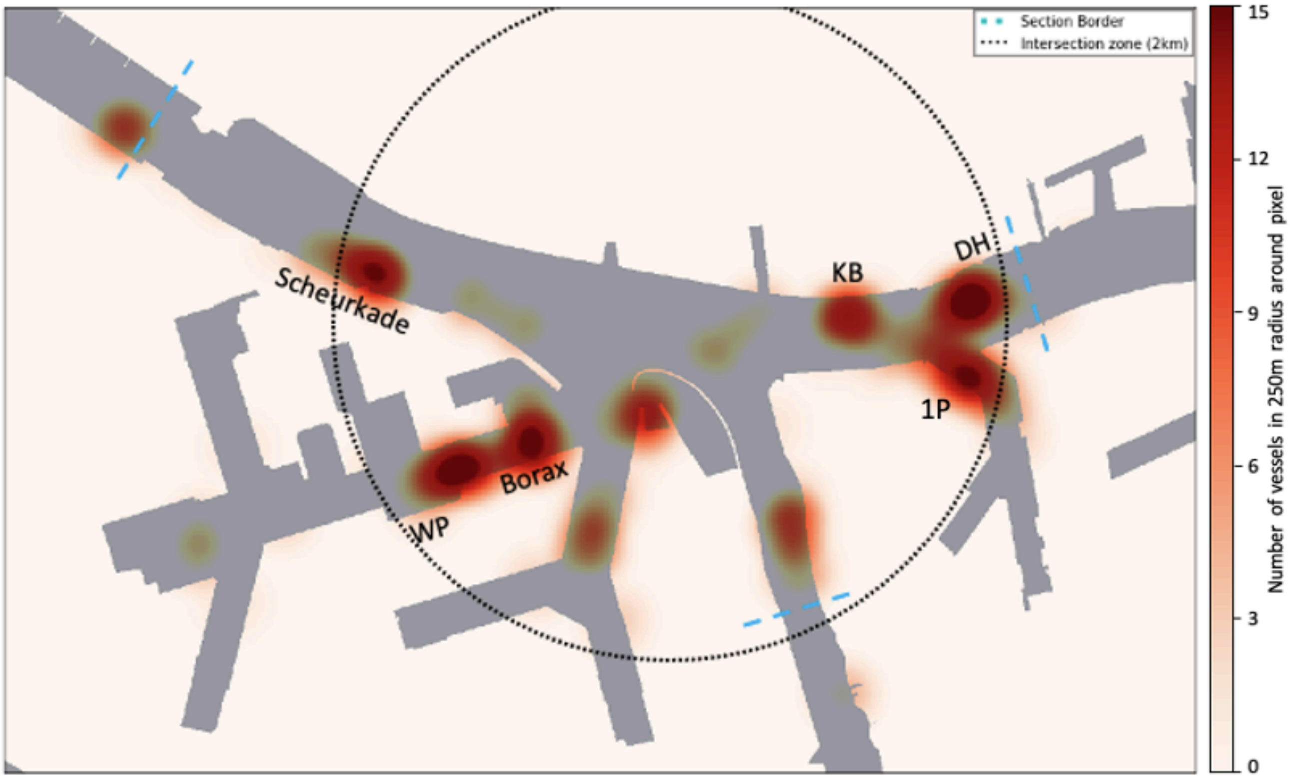

Figure 6-6 Heatmap including observing vessel locations. The colours indicate the number of observing vessels in 250 m around pixel.

As can be seen in the figure, the locations of where the announcements have been made without a traffic image as response are most often located inside the harbour basins or at a sector border. Because at these locations no relevant targets were present at the time, no traffic image is shared. When looking at the locations where eventually traffic images are shared towards the concerned vessels, it can be concluded that most of these locations are located in the hotspot areas close to the intersection. This holds for the vessels *Annabel, Anvisa 2, Aquisala, Holland Diving 1, Pictor, Rigel, Superiority* and *Stolt Shearwater*, See all the “T’s” in figure 6-7. Only for the vessels *Disponible* and the *Spaarneplus*, no further traffic images have been shared after the skippers of these vessels made an announcement earlier already. This is a bit odd because both vessels were crossing the intersection. A possible clarification for this could be that there were no relevant targets at the moment these vessels crossed the intersection. The locations of these vessels are indicated with “AO”, which means announcement only.

Similar results can be concluded when is looked in more detail into the vessels which made an announcement at non-hotspot locations and did receive information regarding traffic images as a response. Even though these skippers already received a traffic image, in most cases another traffic image has been shared at the moment they were navigating at the height of one of the hotspots locations or at a location closer to the intersection. This indicates that the first shared traffic image was only regarding the targets in the surrounding environment of the particular vessel, however new or updated images had to be shared at the moment these vessels approached the intersection area. This is shown in figure 6-8, in which the locations of the first traffic image outside the hotspot locations are indicated with “T1” and the eventually later shared images are indicated with “T2” and “T3”, if applicable. Again, the colours are indicating the different vessels considered.

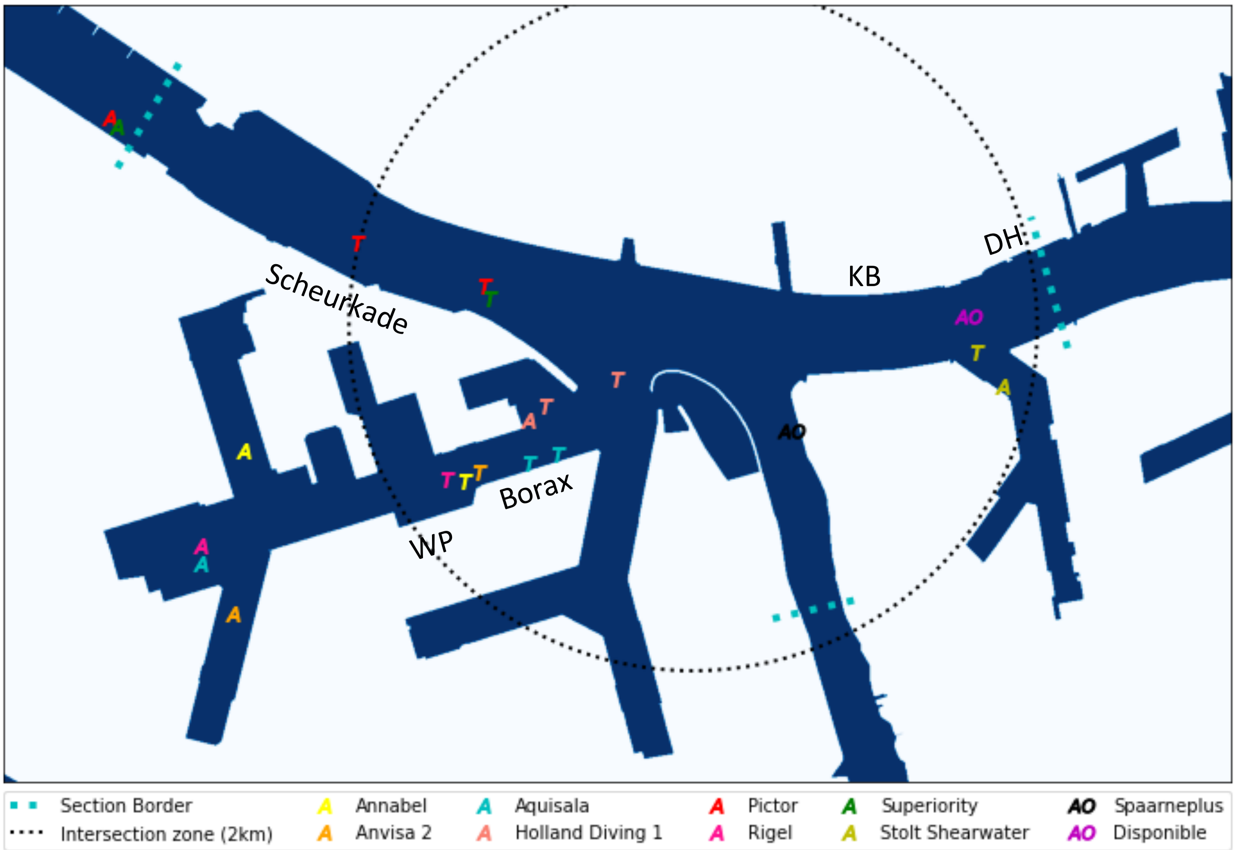

Figure 6-7 Observing vessel locations. First announcements indicated with "A", Eventually shared traffic.

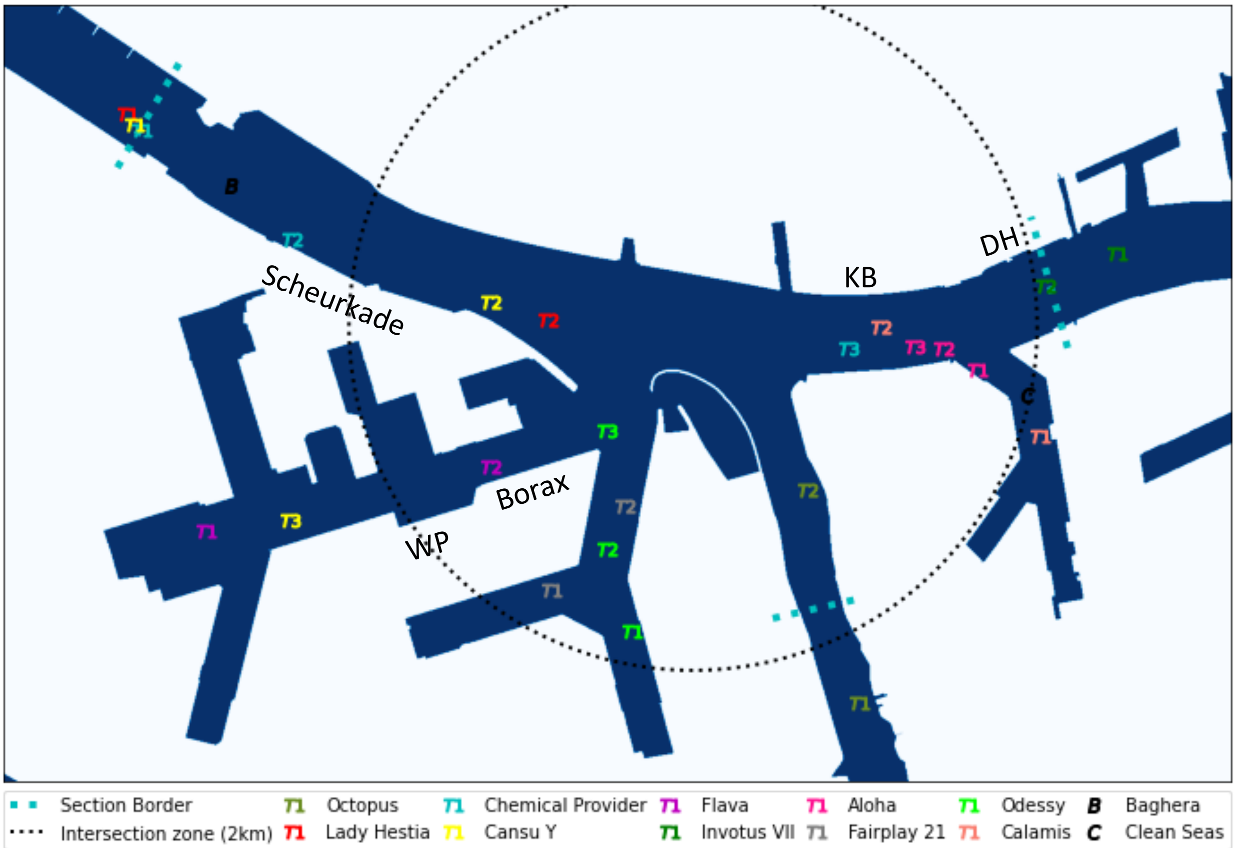

Figure 6-8 Observing vessel locations. First shared traffic image indicated with "T1", Second shared traffic image "T2"

Once more, it can be seen that even though a vessel is provided with a traffic image on non-hotspot locations, another traffic image is shared eventually when the vessel is reaching the hotspot locations. This holds for the vessels *Octopus, Lady Hestia, Chemical Provider, Cansu Y, Flava, Invotus VII, Aloha, Fairplay 21, Odessy* and *Calamis.* Only for the vessels *Baghera* and the *Clean Seas* no further traffic images have been shared during the tape. For the *Clean Seas* this can be clarified by the fact that this vessel was navigating towards the city, and therefore it was not passing the intersection because it was coming from the 1st Petroleumhaven. The location of the *Clean Seas* is indicated with a “C”. The *Baghera* was navigating downstream of the Scheurkade and was destinated in the direction of the city and therefore did pass the intersection, however no traffic image(s) have been shared at the hotspot at the Scheurkade. In the single traffic image that has been shared with this vessel no further information regarding relevant vessels around the intersection was shared. This could induce that there were no relevant targets present at the moment the *Baghera* was crossing the intersection. The location of the *Baghera* at the moment it received the first traffic image is indicated with a “B”.

Next to that skippers seem to make use of the tactical hotspots around the intersection, VTSO requesting in their turn skippers to make announcements or keep stand-by at these hotspots well. This holds for example for the announcements made by the vessels *Annabel*, *Anvisa 2*, *Aquisala* and *Rigel* at the harbour basins of the Botlek and the *Stolt Shearwater* which was located in the 1e Pet. See figure 6-7. When these navigating vessels made an announcement from these harbour basins, the VTSO responded with a request for the skipper to keep stand-by or to make another announcement when the particular vessel was reaching the Welplaathaven/Borax or Mouth Botlek. The *Stolt Shearwater* was requested to make another announcement when it was about to enter the fairway. This indicates that the VTSO expects possible future encounters that may arise around the intersection point between the vessel in question and other vessels in the sector. However, it doesn’t really make sense to provide the skipper already with this traffic image because these possible future encounters are not likely to happen within the next 10 minutes. This because either the skippers in question have to keep this given information in mind for a long period and more importantly that this traffic image is likely to be different at the moment when the vessel is actually reaching the intersection. This is a result of the dynamic behaviour of vessels in inland waterways, especially in busy times. Therefore, the VTSO requests the skippers to make another announcement at the Borax/Mouth Botlek because this location is one of the strategical hotspot locations around the intersection. At the time the skipper is located at this location a proper up-to-date traffic image can be made and the traffic around this intersection can be managed.

6.3. Conclusions

The VHF-analysis has been executed to provide an answer to the first and second sub questions:

In what way can VHF-communications be digitized in order to classify the communications according to content, space and time?

To digitize the VHF-communications, a method has been developed in which the spoken VHF-communications has been transferred into text and classified according to content, space and time. This is done by recording the VHF-audio tapes first, whereafter the spoken messages have been written down word by word. The obtained text is subdivided in individual conversations and for each conversation the communication types and involved participants have been addressed. The involved participants consist out of the transmitter and receiver of the messages, as well as the addressed targets in the messages. Subsequently, the corresponding vessel locations of the involved participants have been identified by using historical radar and AIS-data. Finally, the transmitting times and durations of the messages have been identified as well.

What are the substantive, spatial and temporal characteristics of the VHF-communications?

In total 197 forms of communication occurred in 81 conversations, which holds that multiple forms of communication arise within an individual conversation. The communication forms can be classified based on five main categories: Announcements, Traffic Images, Manoeuvres, Intentions and Others. In the majority of the conversations a traffic image has been communicated and this often occurred after an announcement has been made by the observing vessel of that traffic image. Sometimes an additional arrangement of a manoeuvre was added to this combination of communication forms. The sharing of information between participants often occurred by intervention of the VTSO, which has been included in 75/81 conversations. The number of targets addressed in traffic images is varying between 0-5 targets. In most of the cases only one target is addressed, and the number of cases is decreasing for an increasing number of communicated targets.

The distribution of the observing vessel locations is widely spread over the sector, although some hotspot areas can be recognized. These hotspots arise at the Scheurkade, Welplaathaven/Borax and Delta hotel/ Kattenbak, and are all located within 2 km of the main intersection of the sector Botlek. These locations are used by skippers as well as by VTSOs because at these locations the most up to date information can be exchanged required to enter the intersection.

7. Visibility-Analysis

In chapter 6, a method has been developed to determine the visibility as seen by a maritime radar. The visibility has been expressed by a blockage factor (BF), which defines the total invisible fairway area relative to the total fairway area within the chosen detection range. In this section the BF-behaviour is analysed for varying conditions, to get a better insight of the spatial and temporal characteristics of visibility in ports. First the BF-behaviour is analysed for different locations. This is done for the main fairways and the sector Botlek. Next, the BF-behaviour for various vessel parameters such as varying antenna height, target air draft and detection ranges has been investigated. Finally, the influence of dynamic obstructions in the form of moored vessels at berthing places are analysed.

7.1. Blockage factor behaviour for varying port locations

7.1.1. Main Fairway

First the behaviour of the blockage factor is determined over the full length of the main fairways of the port of Rotterdam. These main fairways consist out of the Nieuwe Waterweg, Nieuwe Maas and Oude Maas. The Nieuwe Waterweg is the part of the river that connects the sea towards the intersection point in the sector Botlek, where the river diverges into two separate branches. These two branches are the Nieuwe Maas, which is continuing upstream of the intersection towards the city centre, and the Oude Maas, which is directed southwards upstream from this crossing. On these fairways, locations with equal mutual distancing of 250 meters are defined and the viewsheds- and corresponding blockage factors for these locations are determined. The corresponding blockage factors of the individual locations on the main fairways are presented in figure 7-2 and 7-3. The combined results are plotted as a scatter plot in figure 7-1.

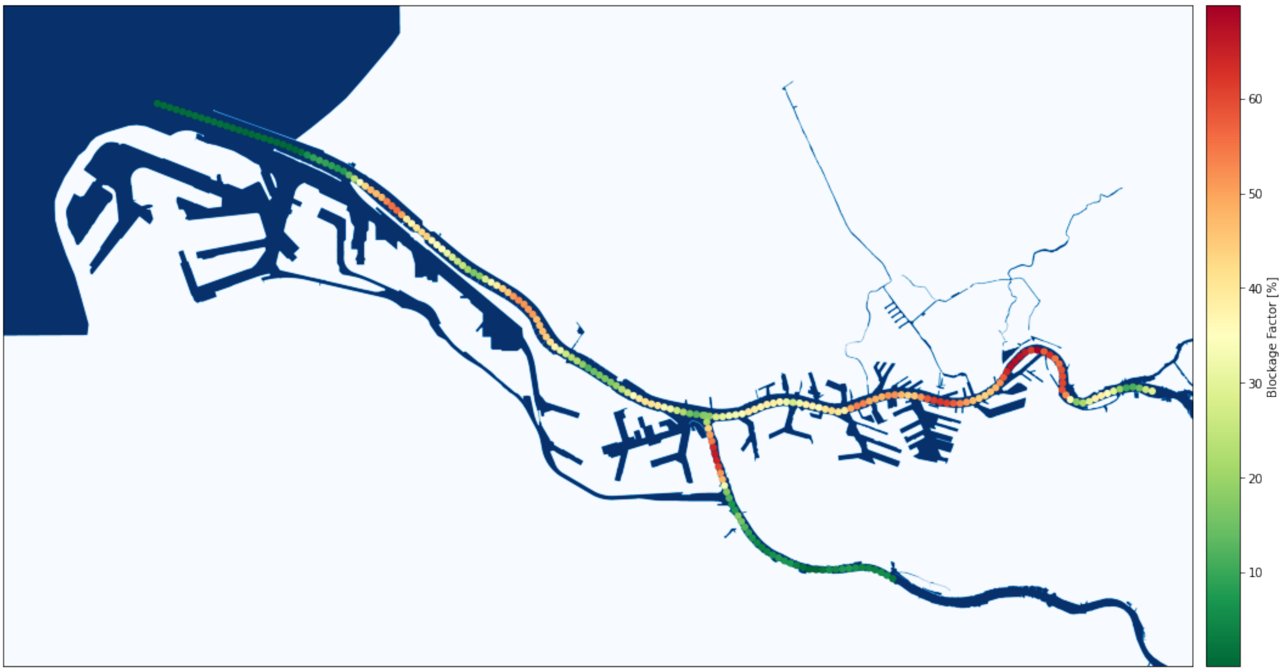

Figure 7-1 Blockage factor behaviour on main fairway.

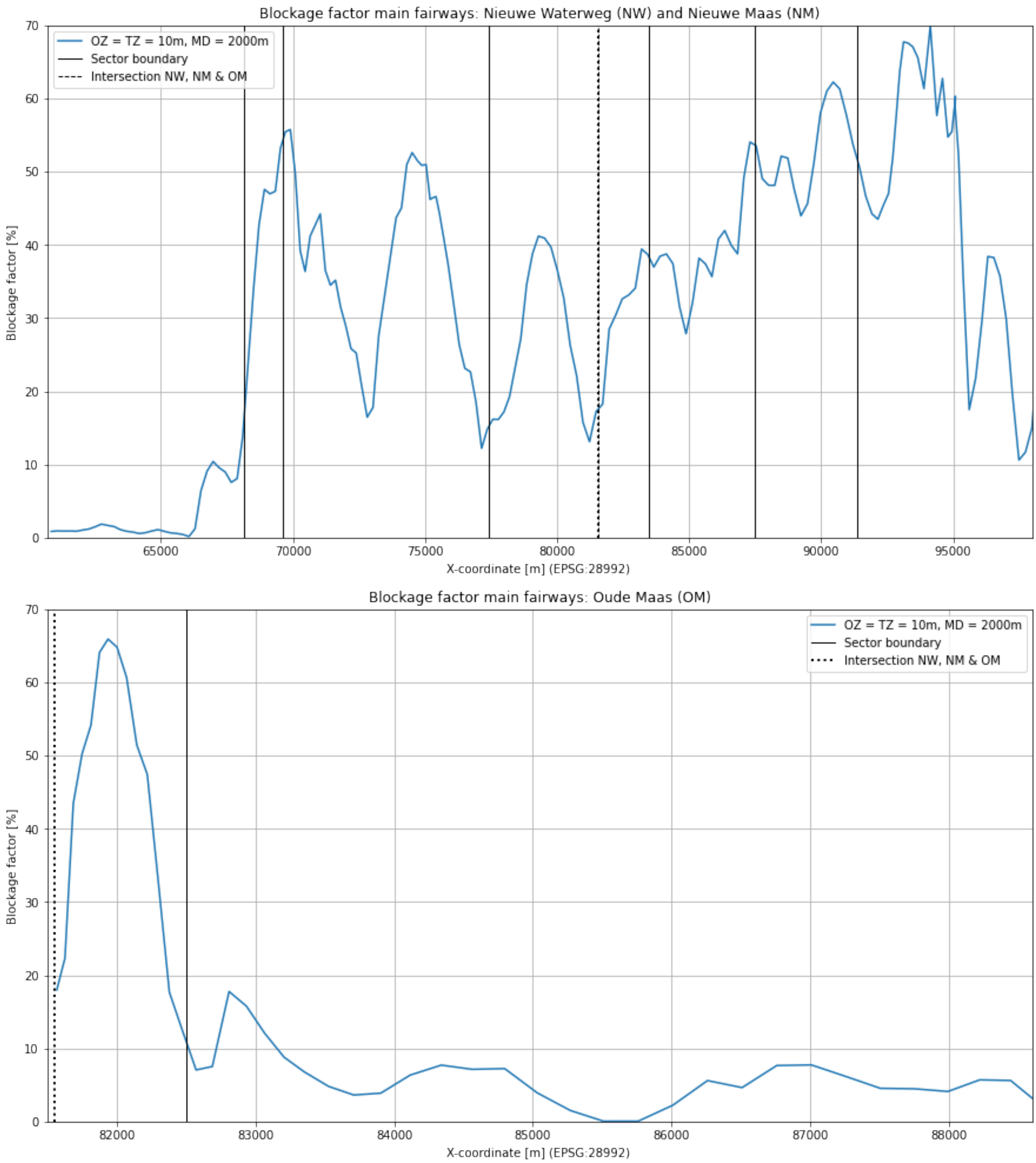

Figure 7-2. Blockage Factor behaviour over main fairway.

As can be seen in figures, the blockage factor (BF) is varying extensively for different locations of the main fairway. When a vessel is entering the port at the Maas Approach area, the BFs of the maritime radar are low. This can be related to the fact that the surrounding areas around the vessel in the approach area consist mostly out of open sea, and therefore no significant blockage will occur. The first high BFs will be experienced in the small main fairway area of the sector Rozenburg, in which values between 50-60% are experienced. In the sector Maassluis the BF is varying a lot between 15-55%, which are caused by the presence of the 5th and 7th Petroleumhavens in the adjacent Calandkanaal. When the vessel is navigating at the height of these harbour basins, the areas of the basins are within the detection range of the radar and therefore included in the BF, which results in a higher BF.

In the sector Botlek the BF is showing a variable behaviour as well. Over the Nieuwe Waterweg part of this sector the BF is varying between of 13-42%, however at the southern branch the Oude Maas relatively high BFs of 66% are found. When navigating further upstream on the Oude Maas, the BF will decrease again to values around zero. This is illustrated in figures 7-2 and 7-3. In the sector Eemhaven, the average blockage factor is higher in comparing to the sector Botlek, however the variability is lower. The same holds for the sector Waalhaven, which average is even more increased in comparing to the sector Eemhaven. The highest blockage factors occur at the sector Maasbruggen, which is located in the Rotterdam city centre. This higher BFs are related to the combined presence of high buildings and a meandering river profile, which is likely to interfere with the line of sight of maritime radar signals and therefore causing higher BFs.

7.1.2. Sector Botlek

The sector Botlek is centrally located in the port of Rotterdam in which the main river the Nieuwe Waterweg diverges into the Nieuwe Maas and the Oude Maas. The sector Botlek consists out of three main harbours: 1) The Botlek harbour basins, including the Chemiehaven, Sint Laurenshaven, Torontohaven, 1st and 2nd Werkhaven and Welplaathaven. 2) The 1st Petroleumhaven and 3) the 3rd Petroleumhaven. The Botlek area is mainly characterized by the petrochemical industry and tank storage companies, however some dry bulk and container storages can be found as well. The terminal areas consist mainly out of tank storage which can reach upon a height of 30 meters. See Appendix A for a detailed overview of the section.

Likewise, the determination of the BF-behaviour on the main fairway, the BF-behaviour of the sector Botlek has been determined by executing the visibility-analysis for various locations within the sector. For this analysis, observer points with mutual distancing of 50 meters have been defined for the main fairway, central channels and harbour basins of the sector. The results are presented in figure 7-3. As can be seen, the BFs of the sector are varying between 10-95%. One can conclude that the highest BFs are occurring at the very ends of the harbour basins. This holds for the side harbours of the Botlek area, the 1st- and the 3rd Petroleumhaven. Inside the Geulhaven lower BFs are present, which can be related to the low height of the dam at the north and east side of this harbour basin. For the central channels of the Botlek harbour basins and the 3rd Petroleumhaven the BFs are varying between 50-70%. This is different to the 1st Petroleumhaven, where BFs of at least 80% arise for the full length of the central channel. Relatively low BFs arise at the mouth of the Botlek, where the central channels of the Botlek and 3rd Petroleumhaven are merging into the main fairway. The BFs on the main fairways are similar to the results as determined in section 8.1.1.

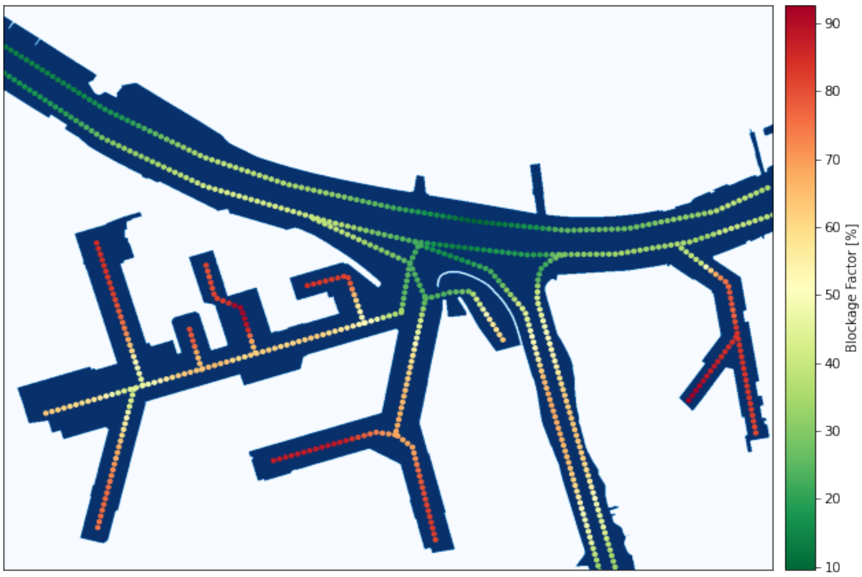

Figure 7-3. Blockage factor behaviour within the sector Botlek

7.2. Blockage factor behaviour for varying input parameters

7.2.1. Antenna height

In the first analysis the influence of different antenna heights is investigated. The different antenna heights represent different types of vessels. The maritime radar antenna of an inland vessel is often positioned on a radar mast, for which the elevation can be adjusted. By means of this adjustable mast the antenna heights of an inland shipping vessel can vary between approximate 5 and 15 meters above the water level. Navigators adjust the height of the mast based on the vertical restrictions in the port, such as bridges. The height of the mast can also be dependent on the type and amount of cargo stacked on the vessel. For sea shipping vessels the maritime radar is often positioned on the highest part of the vessel, which is on top of the bridge. Because the size and shape of various types of vessels is unique and strongly different, there is chosen to add two extra antenna heights for sea shipping vessels. These heights are 20 m and 25 m respectively. Obviously, the antennas of the largest container vessels will reach higher than 25 meters, however these types of vessels cannot navigate all the way upstream to the city centre of Rotterdam because of depth restrictions. Therefore, there is assumed that an antenna height range of 5 – 25 m covers the largest part of the navigating vessels on the fairways of the port of Rotterdam. In here, the target detection height is set to 10 meters and the maximum detection range is set to 2000 m. The influences of the different antenna heights are presented in figure 7-4.

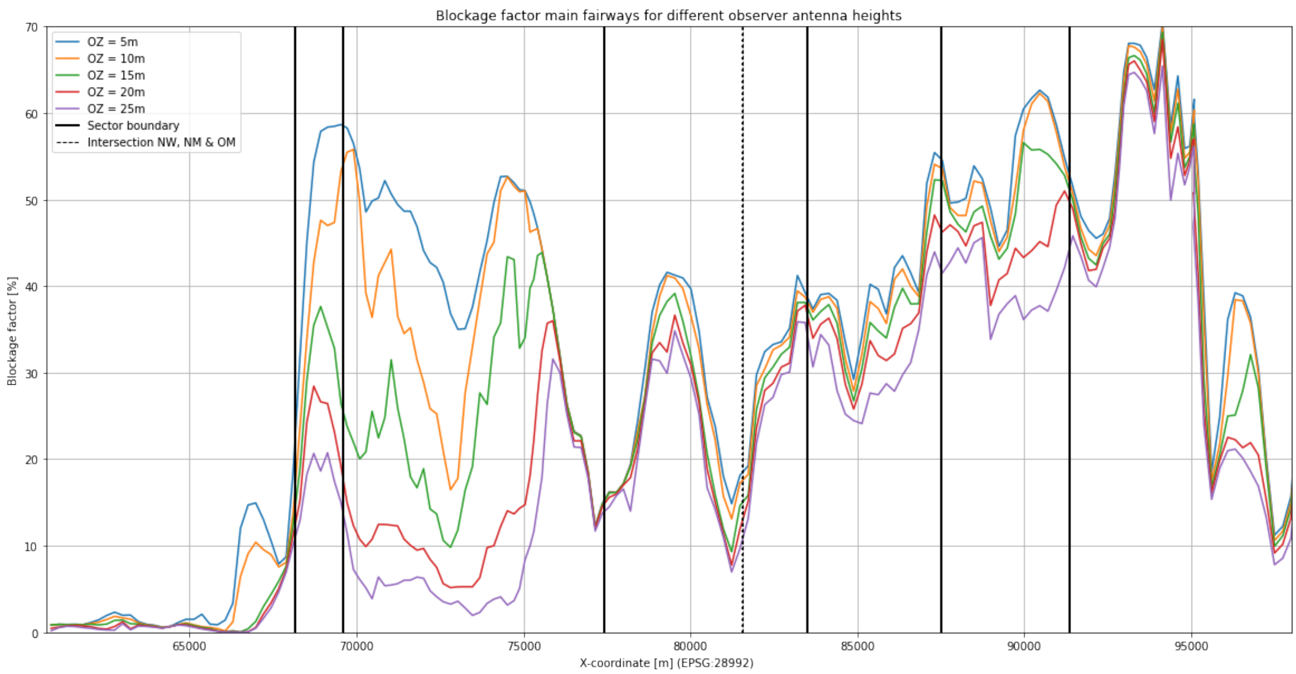

Figure 7-4. Blockage factor behaviour over main fairway for varying antenna heights.

As can be seen in the figure above, the BF of the main fairway is largest for the lowest antenna height. This is an expected result because when the antenna height is low relative to the fixed objects which are located throughout the port, the influence of these objects on the visibility becomes larger. One can conclude that the range between the BFs is varying is different from sector to sector. The BF range for the sector Maassluis is in the order of 30 – 40% and this range is larger than the varying BF range of other sectors. This large BF difference is caused by the Landtong Rozenburg dike, for which height differences of 5-15 meters arise along the length of the dike. In case the antenna height increases relative to this dike, the fairway area of the adjacent Calandkanaal becomes more and more visible, which will reduce the BFs at these locations. Except for the upstream part of the sector Waalhaven and the upstream part of the sector Maasbruggen, the BF only ranges between 0-15% difference between the highest and lowest antenna height. This holds that an antenna height increment of 500% only produces a BF difference in the order of 0-10% for the most regions on the main fairway. Especially in the downstream part of the sector Maasbruggen the differences in BF are low. This can be clarified by the fact that this part of the fairway is located in the city of Rotterdam, in which relative more high buildings are present than in other regions along the fairway. Since the varying antenna heights are relatively small compared to the high buildings, the influence on the blockage factor is low as well.

7.2.2. Target air draft

As described earlier, there are sailing various types of different vessels through the port. These vessels cannot be classified by one vessel height only. Therefore, in the second analysis the influence of different target heights on the BF is investigated. In here, the antenna height is set to 10 meters and the maximum detection range is set to 2000 meter. The results are presented below:

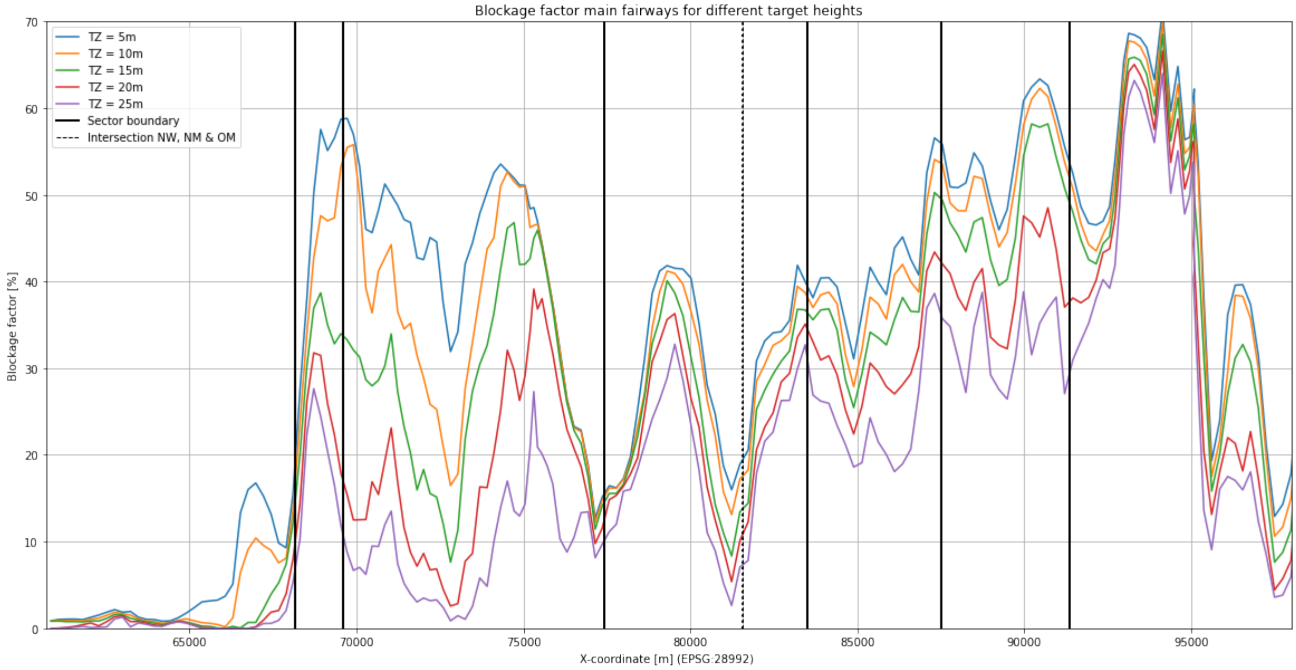

Figure 7-5. Blockage factor behaviour over main fairway for varying values for the target air draft.

As can be seen in figure 7-5, the influence of the target height on the blockage factor is following more or less the same results as the influence of the antenna height on the BF. This is quite logical because this analysis is actually the other way around as the previous analysis. Imagine the simple case in which the mutual detection of two objects which are separated by a wall is investigated. When the height of the wall and object B remains the same and the height of object A is increased, there will be a certain height for which the objects become visible for each other. This required height is equal to the case in which the height of object B is increased, and the height of the wall and object A remains the same. Therefore, the BF range is again largest in the sector Maassluis, and this can again be clarified by the presence of the Landtong Rozenburg dike. Next to that the BF range for the sector Botlek is still in the order of 0-10%.

7.2.3. Detection range

Finally, the influence of different detection ranges is investigated. The detection range of a maritime radar can be adjusted, and a different range will be used depending on the situation and environment. When navigating on a narrow channel, the traffic density is high, and a detailed overview of the surrounding environment is desired. Therefore, a smaller detection range is used. This is differing from the scenario in which a vessel is navigating on a sea or ocean because in that case, the traffic density is smaller, and a wider detection range is used. As shown by the real radar images, the MSC Factofour was using a detection range of 2250 m. For the analyzation of the influence of the detection ranges on the radar visibility the different detection ranges have been chosen between 500 and 2500 m. See the results in figure 7-6.

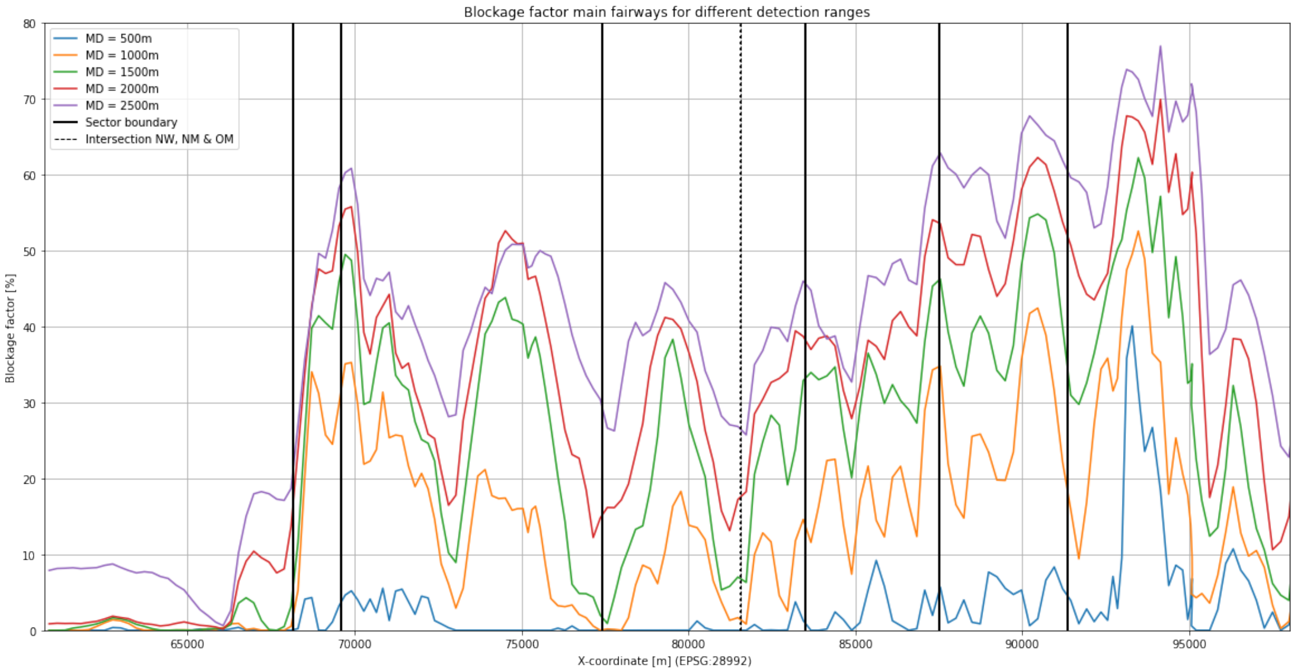

Figure 7-6. Blockage factor behaviour on the main fairway for varying detection ranges.

The results are pretty straightforward. The lower the detection range the lower the visibility, which is logical because when the detection range gets smaller relative to the fairway width, the blocked areas around the corner will vanish more and more. This holds for every port sector except for the Maas approach area, in which the blockage factor was around zero anyway because of the open sea environment. This means that there are no obstacles present, which holds for every detection range. Therefore, the BF is not influenced by any detection range in this sector.

7.3. Blockage Factor behaviour for dynamic obstructions

In the previous sections the influence of static obstructions on the behaviour of the BF is analysed, in which only has been focused on the influence of elevations ashore. To get an idea of the influence of dynamic obstructions on the visibility, moored vessels are simulated at the locations of the berthing places. Most of the berthing places are located in harbour basins or parallel to the main fairway. Therefore, the influence of these berthing places is not that significant since either the maritime radar signals will be blocked by the elevations behind the berthing place ashore or there are no fairways areas located behind these berthing places. To overcome this problem and find a location for which dynamic obstruction can be significant, there is searched for berthing places for large tanker vessels. A berthing place of a tanker vessel consists out of a jetty which is positioned further away from the quay because of safety reasons. Because a moored tanker ship is positioned more to the central of the fairway, the blockage rates for the areas behind could be higher in comparing to when a vessel is moored close to the quay.

A location where is dealt with large tanker vessels is at the Maasvlakte Oil Terminal (MOT), which is located at the entrance of the sector Europoort. In order to tranship the oil from the ships, four jetty berths are attached to an 800-meter-long jetty dike which is directed into the direction of the Beerkanaal. The jetty dike has a height of 5 meters which is relatively low in comparing to the elevations in the surrounding areas. The adjacent sea defence dike has a height of 22 meters and the height of the oil storage tanks is ranging between 10 – 55 meters. See figure 7-7, in which the berthing places are indicated in yellow. Because of the low elevation of the jetty dike height, vessels navigating on the Yangtzekanaal are able to detect targets on the main fairways of the Maas approach area, and vice versa. In the scenario when tanker vessels are moored at the jetty berths this is not the case anymore. This will result in an increasing blockage factors on the locations around the jetty dike. The influence of the dynamic obstructions is presented in figure 7-8.

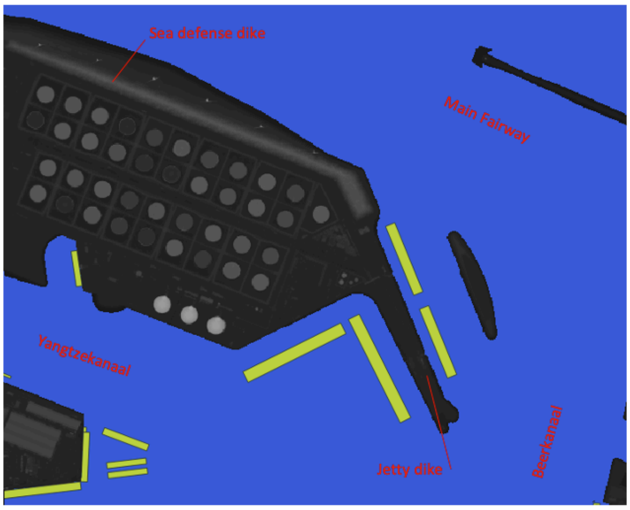

Figure 7-7. Overview MOT terminal.

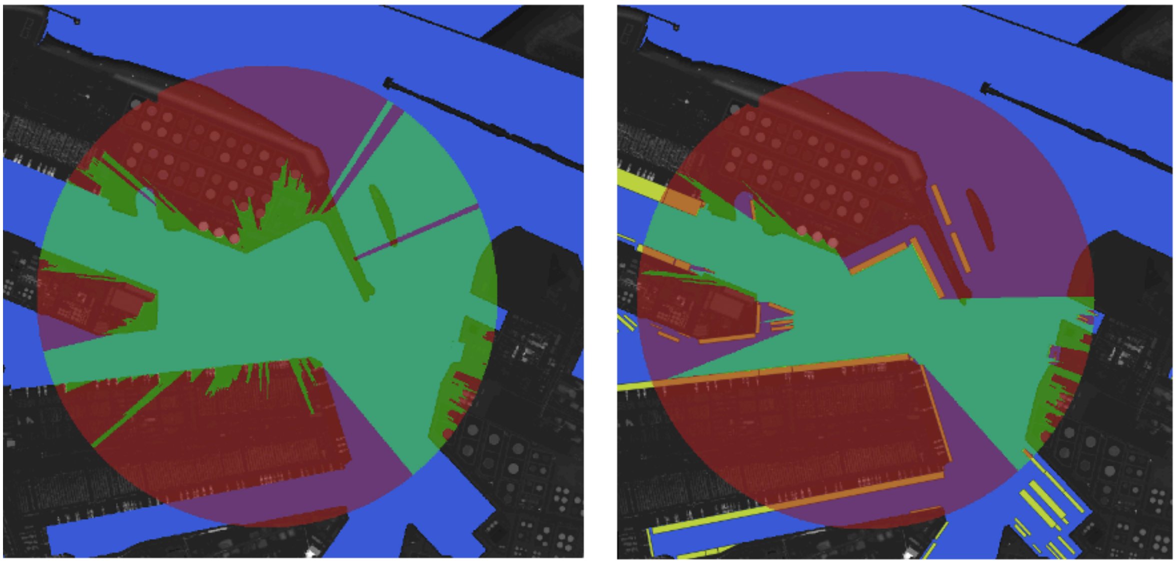

Figure 7-8 Viewshed MOL. Left: Static obstruction. Right: Static + dynamic obstruction.

Finally, the blockage factors for multiple locations around the MOT terminal are determined for both the scenario with- and without the influence of the berthing places. This is again done by means of a scatter plot, for which the mutual distances between the observer locations are set to 50 meters. The analysis is executed for an antenna height of 10 meter, a target detection rate of 10 meters and a detection range of 2000 meter. To get an overview of the differences, the absolute difference of the results of both analyses is calculated and shown in the scatter plot of figure 7-9. One can see that BF differences up to 30% occur by the presence of the vessels moored on the berthing places.

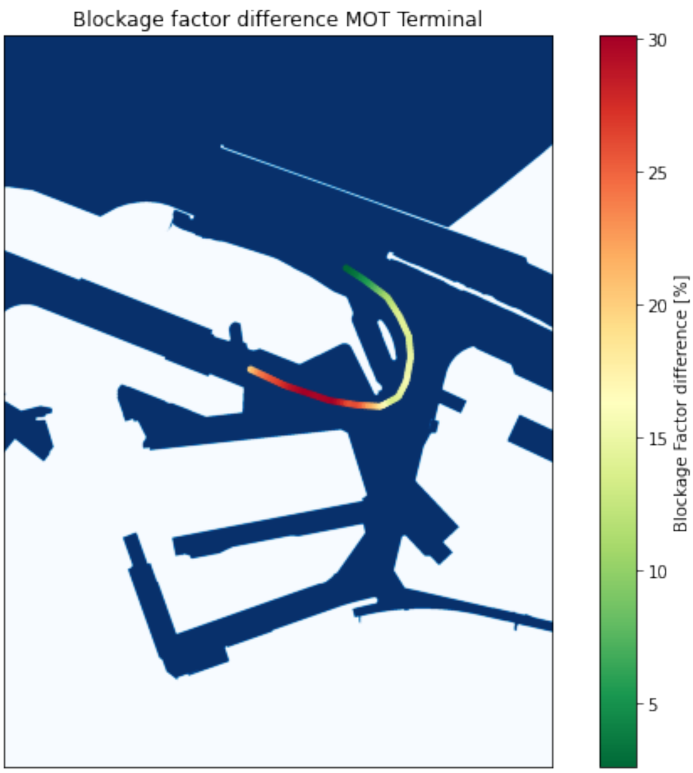

Figure 7-9 Absolute BF differences static & dynamic obstructions

7.4. Conclusions

The Visibility-analysis has been executed to provide an answer to the fourth sub question:

What are the spatial and temporal characteristics of the fairway system property visibility?

The visibility has been expressed by means of a blockage factor, which is estimated by means of the visibility-analysis. In this chapter the behaviour of the BF is verified for several varying conditions. It can be concluded that the visibility is strongly dependent on the elevations in the surrounding environment where a vessel is navigating. The visibility is varying extensively over the main fairway, for which an oscillating behaviour appeared with BFs between 0-70%. Low BFs occurred at seaside of the main fairway and high BFs occurred close to the city centre and at the beginning of the Oude Maas. In the sector Botlek the BFs are varying between 10-95%, with high values deep inside the harbour basins. Next to that it can be concluded that the visibility of an observing vessel is dependent on the antenna height and detection range of the radar and the air draft of targets. The BF is in general decreasing for increasing antenna heights and target air draft. For some sectors this difference is small, however big differences occur at the sector Maassluis, which is due to the presence of the adjacent Landtong dike and Calandkanaal. Lower BFs arises for smaller detection ranges. Finally, it can be concluded that moored vessels at berths can have a significant influence on the visibility. This holds especially for berths for tanker vessels, which are positioned more away from the quays for safety reasons.

8. Visibility in Traffic Images

In the final analysis the results of the VHF-analysis and the Visibility-analysis are combined to verify whether VHF-communications are related to the fairway property visibility. This is done by linking the substantive, spatial and temporal characteristics of the VHF-communications to the spatial and temporal characteristics of visibility. In this way it can be determined whether the occurrence of a certain type of VHF-communication is related to a lack of visibility. In this analysis is focused on communications regarding traffic images because in this form of communication an overview of the locations of target vessels is presented by the VTSO towards the navigating skippers. For each communicated traffic image, the visibility has been analysed, in which is focused on two aspects: the visibility of the observing vessel locations and the target visibility.

8.1. Visibility observing vessel locations

Figure 8-1 presents an overview of the blockage factors of the observing vessel locations towards where traffic images have been communicated. As can be seen in the figure, the blockage factors are varying between 15% - 80%, which indicates that traffic images have been communicated to low as well as medium and high visibility zones.

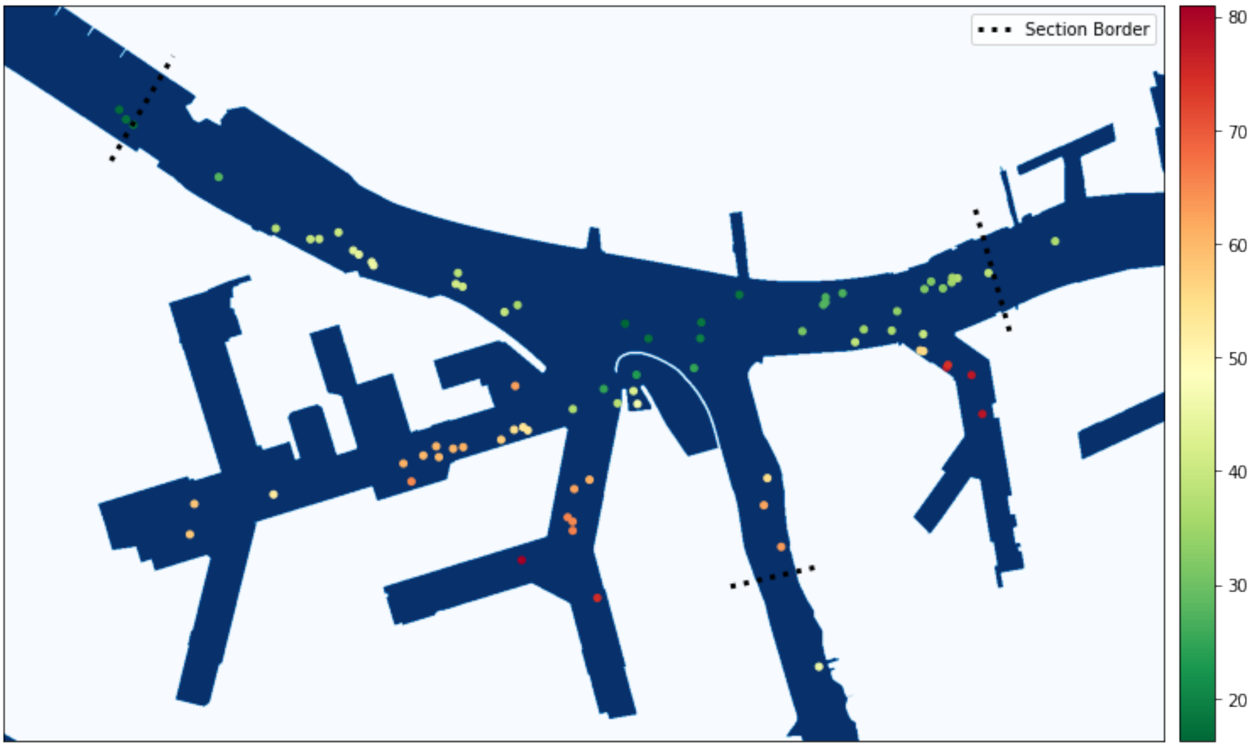

Figure 8-1 Observing vessel locations & Blockage Factors

To verify whether significant more VHF-communication is occurring on locations where significant higher blockage factors arise, a distribution plot of the blockage factors of the locations of the observing vessels is made. In this way it can be analysed in what quantities the VHF-communications have occurred for each blockage factor. To verify whether these blockage factors coincide with high blockage factors in the sector, this distribution plot will be compared with a distribution plot of the BFs of the entire sector. In this way it can be verified whether significant more VHF-communications are occurring at locations where significant higher blockage factors arise in the sector. The density plot of the sector Botlek is determined by using the associated BFs of the sector, which have been computed in section 8.1.2. As can be seen in figure 8-1, traffic images only have been communicated to vessels which were located on the main fairways or central channels of the sector, and no traffic images have been communicated to vessels which were located inside the harbour basins. Therefore, only the BFs of the main fairway and central channel are considered when determining the distribution plot of the BFs of the entire sector. The distribution plots of the BFs of the observing vessel locations and the BFs of the main fairway and central channels of the sector Botlek are illustrated in figure 8-2.

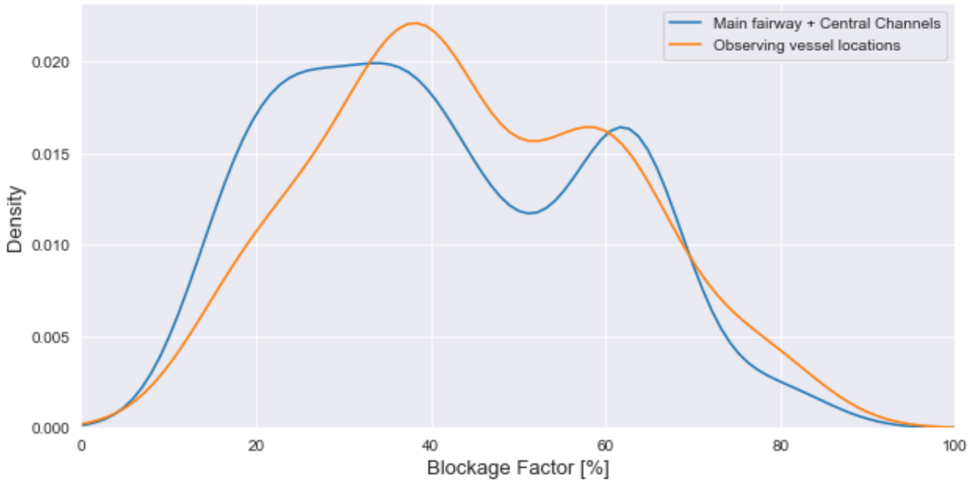

Figure 8-2 Distribution comparison. BFs observing vessel locations vs BFs main fairway + central channels.

Considering the distribution plot of the BFs of the observing vessel locations, one can conclude that the majority of the traffic images have been communicated to vessels positioned on locations with BFs of 35-40%. Another lower peak can be recognized at BFs around 55-60%. The distribution plot of the BFs of the sector has a maximum at 25-35% and another lower peak can be identified around a BFs of 60-65%. The left peak is mainly caused by the contribution of the main fairway areas, for which the average BF is equal to 32.85% occurred. The right peak is mainly caused by the contribution of the central channels for which an average BF of 53.53% is present. It can be concluded that the distribution plot of the observing vessel locations is having the same kind of shape as the BFs of the sector, however the spread of the distribution is smaller, and the peaks are higher. Especially in the mid-ranges, at BFs in the order of 30% – 60%, and at BFs above 70%, the distribution curve of the observing vessel's locations is higher than the BFs of the sector. At the lower BF ranges the opposite is true. A Two-Sample Kolmogorov-Smirnov Test (K-S test) has been performed to analyse whether the two distributions can be classified as similar (Press & Teukolsky, 1988). The results of the test showed that the differences between both distributions are not significant.

8.2. Target visibility

When the location- and the amount of relevant target vessels have been analysed, the visibility of the targets as seen from the observing vessel is analysed next, to verify which numbers of the communicated targets are actually visible and invisible. This is done by making use of the viewshed analysis model as described in the previous chapter. For each case in which a traffic image is communicated, a viewshed is made around the location of the observing vessel and there is verified whether target vessels are located in the visible green areas or the invisible red areas. The viewshed analysis is carried out for the mutual detection of vessels with an antenna height of 10 meters and a detection height of 10 meters as well. As could be seen in figures 7-4 and 7-5, the differences for varying antenna and detection height were not significant in the sector Botlek, and therefore there is assumed that these input values are a valid representation of the practice. The detection range in these analyses is chosen such that each communicated target will be inside the observing range. Obviously for some cases the range of the maritime radar is smaller than the distance for which some targets are located, however the emphasis of this analysis it to verify whether a target is visible or not and not whether the target is within the detection range or not.

In Figure 8-3, an overview of the target visibility is illustrated for the example conversation between the Fiona, Renata and the VTSO, which has been addressed in section 6.1. In this conversation one traffic image has been communicated to the observing vessel the Fiona, in which two targets have been addressed, the Renata and the Spica. From figure 8-3 one can conclude that the target Renata has been invisible for the Fiona and the Spica has been visible.

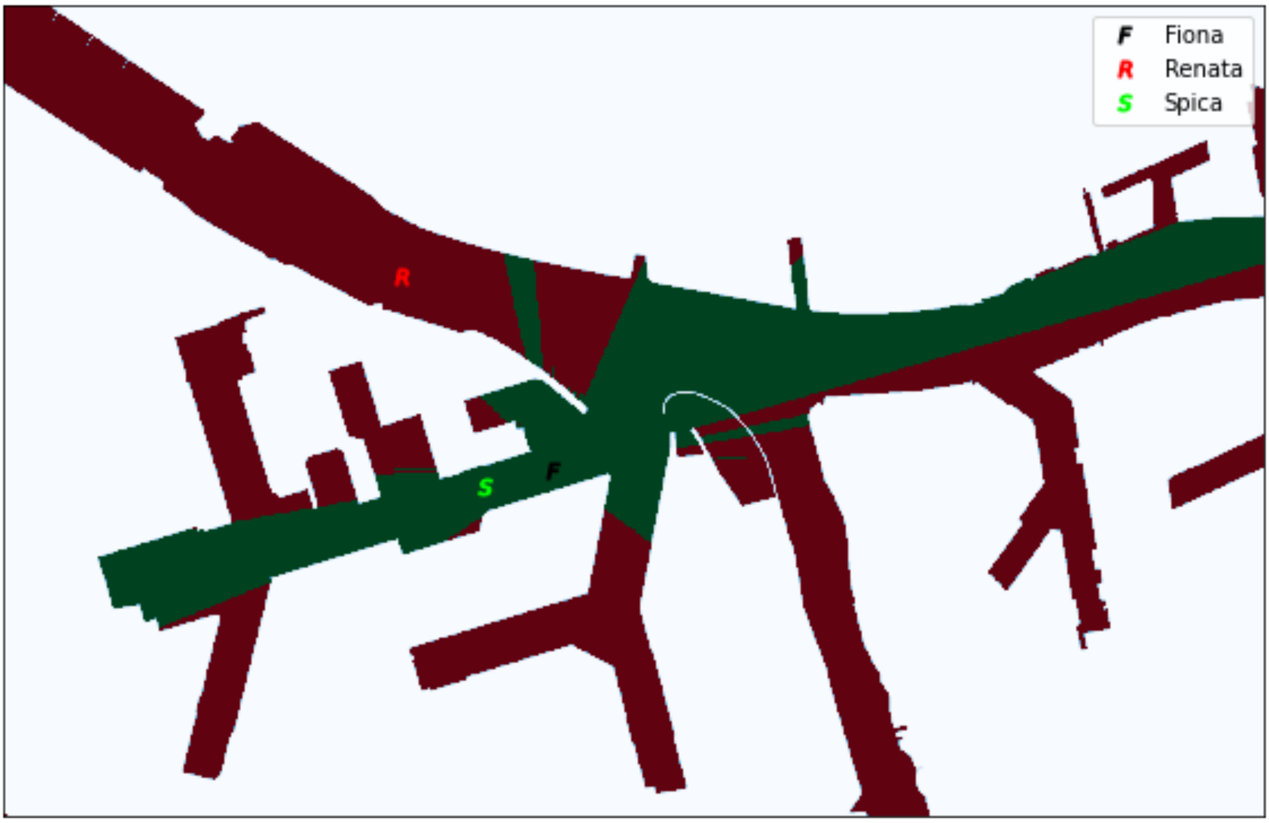

Figure 8-3 Target visibility for observing vessel Fiona

This analysis has been executed for each of the 79 communicated traffic images which have been defined in the VHF-analysis. The results regarding the visibility of the targets are shown in figure 8-4. A total of 143 relevant targets have been communicated towards the observing vessel by means of a traffic image. With 87 targets, the majority of the communicated target vessels have been visible for the observing vessel towards which the traffic image has been communicated to. From this, it can be concluded that VTSOs do not take into account whether a target vessel is visible for an observing vessel or not, while communicating a traffic image.

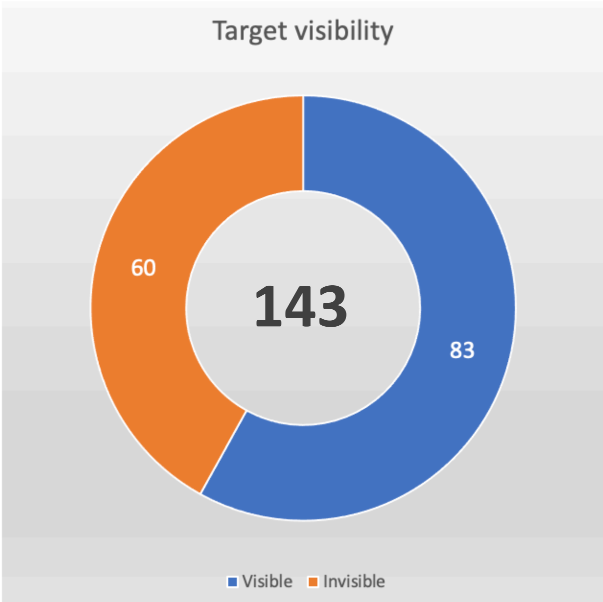

Figure 8-4 Target visibility in traffic images.

8.3. Conclusions

The objective of the final chapter of the results is to provide an answer to the last sub question:

To what extent is the occurrence of a certain type of VHF-communication related to the occurrence of blocked visibility for the vessel radar?

To verify this sub-question, two aspects has been determined, the BFs of the locations of the observing vessels is analysed, as well as the target visibility. It was found that traffic images have been communicated to vessels located on high, medium and low visibility zones. The distribution of the BFs of the observing vessels has been compared with the distribution of the BFs of the entire sector and it has been found that no significant differences occurred between these distributions. From this it can be concluded that there is no significant more VHF-traffic occurring at locations with significant higher BFs. Subsequently, the visibility of the targets has been analysed. In total 143 targets have been addressed in the traffic images. The results showed that, with 83 targets, the majority of the communicated vessels in traffic images have been visible for the observing vessel. From this it can be concluded that VHF-communications are not necessarily regarding objects that are not visible for the observing vessel.

IV. Concluding Remarks

9. Discussion

In this chapter is reflected on the work as a whole. First is reflected back on the results of the VHF-analysis, with respect to the considered data. Next, emphasis is put on the assumptions and limitations of the Visibility-analysis and their effect on the accuracy of the results. Furthermore, with the newly acquired knowledge gained in this thesis, the basic idea of full object detection and visibility is reflected back. Finally, suggestions for other model applications are proposed.

9.1. Limitation in VHF-data analysis

The VHF-analysis is based on one hour of VHF-data, which has a consequence that the results may be very specific for the chosen data. For the analysis of the VHF-traffic is chosen to use a VHF-tape in which a lot of communications occurs because this provides a lot of input data to analyse. A tape with a lot of VHF-communication can be linked to a busy sector, in which many navigating skips are present. In this section the obtained results are reflected and there is verified whether these are representative for the entire port or that these stick to the conditions of the dataset. This involves looking at the influence of the considered sector and the occurring traffic intensities.

The VHF analysis has shown that the communications can be divided into five categories: Announcements, Traffic Images, Manoeuvres, Intentions and Others. These categories can be derived from the prescribed rules and codes of conduct for the VTS-service and VHF-communication, as presented in chapter 2. Therefore, it is expected that the same communication types will be found if the analysis is carried out for other moments, sectors or traffic densities. A revision of the 1089 guidelines for VTS-service is proposed by IALA and currently pending for adoption at IMO. In many respects, the current version of Guideline 1089 will still valid, but the updated revision will remove the confusion over Types of Service being optional and establishes these services as capabilities of any VTS. Therefore, it is expected that still the same types of communication will arise in case the new guidelines will be adopted by IMO.

It has been shown that in most of the conversations of the analysed VHF-data of the sector Botlek a traffic image has been shared and this often occurred in combination with an announcement and/or an arrangement of a manoeuvre. The proportions in which these forms of communication will occur can be different for other sectors in comparing to the results as has been found in the analysis for the sector Botlek. The complexity of the sector layout and the density of the traffic are having an important factor in here. For example, sectors with higher traffic densities will induce more VHF-communication in absolute terms because more participants are present, but more communications regarding manoeuvres can also be expected, as more encounters are likely to take place as well. Another example is that in sectors in which relatively more harbour basins are present, relatively more communications regarding announcements are expected to occur, since navigating skippers are obligated to make an announcement before leaving a harbour basin.

Concerning the involved participants in the VHF-communications, it has been shown that in most of the communications a VTSO has been involved. Only 7% of the communications has been between skippers mutually. Since VTSO has been involved in communications of both complex and obvious situations, it can be concluded that skippers have blind faith in the shared information by the VTSO. Therefore, it is expected that this also applies to other sections in the port.

Lastly, the observing vessel locations, towards where VHF-communications have been communicated, have been analysed. Although the limited length of the dataset, still some hotspot locations could be recognized towards where relatively more VHF-traffic have been communicated. By means of a heatmap it has been illustrated that these hotspot locations arise at locations close to the main intersection point of the sector and it seems like the skippers wait until they reach these tactical points around the intersection before they are making an announcement. In this way they receive the most up to information which is required to enter the intersection. It is expected that these hotspot locations will be defined more extensively in case a longer dataset will be analysed. Next to that, it is expected that these kinds of hotspot locations will be recognized in other sectors as well. Similar to the sector Botlek, the expectation is that these hotspots will mainly arise at locations before intersections or branches to adjacent waterways or harbour basins in other sectors.

9.2. Visibility modelling study

A modelling study has been used to provide insight into the visibility of vessels while navigating to the port of Rotterdam. In general, the use of a model inevitably leads to inaccuracies when comparing with the reality. The main assumptions and limitations of the model are addressed below. For each limitation the influence on the accuracy of the output results is discussed as well.

Absolute visibility

To express the visibility of a particular location, the visibility of the waterway areas in a circle around that observer point is determined. This creates a so-called “absolute visibility”. A drawback of this method is that in this way irrelevant waterway sections can be located within the detection circle. Irrelevant waterway sections are, for example, adjacent canal stretches, which are close to the observing vessel location in terms of absolute distance, but due to the layout of the fairway system, far away in terms of actual distance. Possible targets located on these irrelevant waterway sections may be in the vicinity of the observing vessel, but due to the actual navigating distance, no short-term encounters can be expected and therefore these targets are not of interest for the observing vessel. In the port of Rotterdam, these irrelevant waterway sections especially arise at the height of the Calandkanaal, which is positioned adjacent to the main fairway in the sectors Rozenburg and Maassluis. Especially in these sectors, the presence of the adjacent channels is having a big influence on the visibility.

False and unwanted radar responses

To determine the visibility, only the effects of non-on-board obstructions are taken into account. In this way the effect of unwanted errors caused by on-board obstructions, such as equipment, freight or vessel structure are not considered. Other unwanted echoes caused by weather conditions, such as rain- and or sea clutter are neglected as well. The visibility is determined based on a line-of-sight method, in which visible zones are defined by the areas for which a straight line with the observing point can be realized. In this way the possible detection of targets located in shadow zones, which can be detected through diffraction of the energy pulses, is not considered. There is assumed that antenna equipment is positioned in the most optimized way to reduce the formation of unwanted blind and shadow radar spots. Next to that, the current maritime radars are equipped with anti-clutter control settings to reduce the influence of clutter and there is assumed that these functions will be used if needed. Therefore, little to no influence on the results is expected caused by the neglection of these false and unwanted radar responses.

Fairway layer

An issue of the applied DEM is that no elevation information is assigned to pixels which are classified as water. To be able to assign elevations to waterway areas, a layer in which the fairway areas of the port of Rotterdam are defined has been merged over the corresponding DEM file. A fixed value of the water height has been applied for the entire fairway, which is deviating from reality in which water height differences arise along the length of the port. Considering the length of the main fairway channel and the small water level differences between the east and west-side of the port, neglecting a sloping water surface profile is expected to have no influence on the model outputs.

Secondly, the addition of the fairway layer caused the loss of elevation information regarding structures located above the fairway, such as bridges, jetties and other fixed objects. These obstructions are not considered while determining the visibility. Especially bridges could block the transmitted radar energy pulses and therewith block the visibility as seen by a maritime radar. The determined visibility at locations around bridges is therefore likely to deviate from the actual visibility in case bridges were included. It is complicated to judge what the influence would be on the accuracy of the output results, since bridges often contain out of unique yet complicated structures. It is unclear whether radar pulses would be able to “penetrate through” the structure or will be reflected back. Obviously, the latter scenario would induce that the visibility behind these structures will deviate strongly from the model outputs.

Dynamic obstructions
To determine the influence of moored vessels on the visibility, highly simplified box-shaped obstructions of 20 meters elevation have been created at the locations of the berths. This is done to indicate that at certain locations the dynamic obstructions can have an important influence on the visibility of maritime radars. Obviously, box-shaped obstructions are an overestimating of the actual cross-sections of vessels and therefore higher blockage rates will be found than are likely to occur in reality. Therefore, the model outputs in which dynamic obstructions are included are not really accurate and should only be used as a first estimation to identify locations where dynamic obstructions could be of influence.

Visibility in Traffic images
To analyse the visibility at moments that traffic images has been shared, only the influence of static obstructions is included. This is deviating from reality since in this way the influence of (dynamic) obstructions on the fairway are neglected, such as navigating vessels or vessels which are anchored at berthing places. The rate of influence of the dynamic obstructions on the BF depends on the location of the observing vessel and target vessels, the height of the antenna and the size of the target vessel. Because these parameters are varying constantly, it is difficult to estimate to what extent this additional dynamic obstruction would affect the visibility of the maritime radar. Most berths in the sector Botlek are located parallel to the quay/shore. In addition, many static obstructions such as buildings, infrastructures and oil storage tanks are present on the shore. Because of these obstructions it is not possible to detect targets at adjacent channels at the other side of the shore and this holds for antenna heights up to 40 meters. This means that additional influences from dynamic visual obstructions, as shown for example in section 7.3 for the MOT terminal, are not expected for this sector. Nevertheless, it must be taken into account that ignoring these dynamic obstructions will result in an overestimation of the actual visibility. In reality the visibility will be lower than the visibility as calculated by the model.

Furthermore, the visibility is determined by a model based on an antenna height and target air draft of both 10 meter. This is a major simplification, since in reality all vessels are unique and are differing extensively in size. This holds that the air draft and offset of the antenna of individual vessels can be higher and/or lower than the used 10 meters by the model. Therefore, one should know that the visibility may differ from reality and the number of visible targets could be different as well. In section 7.2, the influence of varying antenna heights and target air drafts on the visibility is analysed. It has been shown that these varying antenna offsets and target air drafts are not having a significant influence on the visibility for the sector Botlek. Therefore, it is expected that the simplification of the antenna heights and target air drafts will not have a significant influence on the results for the sector Botlek neither. One should keep in mind that varying antenna offsets and target air drafts could have more influence on the visibility in other sectors, which means that the simplification made in this analysis would induce less accurate results in other sectors.

DEM Accuracy
The visibility is determined based on a Digital Elevation Model (DEM), which is available at “het Algemeen Hoogtebestand Nederland”. The DEM files are available in two different accuracy levels: DSM 0.5 m and DSM 5m, which are having pixel sizes of 0.5 x 0.5 m and 5 x 5 m respectively. In this study the less accurate DEM 5 m files have been used, because of practical reasons regarding storage and computation times. For the sector Botlek it has been verified that no significant differences occurred in output results between the two different accuracy levels, however it has not been verified whether this holds for the entire port area.

Data collection mismatches
In the analysis, the characteristics of the VHF-communications are linked to the characteristics of the fairway property visibility. The visibility is determined based on a DEM file, for which the elevation information is gathered during the period of 2014-2019. For the VHF-analysis, VHF-data of September 2020 is used. There are inevitable differences between the elevation model of 2014-2019 and the actual present obstructions during the collection of the VHF-tape.

9.3. Full object detection & Visibility

In this thesis has been chosen to investigate to what extent a “blocked visibility” is likely to trigger VHF-traffic. This is in line with an ongoing research into the digital transition of the VTS-service, in which is aimed at creating full object detection and visibility. Prior to this research, it was thought that VHF-traffic regarding traffic images could be reduced by creating this full object detection and visibility. During the VHF-analysis is this research, it was found that in traffic images only information regarding relevant targets is addressed. Relevant targets are vessels for which a future encounter with the observing vessel is expected. Whether a target can be classified as relevant is depending on the positions, courses, navigating speeds and intentions of both the observing vessel and the other participating vessels in the sector. This classification is made by the VTSO, who is trained to recognize patterns and predict future situations. Furthermore, it has been shown that for these relevant targets not only information regarding the location is shared, but also information regarding the intentions of the targets is included. This was the case for 82% of the addressed targets and this number would be even higher in case the intentions of the remaining targets had also been known by the VTSO.

When full object detection and visibility is realized, only one part of the provided information in a traffic image is covered, namely the information regarding the positions of the targets. However, no information regarding the intentions of vessels is shared in this way. Next to that, by only providing full object detection and visibility, no distinguishing is made between relevant and irrelevant targets either. This distinguishing is required for the skipper of the observing vessel to judge with which targets agreements regarding manoeuvres have to be made. In section 8.2, it has been showed that 58% of the addressed targets in traffic images are visible for the observing vessel in question. Full object detection and visibility will ensure that the other 42% of the targets will be visible as well. However, this will not lead to the desired reduction of VHF-traffic because still information regarding intentions and relevant/irrelevant is lacking. Because all information in the VTS-sector is communicated via VHF-radio, this information will still have to be communicated by means of VHF.

9.4. Other model applications

9.4.1. Apply method to analyse other fairway properties

In this study a method has been developed in which VHF-communications have been linked to characteristics of a fairway system, to verify whether the occurrence of a certain type of VHF-communication can be related to the occurrence of a particular fairway property. The focus in this thesis was on investigating to what extent blocked visibility is likely to trigger VHF-communications. To verify this, two individual methods have been developed to analyse the VHF-communications and the visibility in ports. The method can be applied to investigate the influence of other fairway properties as well. To do so, the set of digitized VHF-data can be used, or the method can be used to digitize a new set of VHF-data. Depending on which fairway property is analysed, a method should be found to identify the spatial and temporal characteristics of the property, to be able to link them to the characteristics of the VHF-communications.

9.4.2. Visibility-analysis for other locations

Using the visibility-analysis, an accessible model has been set up which can be used for many occasions. The only required input data is a Digital Elevation Model of the desired location of interest. In case the visibility on fairways is investigated, an additional layer including the considered fairway is needed. In this thesis, a DEM of the port of Rotterdam is used in combination with a corresponding fairway layer. Based on this data, the model can further be used to analyse the visibility around each location in the port of Rotterdam. The AHN DEM files are openly accessible and available for the whole area of the Netherlands, therefore the model can be used to analyse various locations throughout the country. When including the corresponding fairway layers, the model can be used to determine the visibility of other ports and inland fairways/channels within the Netherlands. In case global DEM files are available, the model can be used for analysing the visibility of areas outside the Netherlands as well.

10. Conclusions & Recommendations

In this chapter the main conclusions of this work are presented by first elaborating on the different sub questions, subsequently converging towards the answer to the main research question. The main conclusions are followed by recommendations for future work.

10.1. Conclusions

The objective of this research was to investigate whether VHF-communications are triggered by properties of a fairway. This has been done by developing a method in which VHF-communications are digitized and linked to characteristics of a particular fairway property. In this way it has been analysed whether the occurrence of a certain type of VHF-communication is related to the occurrence of a certain fairway property. This method can be applied in multiple questions, but in this thesis the focus was in analysing to what extent blocked visibility is likely to trigger VHF-communications. To investigate this, 5 sub-questions have been defined: 1) In what way can VHF-communications be digitized in order to classify the communications according to content, space and time? 2) What are the substantive, spatial and temporal characteristics of the VHF-communications? 3) What method can be used to determine the visibility of vessel radars? 4) How does the visibility of vessel radars behave for varying locations, vessel parameters and obstructions? 5) To what extent is the occurrence of a certain type of VHF-communication related to the occurrence of blocked visibility for the vessel radar? In this chapter, these questions will be answered by summarizing the major findings.

VHF-communications

To digitize the VHF-communications, a method has been developed in which the spoken VHF-communications has been transferred into text and classified according to content, space and time. This is done by recording the VHF-audio tapes first, whereafter the spoken messages have been written down word by word. The obtained text is subdivided in individual conversations and for each conversation the communication types and involved participants have been addressed. The involved participants consist out of the transmitter and receiver of the messages, as well as the addressed targets in the messages. Subsequently, the corresponding vessel locations of the involved participants have been identified by using historical radar and AIS-data. Finally, the transmitting times and durations of the messages have been identified as well.

By means of the method, VHF-data of the sector Botlek has been digitized and analysed. It can be concluded that the communications can be classified based on five main forms of communication: Announcements, Traffic Images, Manoeuvres, Intentions and Others. In the majority of the conversations a traffic image has been communicated and this often occurred after an announcement has been made by the observing vessel of that traffic image, whereafter sometimes an arrangement for a manoeuvre is made eventually. The sharing of information between participants often occurred by intervention of the VTSO, which has been included in 75/81 conversations. The number of targets addressed in traffic images is varying between 0-5 targets. In most of the cases only one target is addressed, and the number of cases is decreasing for an increasing number of communicated targets. The distribution of the observing vessel locations is widely spread over the sector, although some hotspot areas can be recognized. These hotspots arise at the Scheurkade, Welplaathaven/Borax and Delta hotel/Kattenbak, and are all located within 2 km of the main intersection of the sector Botlek. These locations are used by skippers as well as by VTSOs because at these locations the most up-to-date information can be exchanged, which is required to handle the traffic around the intersection safely.

Visibility
The visibility as seen by a vessel radar is depending on the location of the observing vessel, the height and the detection range of the equipped radar and the position and air draft of the targets in the surrounding environment. To determine the visibility, a model has been developed with which the visibility around a chosen observer point can be determined. This is done using the visibility-analysis, in which the visibility is expressed by means of a blockage factor (BF). The BF is defined as the total invisible fairway area within the detection range around a chosen observer point ($A_{FW,C,Invisible}$), divided by the total fairway area in that detection range ($A_{FW,C}$).

$$BF = \frac{A_{FW,C,Invisible}}{A_{FW,C}} * 100\%$$

The BF is computed by means of a viewshed-analysis and a subsequent area-analysis. In the viewshed-analysis the required pixel elevations are determined, which are required to make that pixel visible as seen from the chosen observer point. This is done following the line-of-sight method, based on a Digital Elevation Model (DEM), and input parameters regarding the location, antenna height and detection range. The output of the viewshed-analysis forms the input for the area-analysis, in which the viewshed is subdivided in visible and invisible areas and relevant and irrelevant areas. Relevant areas are defined by the areas which are positioned on the fairway. When the (in)visible and (ir)relevant areas have been defined, the BF can be computed, which forms the output of the visibility-analysis.

The visibility-behaviour is analysed by investigating how the BF is varying for varying conditions of several input parameters. It can be concluded that the visibility is strongly dependent on the elevations of the surrounding environment in which a vessel is navigating. The visibility is varying extensively over the main fairway, for which an oscillating behaviour appeared with BFs between 0-70%. Low BFs occurred at the seaside of the main fairway and high BFs occurred close to the city centre and at the beginning of the Oude Maas. Within individual port sectors even higher BFs have been found. For the sector Botlek, BFs up to 95% occurred for locations deep in the harbour basins. Next to varying locations, the dependency of the visibility on the antenna height and detection range of the radar and the air draft of targets has been identified. It can be concluded that the BF is in general decreasing for increasing antenna heights and target air drafts. For some sectors this difference is small, however considerable differences occur at the sector Maassluis, which is due to the presence of the adjacent Landtong dike and Calandkanaal. Lower BFs arise for smaller detection ranges. Finally, it can be concluded that moored vessels at berths can have a significant influence on the visibility. This holds especially at berths for tanker vessels, which are positioned more away from the quays for safety reasons.

Visibility during VHF-communications
To verify whether the occurrence of particular types of VHF communications are related to the occurrence of characteristics of fairway properties, the following hypothesis is verified:

At locations with significant higher blockage factors arises significant more VHF-traffic regarding objects which are not visible for the observing vessel.

To verify this hypothesis, the visibility around traffic images has been analysed. The BFs of the observing vessel locations are determined and it has been verified that traffic images have been communicated to vessels located on high, medium and low visibility zones. The distribution of the BFs of the observing vessels has been compared with the distribution of the BFs of the entire sector and it has been found that no significant differences occurred between these distributions. From this, it can be concluded that there is no significant more VHF-traffic occurring at locations with significant higher BFs. Subsequently, the visibility of the targets has been analysed. In total 143 targets have been addressed in the traffic images. The results showed that, with 83 targets, the majority of the communicated vessels in traffic images have been visible for the observing vessel. From this it can be concluded that VHF-communications are not necessarily regarding objects that are not visible for the observing vessel. Based on this analysis it can be concluded that the hypothesis has to be rejected.

Finally, an answer can be given to the main research question:

To what extent are VHF-communications triggered by a blocked visibility for the vessel radar?

It can be concluded that the majority of the transmitted VHF-messages in the sector Botlek are communicated to vessels which are located on hotspot locations around the central intersection point of the sector. These hotspot locations are located at the height of the Scheurkade, Borax/Welplaathaven and Delta Hotel/Kattenbak and are all located within 2 kilometres of the centre of the intersection. The corresponding blockage factors of the hotspot locations is varying between 10-80%, which indicates that communications have been made towards vessel which were positioned on low, medium as well as high visibility positions. By comparing the distributions of the BFs of the observing vessels with the overall BFs of the sector it has been determined that no significant differences occurred, which indicates that no significant more VHF-traffic has occurred at locations where significant BFs are present. Next to that, the majority of the addressed targets in the messages have been visible for the observing vessel, which indicates that there is communicated regarding visible as well as invisible targets. Because VHF-communications have not necessarily communicated towards vessels located on locations with high BFs, and these communications were not necessarily regarding invisible targets, it can be concluded that a blocked visibility for a vessel radar is having a minor influence in triggering VHF-communications.

10.2. Recommendations

10.2.1. Intentions

In the discussion it has been addressed that only realizing full object detection and visibility will not be an effective measure to reduce VHF-traffic because still information regarding intentions of other vessels is missing. This information is required to identify which targets can be classified as relevant targets, which is necessary to identify with which targets a future encounter is expected and an arrangement of a passage is desired. Therefore, input for follow-up studies is regarding the intentions of other vessels.

It has to be verified in which way the information regarding intentions has to be presented to the navigating skippers. In here it is very important to judge whether the task of classifying relevant/irrelevant targets should be done by the skippers of the navigating vessels. It is very uncertain whether skippers would be able to identify relevant from irrelevant targets in case information regarding intentions is shared next to the information regarding vessel positions. Furthermore, it should not be forgotten that a skipper is also busy with navigating its vessel and especially in sectors where VTS is provided, a high level of alertness is required. An extra duty in the form of identifying relevant targets could distract the skipper from its main duty to safely navigate it vessel.

In the ideal scenario, a system has to be developed in which the locations and intentions of targets are incorporated. Based on this information, the system should be able to identify which targets can be classified as relevant. When this is presented on a simple/user-friendly manner to the skippers, a clear overview of the positions of relevant targets is obtained. Based on this overview, skippers are able to immediately identify targets for which a future encounter is expected and can make contact to the skippers of the corresponding vessels to make an arrangement of a passage. This could replace the VHF-communications regarding traffic images. It might be possible to link this system to the current used AIS-data on board of the vessels.

10.2.2. Hotspot locations

For the sector Botlek it has been found that most of the VHF-communications were occurring at strategical hotspot locations around the main intersection point of the sector. It has been concluded that these hotspot locations in the sector Botlek are not triggered by visibility, but most likely arise because it is the desired spot to exchange information. The proposed method can be used to verify whether more hotspot locations can be identified in other port sectors. Next to that, the visibility model can be used to determine whether visibility around these possible other hotspot locations is an issue, for which measures can be made to tackle these issues.

10.2.3. Digitization of VHF-Audio

The most time-consuming process in this research was to transfer the spoken VHF-communications into text. This is mainly caused by the fact that no programming software could be found which is able to transfer the spoken VHF-communications into text. Further research in finding an appropriate solution for transferring the spoken audio in text would make the method more effective.

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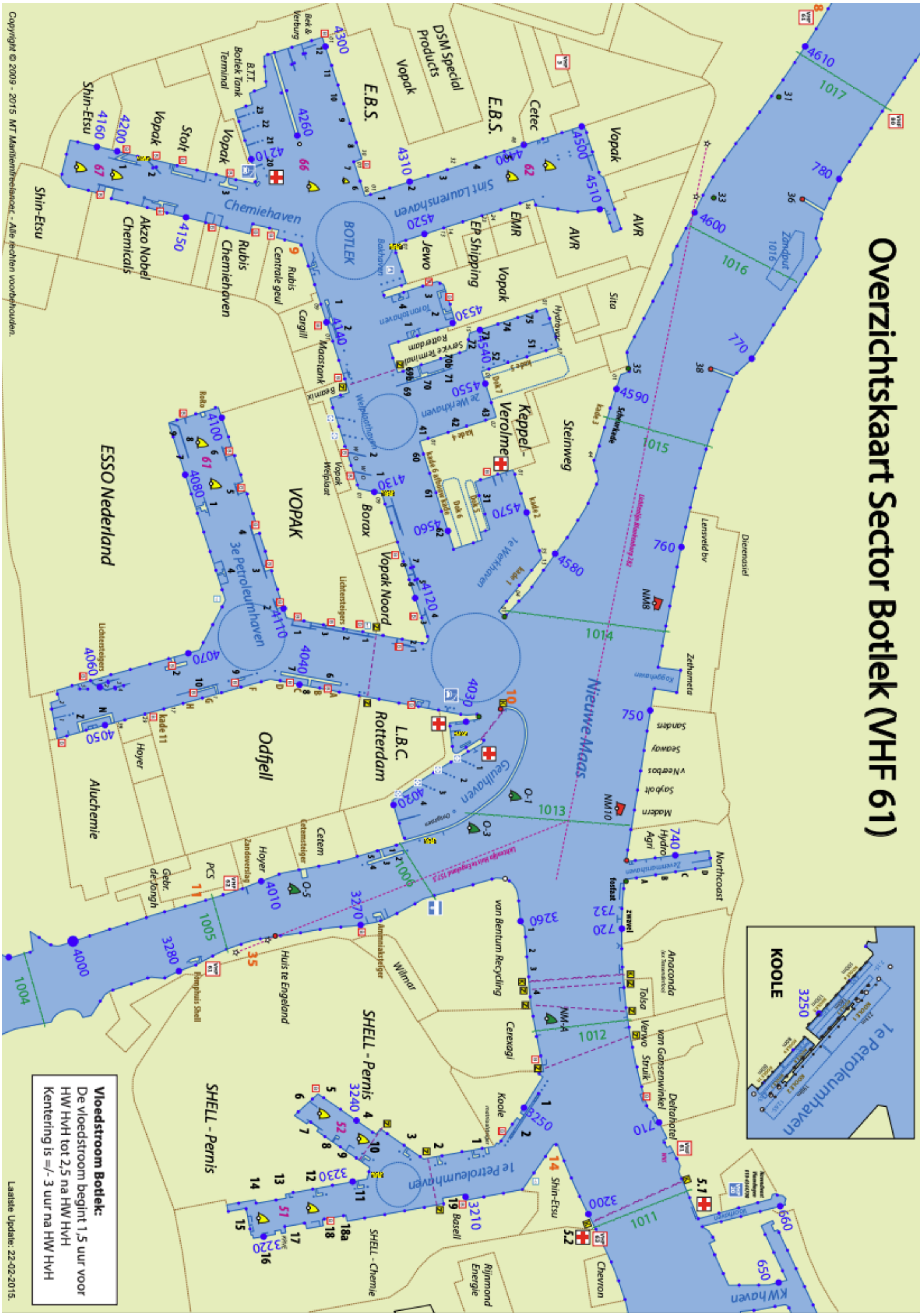
V. Appendices

Appendix A – Overview sector Botlek



Appendix B – VHF Communications

Introduction

- For each conversation it is stated from what time until which the communication took place, between which actors and to which category the form of communication can be assigned. Within the conversations several forms of conversations took place. The types of communication are:
    - Announcements
    - Traffic Image
    - Maneuver
    - Intentions
    - Other
- VHF-radio communications which are coming from the VTS-operator (VTSO) are indicated with black.
- VHF-radio communications which are coming from the navigating skippers are indicated with colors
    - Usually, a conversation is only between the VTSO and a single skipper. There are situations where several skippers are involved.
        - Red = primary skipper
        - Blue = secondary skipper
        - Greeen = tertiary skipper
        - Orange = quaternary skipper
        - Purple = quintal skipper

B1. Overview communicated messages

Overzicht gesproken berichten

0:48 – 1:34 | VTSO, Sten Fjell & Roeiers 52 | Aanmelden + Verkeersbeeld + Manoeuvre

1. Botlek, die Sten Fjell aan de Borax voor lager uit.
2. Sten Fjell dat is begrepen, zeevaart nu 100 meter beneden de groenhaven ligt komt dan de Botlek in de volgende opvaart is de Roeiers 52, 1000 meter beneden de monding, richting de stad ook.
3. Duizend meter, dan doen we daar stuurboord stuurboord mee
4. Roeiers52 mocht het nog nodig zijn, zeevaart uit de Botlek richting zee stuurboord-stuurboord. Over.
5. Stuurboord-stuurboord, ja hoor voor mekaar.
6. Ik dacht dat u het over zeevaart had
7. De sector Botlek
8. Ja de Sten Fjell, ik dacht dat je het over zeevaart had op 1000 meter.
9. Nee nee, roeiers52 een roeibootje maar die is zo weg
10. Jaa okay precies., voor mekaar.

1:37 – 2:04 | VTSO & Anversa | Aanmelden + Verkeersbeeld

11. Sector Botlek voor de Anversa
12. Dit is sector Botlek over
13. Ja graag gedaan, dit is de Anversa. Komen zo de achteruit de Geulhaven uit en zijn voor de Esso, 3e Petwest tak.
14. Anversa, 3e Pet west tak, ja dat is begrepen. Zeevaart die nu de Botlek invaart die gaat door naar de Vopak 5, uitvaart zeevaart centrale geul richting zee.
15. Ja okay we houden er rekening mee

2:06 – 2:53 | VTSO, Spica, en nog een ander schip | Aanmelden + Verkeersbeeld + Manoeuvre

16. Sector Botlek over voor de Spica
17. Zegt u het maar
18. Ja de Spica aan de Borax, en richting de Oude Maas
19. *** 2 gesprekken door elkaar***
20. Uitvarende zeevaart een 500 meter binnen de monding centrale geul naar zee.
21. Ja dan wou ik daar stuurboord-stuurboord mee doen, dan houden wij wel een beetje de dam aan en dan draaien we zo de 3e Pet in naar de auto-steiger?
22. Ja en daar vertrekt weer binnenvaart naar de west tak. Stand-by
23. Ja die gaat de west tak in okay. Dan houden we het allemaal wel even in de gaten en in ieder geval dan met die uitgaande zeevaart uit de centrale geul dan stuurboord-stuurboord, als die loods daarmee akkoord gaat?
24. Ja, ja okay. Ja ik zeg uit vanuit de autosteeg (aux steiger) maar ik bedoel vanuit de Geulhaven. Dat is de Anversa, die gaat naar de west tak. Nee die zeevaart ga ik zo inlichten hoor die moet eerst even die andere zeevaart laten lopen maar die ga ik zo inlichten stand by.
25. Ja okay. Ja die Anversa die zie ik al komen maar die zal wel wegwezen voordat wij zover zijn, want wij gaan niet zo hard.

2:57 – 3:31 | VTSO, Sten Fjell & Main 21 | Verkeersbeeld + Manoeuvre

26. De Sten Fjell, sector Botlek. Mocht het nodig zijn van boven vandaan een 800 meter boven de Botlek, is binnenvaart de Main 21 die wil graag via de dam naar de auto steiger en stuurboord-stuurboord met u varen.
27. Ja de Sten Fjell is akkoord hoor. Zie er wel eentje liggen hier bij de autosteiger bij uhh TNSE(?)

28. Ja correct. De Main 21, autosteiger is in ieder geval bezet, dat had ik al gemeld en die Sten Fjell zeevaart is stuurboord-stuurboord akkoord.
29. Ja okay, ja ik hoef alleen even iemand af te zetten, die moet iets uit z'n auto halen en dan gaan we gelijk weer weg, dus uhh we hoeven geen auto af te zetten.
30. Okay, prima

3:40 – 4:13 | VTSO & Spica | Aanmelden + Verkeersbeeld

31. Sector Botlek voor de Spica
32. Spica sector Botlek over
33. Ja we zitten aan de Borax en bestemd voor de Oude Maas
34. De Spica, bij de Welplaathaven, ja dat is begrepen. De zeevaart voor u die gaat richting zee. Van bovenaf komt dan op 500 meter een binnenvaartschip de Botlek in die gaat naar de autosteiger monding 3e Petroleumhaven. Uit de Geulhaven komt weer binnenvaart voor de 3e Petroleumhaven
35. Okay

4:17 – 4:31 | VTSO & Valburg | Aanmelden + Verkeersbeeld

36. Botlek Valburg goeiemiddag
37. Valburg sector Botlek zegt u het maar
38. Komen zo uit de Oude Maas richting de stad
39. Valburg sector Botlek, ja begrepen hoor. Kleine opvaart binnen de monding en kleine opvaart 1000 meter beneden de monding richting stad, over
40. Ja begrepen

4:47 – 5:10 | VTSO & Eiltank 24 | Aanmelden + Verkeersbeeld

41. Sector Botlek de Eiltank 24
42. Eiltank 24 de sector Botlek over
43. Ja goedemiddag, in de afvaart bij het Delta Hotel, bestemming Laurenshaven
44. Ja Eiltank 24 sector Botlek begrepen hoor. Zeevaart 400 meter binnen de monding Botlek richting de zee, ehmm meldt u nog even als u oversteekt over
45. Okay stand-by

5:33 – 5:52 | VTSO & Annabel | Aanmelden

46. Sector Botlek, de Annabel, goede middag
47. Annabel sector Botlek over
48. Ja hoor we komen de Laurenshaven uit en dan richting de monding en later naar richting stad
49. De Annabel begrepen, meldt u dan in de monding van de Botlek over.
50. Okay

6:03 – 6:24 | VTSO, Hydrovat 10 | Aanmelden + Verkeersbeeld

51. Sector Botlek, Hydrovat 10
52. Hydrovat 10 sector Botlek over
53. Afvaardig kattenbak, bestemd voor de Chemiehaven
54. Hydrovat 10, begrepen hoor. Binnenvaart voor u gaat naar de autosteiger 3e Pet. Tegenligger dwars van de monding Botlek richting stad, zeevaart monding Botlek richting zee, over.
55. Ja okay

6:30 – 6:49 | VTSO, Main 21 en Roeiers 52 | Manoeuvre

56. Main 21, u vaart ook stuurboord-stuurboord met die roeiers52 zo te zien?
57. Jaa dat wou ik wel doen. Want uhh, nou ik zit er al dwars voor dus ik ben al onderweg
58. Nou hij moet wel medewerking verlenen. Roeiers 52 mee gehoord?

59. Ja ik heb het gezien hoor, stuurboord-stuurboord is goed.
60. Jaa haha okay

7:00 – 7:36 | VTSO, Renata & Sten Fjell | Aanmelden + Verkeersbeeld + Manoeuvre

61. Botlek, Renata. Aan de scheurkade voor de Oude Maas
62. Renata Oude Maas, ja begrepen. Zeevaart monding Botlek voor zee, over.
63. Ja gaat die voorlangs?
64. Als u goed uw kantje houdt dan gaat die voor langs maar hij gaat nu al de rivier op, over.
65. ….
66. Sten Fjell, 1400 meter beneden de Botlek binnen voor de Oude Maas, hij zit wat uit de kant maar u steekt direct over neem ik aan he?
67. Steken gelijk over, Sten Fjell ja hoor
68. Ja begrepen, Renata als u gewoon uw kantje houdt dan komt hij gewoon voor u langs
69. Ja

7:37 – 8:19 | VTSO, Fiona en Renata | Aanmelden + Verkeersbeeld + Manoeuvre

70. Sector Botlek, Fiona uit
71. Fiona sector Botlek over.
72. Vertrekkend Vopak noord en dan richting de scheurkade
73. De Fiona dat is begrepen, uitvaart uit de centrale geul, 500 binnen de monding naar de Oude Maas, opvaart aan de scheurkade 1000 meter beneden de monding Botlek, die gaat ook naar de Oude Maas over.
74. Ja dan zou ik graag stuurboord-stuurboord willen doen met die ene die naar de Oude Maas gaat zeg maar, dan blijf ik aan de verkeerde wal.
75. Ja u steekt nu gelijk al over toch? Ja is okay. De Renata, er komt nog kleine vaart vanuit de centrale geul naar de scheurkade, die blijft heel dicht onder het walletje vaart met u stuurboord-stuurboord over.
76. Ja duidelijk

8:24 – 8:38 | VTSO & Superiority | Aanmelden

77. Sector Botlek de Superiority over
78. Dit is sector Botlek over
79. Sector Botlek, de Superiority. Die is opvarend aan de 25 en voor de Oude Maas.
80. De Superiority dit is sector Botlek begrepen

8:40 : 9:08 | VTSO & Eiltank 24 | Aanmelden + Manoeuvre

81. Sector Botlek dit is de Eiltank 24
82. Eiltank 24 sector Botlek over
83. Ja ik ben voor de eurosteiger. Uhh ik wil met die opvarende aan de scheurkade stuurboord-stuurboord
84. Ja Eiltank 24 ja dat is begrepen stand by die is wel voor de Oude Maas bestemd. Over
85. Die is voor de Oude Maas bestemd... ja okay. Ik vaar wel wat langzamer okay
86. U gaat dan achterlangs. Ja hoor begrepen dank u wel

9:10 – 9:21 | VTSO & Spaarneplus | Aanmelden

87. ……? dit is Spaarneplus
88. Uhh iets met plus, sector Botlek
89. Spaarneplus, in de monding van de Oude Maas richting stad
90. Spaarneplus, sector Botlek begrepen

9:27 – 9:36 | VTSO & Holland Diving 1 | Aanmelden

91. Sector Botlek Holland Diving 1
92. De sector Botlek over

93. Ja Holland in is klaar met duiken, en we gaan door de eerste Werkhaven in
94. Holland Diving, sector Botlek begrepen

9:40 – 9:47 | VTSO & Main 21 | Intenties

95. Main 21 gaat u zo afmeren bij de auto steiger?
96. Ja wij schieten zo kop voor even opzij
97. Ja begrepen

10:05 – 10:20 | VTSO & Bunga Lavender | Aanmelden + Verkeersbeeld + Manoeuvre

98. Sector Botlek de Bunga Lavender, zo over bakboord keren en dan zwaai ik om, achteruit de west tak in Vopak 5
99. De Bunga Lavender sector Botlek dat is begrepen. Binnenvaart achter u ook voor de west tak bestemd en die weet ook dat u daar heen gaat over
100. Bunga, dank je wel

11:40 – 12:20 | VTSO, Anversa en Annabel (twee gesprekken) | Aanmelden + Verkeersbeeld + Intenties

101. Botlek de Anversa
102. Sector Botlek de Annabel, nu aan de Borax richting stad
103. Ja Annabel sector Botlek dat is begrepen. Opvarende binnenvaart aan de monding Botlek, eerstvolgende aan de scheurkade nog niet gehoord.
104. Botlek de Anversa
105. De Anversa Botlek
106. Ja wat gaat die zeevaart voor me precies doen?
107. Als het goed is was dat u net verteld. Die gaat keren en dan achteruit de west tak in
108. Nee okay

12:22 – 12:48 – VTSO & Nancy | Aanmelden + Verkeersbeeld + Manoeuvre

109. Sector Botlek, Nancy goedemiddag
110. Nancy Botlek goedemiddag
111. Opvarend aan de scheurkade en door naar de stad
112. Ja dat is begrepen, de Fiona S, kort aan de zuidoever voormalige hellingen, is bestemd voor scheurkade bestemd, die houdt hem dan aan de zuid. Uitvaart aan de Borax richting de Oude Maas. Correctie richting stad
113. Okidoki dan gaan wij een beetje midden opzoeken.

12:50 – 13:20 | VTSO & Denzo | Aanmelden + Verkeersbeeld

114. Sector Botlek de Denzo
115. Botlek geroepen?
116. Ja goedemiddag, Denzo in de afvaart, Delta Hotel. We zijn bestemd voor de Botlek in de centrale geul
117. Wat wordt uw bestemming in de centrale geul
118. Ja we zoeken een plekkie, het wordt maastank cargo of anders achterin op steigers
119. Ja sector Botlek dat is uh begrepen. Opvaart aan de scheurkade en uitvaart bijna aan de monding centrale geul die gaan beiden naar de stad
120. Okay over uit.

13:21 – 13:41 | VTSO & Aquisala | Aanmelden + Manoeuvre

121. Sector Botlek de Aquisala
122. Aquisala de sector Botlek over
123. Goedemiddag, van de BTT zuid naar de 3e Pet, west tak, voor de Bunga Lavender
124. Ja dat is begrepen. Nou die gaat zo meteen keren en dan zwaait die nog achteruit naar de Vopak 5.

125. Okay

13:42 – 14:02 | VTSO & Flava | Intentie + Verkeersbeeld

126. De Flava, sector Botlek.
127. Flava geroepen
128. Positief, goedemiddag wat wordt uw bestemming over?
129. Wij gaan de Oude Maas weer op
130. De Oude Maas dat is begrepen. Aan de overkant ter hoogte van boei 66 komt de Aquisala richting de 3e Petroleumhaven. Voor u dan nog graag een melding aan de Borax
131. Is goed

14:10 – 14:38 | Barones & Calandula 12 | Intenties

132. Barones, Calandula 12
133. Ja die luistert
134. Goeiendag buur, was u ook voor de Botlek
135. Nee wij gaan richting de stad
136. Oh u gaat richting stad. Mocht het zover komen dan laat ik hem over bakboord lopen, ik ben voor de Botlek
137. Geen probleem hoor, als u er nog zin in hebt dan laat maar gaan
138. Okay merci goede reis heee
139. Joeee

14:39 – 15:04 | VTSO & Charlotte | Aanmelden + Verkeersbeeld

140. De sector Botlek voor de Charlotte
141. Charlotte Botlek over
142. We komen van de welplaat 2 achteruit, en dan gaan we naar de monding richting de stad. Het waterbootje die heb ik al in de gaten die is al weg die zit achter mij, dus we komen nu achteruit
143. Ja dat is begrepen. Voor u dan nog tweemaal uitvarende binnenvaart dwars van de Chemiehaven, eerste in de opvaart en de tweede voor de 3e Pet bestemd
144. Jaaa daar ken ik nog wel voor langs

15:06 – 15:51 | Main 21 – Tristan | Intenties

145. Main 21 de Tristan
146. De Main 21
147. Tristan
148. De Tristan
149. Ja spreek ik met de Main 21
150. Ja klopt
151. Ja kan je bij ons langs zij komen, je hoeft alleen de auto af te zetten zeker?
152. Nee, nee hoor. Die jongens moeten even naar de auto toe, even wat uit de auto pakken en dan als ze weer terug zijn dan gaan we weer weg
153. Okay okay, kan je opzij komen dan, dan kunnen we gewoon blijven liggen
154. Ja hoor blijf maar liggen hoor ik kom gewoon ff bij jou langszij, dat is geen probleem
155. Okay goedendag Michel?
156. Hey hoe is het man
157. Ja prima met jou
158. Ff dubbel
159. Joe

15:52 – 16:09 | VTSO & Beghera | Aanmelden + Verkeersbeeld

160. Sector Botlek sector Botlek de Beghera
161. Ja de Beghera de sector Botlek over

162. Ja we komen de sector binnengevaren en we gaan in de opvaart naar de stad
163. Ja begrepen zeevaart voor u is voor de Oude Maas bestemd
164. Ja okay, bedankt

16:28 – 17:08 | VTSO & Iris 1 en Husky | Aanmelden + Verkeersbeeld + Manoeuvre

165. Sector Botlek de Iris 1
166. De Iris 1, Botlek goedemiddag over
167. Goedemiddag, die wil eerste Pet uitkomen en dan richting stad
168. Sector Botlek dat is begrepen, opvarende binnenvaart 500 meter beneden de monding en dan is de Husky nog bezig met egaliseren in monding van de 1e Pet
169. Ah okay, kan ik daar voor of achterlangs?
170. Dat ga ik even vragen. Husky Botlek?
171. Husky
172. Uitvaart eerste Pet richting stad, aan welke zijde kan die passeren?
173. Ja die kan ook gewoon aan de binnenkant passeren als dat mogelijk is.
174. Ja begrepen, Iris 1 mee gehoord?
175. Ja mee gehoord.

17:11 – 17:19 | VTSO & Maticaria? | Verkeersbeeld

176. En dan voor de Maticaria Botlek, uitvarende binnenvaart uit de 1e Petroleumhaven gaat richting de stad over.
177. Jaa geen probleem

17:20 – 20:18 | VTSO, Barones, Calandula 12, Denzo & Superiority | Aanmelden + Verkeersbeeld + Manoeuvre

178. Sector Botlek de Barones
179. Barones Botlek goede middag
180. Goedemiddag, uh afvaart Oude Maas we draaien richting stad
181. Ja begrepen. Nog tweemaal binnenvaart aan de Oude Maas boei, die zijn ook allebei doorgaand richting de stad. Uh correctie, driemaal binnenvaart.
182. Ja ontvangen. Dan varen we wel kort om het puntje naar boven
183. Ja begrepen. Calandula 12 Botlek.
184. Ja goedemiddag, wij draaien de Botlek in voor de 3e Petroleumhaven de Alu Gem
185. Voor de 3e Pet, dat is begrepen. Opvarende zeevaart 1000 meter beneden de monding van de Botlek die is dan voor de Oude Maas bestemd. De driemaal vaart voor de monding die zijn alle 3 doorgaand. In de afvaart aan de oost kop nog de binnenvaart Denzo, die is voor de centrale geul bestemd.
186. Sector Botlek nog even voor de Denzo, die opvarende Spica die gaat ook naar boven? Want het lijkt erop dat hij de Oude Maas opdraait.
187. Ja ik zie hem nu ook naar binnen draaien maar we zitten nu met z'n allen door elkaar. Ik wil liever nu even de Calandula 12 nu gewoon even afhandelen. Calandula 12, heeft u alles meegekregen?
188. Ja die had het mee gehoord hoor. Ik doe even kalm aan en dan sowieso stuurboord-stuurboord met die binnenvaart en dan draai ik achter die zeevaart aan de Botlek in.
189. Ja u gaat achter de zeevaart langs, dat is begrepen. Voor de Denzo, sector Botlek. Die opvarende zeevaart die passeert u nu ongeveer aan de oostkop Botlek, u wilt na die Nancy gelijk oversteken eventueel stuurboord-stuurboord?
190. Ja dat zou ik graag afspreken ja
191. Ja begrepen. De Superiority Botlek over.
192. Botlek Superiority
193. Voor u een tegenliggende binnenvaart op een 1700 meter, die is voor de Botlek bestemd, die verzoekt dan met u stuurboord-stuurboord. Tweemaal uitkomende binnenvaart uit de Oude Maas, de eerste draait kort om de kant richting de stad, vlak daarachter de Calandula 12 die is voor de Botlek 3e Pet bestemd, die gaat dan achter u langs.

194. Die gaat dan achter mij langs, dus dan stuurboord-stuurboord met die Calandula?
195. Nee die gaat achter u langs dus dat wordt dan een normale passage. Dan draait die uh bakboord-bakboord met u en dan achter u langs de Botlek in.
196. Ja okay dat is begrepen van de Superiority. Normale passage met de calandula en stuurboord-stuurboord met de Denzo.
197. Ja dankjewel. Voor de Denzo, met die tegenliggende zeevaart stuurboord-stuurboord akkoord, eerste uitvarende binnenvaart zit aan de Borax en dan zie ik nog een waterboot maar die schiet dan waarschijnlijk nog voor uw langs de Geulhaven in.
198. Okay bedankt.
199. Calandula 12, u heeft ook alles meegekregen?
200. Ja die heeft alles meegekregen hoor. Ik kan desnoods ook kort over de dam draaien dat ik ook stuurboord-stuurboord maak met die zeevaart, als dat misschien makkelijker is?
201. Ja dat is ook goed. Uh de Superiority, dan die uitvaart Oude Maas die gaat dan kort om en dan naar binnen en dan maakt die wel stuurboord-stuurboord met u. Daarachter alles vrij.
202. Calandula ook stuurboord-stuurboord, begrepen
203. Voor de Calandula 12 dan met de opvarende zeevaart stuurboord-stuurboord akkoord
204. Prima dank u.

20:19 – 21:06 | VTSO, Trivels | Aanmelden + Verkeersbeeld

205. Sector Botlek, de Trivels. Over.
206. Trivels, sector Botlek over
207. Ja goedemiddag, Trivels in de afvaart onder Delta Hotel. Bestemd voor de Oude Maas voor de 2e containersteiger
208. Sector Botlek dat is begrepen. Nog tweemaal uitvaart Oude Maas, de eerste draait al richting de stad, de tweede kort daaronder richting de Botlek, dan tegenliggende zeevaart die zit dan een 1100 meter beneden monding Oude Maas, die is voor Oude Maas bestemd. Pleziervaart erachter door richting stad.
209. Ja dan wacht ik zeevaart nog even af, en die pleziervaart en dan daarna wil ik graag kijken of ik kan verder varen
210. Ja met de huidige koers en vaart passeert u de pleziervaart aan de oost kop Oude Maas

21:09 – 22:35 | VTSO, Flava, Charlotte, Calandula 12 | Aanmelden + Verkeersbeeld + Manoeuvre

211. Sector Botlek dit is de Flava aan de Borax en we willen de Oude Maas op
212. Ja de Flava sector Botlek dat is begrepen. Euhm.. de binnenvaart voor u draait dan richting stad, voor u binnenvaart aan de dam Geulhaven die is voor de derde Pet bestemd. Varende zeevaart dwars monding Botlek voor de Oude Maas
213. Okay
214. Flava Botlek
215. Ja Flava
216. Opvaart aan de dam Geulhaven voor de 3e Petroleumhaven bestemd voor uhh correctie die is voor de centrale geul bestemd. En de opvarende zeevaart dwarsmonding Botlek, die is voor de Oude Maas. Uitvarende binnenvaart uit de monding Oude Maas die is voor de Petroleumhaven bestemd.
217. Gewoon normale passage zeker?
218. Uhh ja met de eerste normale passage. Die uit de Oude Maas voor de 3e Pet blijft onder de dam dus dat wordt dan stuurboord-stuurboord.
219. Okay
220. Voor de Charlotte ook meegekregen die eerste dan bakboord-bakboord die Denzo en die tweede dan stuurboord-stuurboord, die calandula. En die zeevaart waar ging die heen, die Superiority?
221. Die is zo voor de Oude Maas bestemd

222. Okay voor de Oude Maas, dan houden we hem er even achter en anders ga ik er wel bakboord voorbij.

223. Ja dank u wel. Voor de Calandula 12 Botlek, dan 2 maal uitvaart monding centrale geul Botlek maken beide stuurboord-stuurboord met u. Eerste richting stad, tweede richting Oude Maas.

224. Tweemaal stuurboord-stuurboord centrale geul, Ja hoor.

22:35 – 23:00 | VTSO & Odessy | Aanmelden + Verkeersbeeld

225. Sector Botlek, Odessy

226. Odessy Botlek over

227. Nou wij komen weg van de steiger, binnenkant steiger 10 bij de Koole Botlek en gaan richting Chemiehaven.

228. Ja dat is begrepen. Binnenvaart aan de Borax is dan nog voor de 3e Petroleumhaven bestemd en dan graag een melding aan de monding, er is nog binnenvaart aan de zwaaikom, die is voor de west tak bestemd over.

229. Ja okay begrepen.

23:01 – 23:21 | VTSO & Richel | Aanmelden

230. Botlek, Richel

231. Richel sector Botlek over

232. Van de Meyla, naar de Eemhaven 4

233. En waar ligt die Meyla?

234. Helemaal achterin in de centrale geul

235. Ja ik zie u komen, dan graag een melding aan de Borax.

236. Ja voor mekaar.

23:20 – 23:33 | VTSO & Jacobina |Intenties + Verkeersbeeld

237. De Jacobina, de Botlek over

238. Goedemiddag

239. Goedemiddag Jacobina, wat wordt uw bestemming?

240. Richting Breediep

241. Dat is begrepen, binnenvaart voor u straks voor de Oude Maas bestemd

242. Ontvangen

23:37 – 24:12 | VTSO & Trivels | Verkeersbeeld + Manoeuvre

243. De Trivels sector Botlek over

244. Sector Botlek, Trivels hier

245. Voor u, achter die pleziervaart door richting stad nog 2 maal binnenvaart uit de monding Botlek, eerste richting stad, dat is de Charlotte, daarachter de Flava, ook voor de Oude Maas bestemd.

246. Ja, ja doe maar met die Charlotte bakboord-bakboord en die Flava… …….. (geen idee (duits))

247. Ja u wacht die Charlotte ook nog af?

248. Ja ik wacht die Charlotte ook nog af. Ik vaar erg langzaam dus we kunnen gewoon bak-bak doen.

249. Ja begrepen.

24:20 – 24:27 | VTSO & Aquisala | Verkeersbeeld

250. Voor de Aquisala voor u, de eerste uitvaart zit nog aan de Koole 10, komt zo naar buiten voor de Chemiehaven

251. Ja okay.

24:31 – 25:14 | VTSO & Alarmis | Aanmelden + Verkeersbeeld

252. Botlek Alarmis
253. Sector Botlek over
254. Goedemiddag, uit de eerste Pet, via de zuid naar de Oude Maas
255. Ja voor de Oude Maas bestemd, dat is begrepen. Voorlopig nog uhh binnenvaart, een 200 meter beneden de monding en pleziervaart dwarsmonding Oude Maas, die gaan dan door richting stad. En dan nog binnenvaart die komt nu de monding van de Botlek uit, die gaat ook richting de stad.
256. Ja okay, ja die opvaart beneden de 1e Pet die is al weg he, als wij er zijn
257. Ja die eerste wel in ieder geval na die pleziervaart, die heeft er nogal goed de gang in.
258. Ja okay, naja we zien het zo wel even
259. Stand-by

25:23 - 25:40 | VTSO, Aquisala & Calandula 12 | Verkeersbeeld

260. En dan voor de Aquisala, die Calandula 12 aan de autosteiger die is dan ook voor de 3e Pet bestemd
261. Had ik meegekregen
262. Dank u. Calandula 12, de Aquisala aan de monding centrale geul, voor de 3e Pet.
263. Ja Calandula 12 meegekregen

25:42 – 25:50 |? & Erik | Overig

264. Bon voyage
265. Ja van hetzelfde Erik

26:54 – 27:09 | VTSO & Matrio…? | Manoeuvre + Afmelden

266. Sector Botlek, Matrio….
267. Sector Botlek over
268. Ja wij halen die Barones in en dan gaan we over naar de volgende sector
269. Ja begrepen
270. Yes bedankt, dan groet ik u af

27:31 – 28:05 | VTSO, Alarmis & Charlotte | Manoeuvre

271. Botlek de Alarmis
272. De Alarmis, Botlek
273. Uh kan ik met die Charlotte dan stuurboord-stuurboord doen
274. Ja hoor geen probleem met die Charlotte, stuurboord-stuurboord.
275. Een vraag Charlotte, uitvaart eerste Pet voor de Oude Maas die wil dan aan de zuid blijven.
276. Ja ik had al gezegd dat dat goed was. Uhh stuurboord-stuurboord met die uitvaart uit de eerste Pet, geen probleem.
277. Dank u vriendelijk. Nou Alarmis dan stuurboord-stuurboord akkoord en dan voorlopig geen uitvaart uit de Oude Maas
278. Ja okay hoor bedankt.

28:06 – 28:24 | VTSO & Main 21 | Aanmelden + Verkeersbeeld

279. Botlek Main 21
280. Main 21, sector Botlek goedemiddag
281. Goedemiddag, wij vertrekken weer bij de autosteiger en gaan naar de 2e Werkhaven
282. Voor de 2e Werkhaven, dat is begrepen. Voorlopig zit de eerste uitvaart nog aan de Welplaathaven.
283. Okay

28:26 – 28:49 | VTSO & Cansu Y | Aanmelden + Verkeersbeeld

284. Sector Botlek, Cansu Y, over.
285. Cansu Y, sector Botlek, goedemiddag
286. Sector Botlek, de Cansu Y. Die is opvarend in de werkzaamheden bestemd voor de centrale geul en later BTT noord, over.
287. Voor de BTT, stand-by, Ik heb die vaart voor u nog niet gehoord, de Honte.
288. Daar blijf ik in ieder geval nog wel achter

28:51 – 28:58 | VTSO & Pictor Aanmelden

289. Botlek goedemiddag, de Pictor daarachter, voor de stad.
290. Ja Pictor, Botlek goedemiddag, begrepen. Uit.

29:02 – 29:45 | VTSO, Honte & Cansu Y | Aanmelden + Verkeersbeeld + Manoeuvre

291. Sector Botlek, voor de Honte
292. Sector Botlek over
293. Ja dit is de Honte. We zijn hier opvarend, even aan het bunkeren en dan gaan wij straks door naar de stad met en de bunkerboot als het goed is en dan de Botlek in
294. Ja dat is begrepen, voor u zitten dan zeevaart aan de tunnelwerkzaamheden, die is voor de Botlek bestemd. Over
295. Ja dat is meegekregen. Zal maar zeggen ze mogen mij aan alle kanten voorbij
296. Ja begrepen. Cansu Y sector Botlek, mee gehoord?
297. Sector Botlek, de Cansu Y, Ja meegeluisterd. Als meneer wat meer naar de oever kan dan ga ik hem wel via de noord voorbij.
298. Ja begrepen, Honte meegekregen?
299. Ja ik ga naar stuurboord proberen te komen
300. Dank u wel

30:28 - 31:20 | VTSO, Main 21 & Richel | Verkeersbeeld + Manoeuvre

301. Uh Botlek, de Main 21
302. Main 21, Botlek
303. Met die uitvaart aan de Borax, is het makkelijker om stuurboord-stuurboord te doen, want dan heb ik wel even tijd nodig om over te lopen
304. Ja dat is begrepen. Richel Botlek
305. Richel luistert
306. Ja binnenvaart net losgekomen bij de auto steiger, die uh doet er wat langer over om gang te maken en over te steken, die verzoekt om stuurboord-stuurboord met u, die gaat zo de centrale geul in
307. Komt er nog invaart de Botlek in?
308. Nou de eerste zit nu een 2 kilometer beneden de monding, dat is zeevaart, die is voor de Botlek bestem. Zit dan nog wat binnenvaart aan de scheurkade maar die komt langzaam door, die is nog aan het bunkeren.
309. Ja dat is begrepen dan gaan we er nog een beetje gang bijmaken zodat wij ook voor die zeevaart eruit zijn
310. Ik dank u vriendelijk. Main 21, mee gehoord? Stuurboord-Stuurboord akkoord
311. Okay dank u wel

31:30 – 32:25 | VTSO, Honte & Cansu Y | Verkeersbeeld + Manoeuvre

312. Sector Botlek voor de Honte
313. Honte, Botlek
314. Ja was dat de eerste zeevaart die de Botlek in moest achter me?
315. Ja dat is de eerste zeevaart, de tweede zeevaart die is doorgaand richting Eemhaven
316. Okay en die eerste zeevaart, komt die er zo gemakkelijk voorbij of is het misschien makkelijker als ik gas bijgeef en dat ik ervoor blijf?
317. De Cansu Y, Botlek

318. Sector Botlek, ja ik weet niet hoeveel gas die kan geven met die bunkerboot opzij maar timing-technisch komt het niet zo lekker uit, dan is het beter als die doorvaart dan blijf ik er wel achter.
319. Ja begrepen, Hansa, of de Honte meegekregen?
320. Ja hoor. Ja zachter kan ik niet dus het is alleen harder, dus wat voor de zeevaart het beste uitkomt.
321. Nou die heeft net aangegeven dat het beter uitkomt als u wat harder door kan varen en dan blijft die achter u.
322. Ja dan gaan we nog even gas bijgeven
323. Ja dankjewel,
324. Cansu Y meegekregen?
325. Meegekregen hoor!

32:26 - 32:54 | VTSO & Grote Stern | Aanmelden + Verkeersbeeld
326. Sector Botlek, de Grote Stern. Goedemiddag
327. De Grote Stern, Botlek
328. Ja goedemiddag, dwars van de kattenbak en bestemd voor de Oude Maas
329. De Grote Stern, ja dat is begrepen. Voorlopig geen tegenliggende vaart geen uitvaart uit de Oude Maas. Die Achar B is nog bezig met baggerwerkzaamheden
330. Ja dat is meegekregen, dank u

32:54 – 33:17 | VTSO & Odessy | Aanmelden + Verkeersbeeld
331. Sector Botlek, de Odessy
332. Sector Botlek over
333. In de monding 3e Pet, richting Chemiehaven
334. Ja Botlek, begrepen. Uitvarende binnenvaart de Borax gepasseerd die draait zo in de opvaart richting stad. En dan aan de west kop, de Main 21. Die is nu gang aan het maken en die duikt dan de 2e Werkhaven in.
335. Ja okay begrepen.

33:18 – 33:44 | VTSO & De Lady Hestia | Aanmelden + Verkeersbeeld
336. Sector Botlek, de Lady Hestia. Over.
337. De Lady Hestia sector Botlek. Goedemiddag.
338. Goedemiddag de Lady Hestia die is opvarend tunnelwerkzaamheden voor de Oude Maas over.
339. Ja begrepen. Binnenvaart, of correctie zeevaart voor u die is doorgaand richting Eemhaven, en daarvoor weer zeevaart de Cansu Y voor de Botlek bestemd. Die blijft achter de binnenvaart voor hem, aan de scheurkade, die is toch bezig met bunkerwerkzaamheden.
340. Begrepen.

34:40 – 34:55 | VTSO & Disponibel | Aanmelden
341. Botlek, de Disponibel
342. Sector Botlek over
343. Disponibel. Delta Hotel voorbij en dan door lager uit
344. De Disponibel, sector Botlek. Dat is begrepen!

34:56 – 35:20 | VTSO & Invotus 7 | Aanmelden + Verkeersbeeld
345. Sector Botlek de invotus 7
346. Invotus 7 Botlek over
347. Afarend KW-haven Vlaardingen voor de eerste Pet
348. Ja dat is begrepen. Binnenvaart voor u nog niet gehoord. Dan nu egaliseerwerkzaamheden dwars van de monding eerste Pet, geen uitvaart en voorlopig geen tegenliggende vaart.

349. Dat is begrepen hoor, bedankt.

35:23 – 36:03 | VTSO & Aloha | Aanmelden + Verkeersbeeld

350. Sector Botlek de Aloha
351. Aloha Botlek over
352. We vertrekken uh eerste Pet Koole 5 overstuur de rivier op gaan rivier zuid tussen de steiger vandaan aansluiten voor de Oude Maas
353. Ja dat is begrepen. Nou voor u de eerste opvaart dwars van de monding, of uh in de monding Botlek die draait dan richting de stad en dan in de afvaart, de Invotus 7 voor de eerste Pet bestemd. Dwars van de monding eerste Petroleumhaven en aan de west kop als ik het goed heb nog werkzaamheden
354. Ja die zie ik dat is achter me

36:07 – 36:33 | VTSO, Stolt Shearwater & Invotus 7 | Aanmelden + Verkeersbeeld +

355. Sector Botlek de Stolt Shearwater goedemiddag, op vertrek in de eerste Pet Koole 2 naar zee over.
356. De Stolt Shearwater, de sector Botlek dat is begrepen. Graag een melding als u loskomt.
357. Stolt Shearwater, begrepen.
358. En voor de Invotus 7 sector Botlek, er is nog zeevaart op vertrek gemeld bij de Koole 2, nog niet los.
359. Ja dat heb ik meegekregen, bedankt!

36:35 – 36:51 | VTSO & Pictor | Verkeersbeeld

360. Pictor, Botlek. Mee gehoord?
361. Pictor geroepen?
362. Ja positief, voor u alvast uh zeevaart net op vertrek gemeld Koole 2, nog niet los.
363. Koole 2 op vertrek, aye aye

36:57 – 37:28 | VTSO, Main 21 & Odessy | Aanmelden + Verkeersbeeld

364. Uh Botlek, De Main 21
365. Main 21 Botlek
366. Zo voor de 2e Werkhaven over stuurboord rond, en dan achteruit de 2e Werkhaven in naar 75.
367. Oke begrepen u gaat naar 75.
368. De Odessy, Botlek. U had het meegekregen van die binnenvaart voor u?
369. Nee niet helemaal
370. Main 21 die gaat keren voor de monding van de 2e Werkhaven en dan achteruit naar de STR 75.
371. Ja okay anders doe ik wel rustig aan hoor, dan is die voor me weg.
372. Begrepen

37:39 - 37:54 | Invotus 7 & Husky | Manoeuvre

373. Husky voor de invotus 7
374. Ja Husky
375. Ja waar kan ik u het beste voorbijgaan?
376. Ja ik ga nu weer een beetje vooruit dus je kan wel achterlangs kort om het hoekie naar binnen
377. Ja doen we bedankt.

37:55 – 38:10 | VTSO & Waterboot 12 | Aanmelden + Verkeersbeeld

378. Sector Botlek voor de Waterboot 12
379. Waterboot 12, Botlek over.

380. Vanuit de Geulhaven naar de 2e Werkhaven
381. Naar de 2e Werkhaven dat is begrepen. Er is geen uitvaart centrale geul
382. Begrepen, stand-by.

38:18 – 41:14| VTSO, Variska, Pictor, Aloha, Octopus & Cansu Y | Aanmelden + Verkeersbeeld + Manoeuvre

383. Variska Botlek
384. Daar is tie, zo meteen voor de Oude Maas.
385. U bent voor de Oude Maas, goedemiddag dat is begrepen. Eerste vaart die u gaat tegenkomen is dan tegenliggende zeevaart op een 1800 meter beneden monding Oude Maas, dat is de Pictor MID-vaarwaters die komt u dwars van de monding tegen. En zuid daarvan zit dan nog de binnenvaart Honte, die komt dan rustig door met de SPA1 langszij, die zou u net voor weg zijn.
386. Zal ik anders zo meteen achter die Richel langs even helemaal naar de verkeerde kant toe kruipen dan moet ik ruimte genoeg hebben dacht ik.
387. Ja dat is begrepen. Binnenvaart die u uit de 1e Pet ziet komen die gaat dan zo met u mee richting de Oude Maas en de eerste uitvaart is net de Botlekbrug gepasseerd, nog niet gehoord.
388. Dat is begrepen
389. De Pictor sector Botlek
390. De Pictor
391. Sector Botlek, voor u de 2e en 3e tegenliggende vaart op een 2800 meter zijn beide voor de Oude Maas bestemd. De Aloha komt dan net uit de 1e Petroleumhaven. Noord daarvan de Variska verzoekt alvast stuurboord-stuurboord met u?
392. Ja dat is prima, stuurboord-stuurboord
393. Dankuwel. De Aloha Botlek over.
394. Roept u maar,
395. De Aloha, sector Botlek. Aan de noordzijde van u, de Variska is ook voor de Oude Maas bestemd. Die heeft alvast een afspraak met de opvarende zeevaart 1500 meter beneden de monding van de Oude Maas, die maakt daar stuurboord-stuurboord mee. Eerste uitvaart zit nu binnen 1800 meter beneden monding Oude Maas, nog niet gehoord.
396. Ja hoor dan sluiten we gelijk bij hem aan.
397. Ja begrepen uit.
398. Sector Botlek de eerste uitvaart is de Octopus en die gaat straks richting Maasluis.
399. De Octopus, sector Botlek dat is begrepen. Er zit dan tweemaal afvaart 800 meter boven de monding van de Oude Maas, die zijn voor de Oude Maas bestemd en driemaal opvaart. De eerste is binnenvaart die komt langzaam, een 1100 meter beneden de monding. Op 1200 meter beneden de monding nog zeevaart, die zijn dan doorgaand. Nog zeevaart aan de scheurkade, voor de Oude Maas bestemd.
400. Ja okay we kijken nog wel even, die binnenvaart boven de Oude Maas die zijn al allang binnen neem ik aan?
401. Ja eentje moet nog keren, die sluit bij de eerste aan. Uuhh en met de huidige koers en vaart zal die eerste nog voor u weg zijn inderdaad.
402. Ja okay. Nou anders dan houden we het in de gaten, doen we de tweede stuurboord-stuurboord.
403. Ja begrepen, stand-by
404. Variska, Botlek mee gehoord?
405. Ja meegekregen, ik hou zo meteen wel even wat ruimte hoor, volgens mij moet ik op tijd weg zijn voor de opvaart voor de rest dus dan zal ik wat ruimte maken
406. Dank u wel.
407. En dan voor de Cansu Y, sector Botlek, er is geen uitvaart uit de centrale geul Botlek. Over
408. Botlek Cansu Y, begrepen.

41:26 – 41:42 | VTSO & Chemical Provider | Aanmelden + Verkeersbeeld

409. Botlek, de Chemical Provider, binnenkomend voor de eerste Pet en een uh goeiemorgen
410. Chemical Provider sector Botlek goedemiddag, dat is begrepen. Zeevaart op de Koole 2, eerste Petroleumhaven op vertrek gemeld nog niet los.

41:50 - 42:05 | VTSO & Anvisa 2 | Aanmelden

411. Sector Botlek voor die Anvisa 2.
412. Anvisa 2, sector Botlek over.
413. Ja die Anvisa 2 vaart uit de ??? en dan achterwaarts uit, stuurboord om en dan richting Geulhaven. (Of zoiets)
414. Voor de Geulhaven bestemd, begrepen stand-by.
415. Joo.

42:54 – 45:00 | VTSO, Aloha, Lady Hestia, Acher B, Honte & Octopus | Verkeersbeeld + Manoeuvre

416. De Aloha sector Botlek over
417. Roept u maar
418. Ja die uitvarende binnenvaart zit nu een 1100 meter binnen de monding van de Oude Maas en die gaat in de afvaart uhhh houdige koers en vaart zullen jullie elkaar passeren aan de oost kop, wilt u daar ook een afspraak mee?
419. Ja hoor doe maar stuurboord-stuurboord
420. Ja begrepen
421. De Lady Hestia, Botlek over?
422. Botlek, Lady Hestia
423. Ja voor uw informatie, het is dan 2 maal tegenliggende vaart aan de REKO kade, die zijn beide voor de Oude Maas bestemd en eenmaal uitvarende binnenvaart 1000 meter binnen monding Oude Maas, die is voor de afvaart bestemd. De tweede tegenligger maakt daar stuurboord-stuurboord mee, de eerste is daar nog voor weg.
424. Ja begrepen
425. En dan ik weet niet of u het al kan zien maar de Acher B ten oosten van de Oude Maas boei 1 te baggeren. U heeft dan zo meteen genoeg ruimte met passage uitvaart?
426. Uhh ja dat denk ik wel over
427. Ja dat is begrepen
428. De Acher B, sector Botlek over
429. Ja die luistert
430. Ja voor u die tweemaal afvaart aan de Reko kade voor de Oude Maas uitvaart Oude Maas die gaat in de afvaart, en in de opvaart dan nog zeevaart, die komt dan weer de Oude Maas in.
431. Okay
432. De Honte Botlek over
433. Honte geroepen
434. Ja positief, nog uitvarende binnenvaart in een 700 meter binnen de monding van de Oude Maas, die gaat dan in de afvaart
435. Ja volgens mij zit ik al best een end in het midden he?
436. Ja maar er zit ook nog tweemaal tegenliggende zeevaart achter u, dat u in ieder geval vanaf weet.
437. Ah okay, ik zal nog een beetje naar bakboord gaan.
438. Ik dank u vriendelijk.
439. Voor de Octopus, Botlek
440. Ja de Octopus meegeluisterd
441. Ja de binnenvaart zit tussen de tweemaal zeevaart in en die zoekt nog wat meer de bakboord vaarwater op voor u.
442. Ja okay dankjewel. En de tweede daar doe ik nu stuurboord-stuurboord mee he die van boven komt?

443. Ja de 2e afvaart stuurboord-stuurboord en dan een normale passage met die opvarende zeevaart aan de Botlek, die draait dan ook de Oude Maas in
444. Ja begrepen dan is alles klaar, bedankt.

45:00 – 46:28 | VTSO, Grote Stern, Stolt Shearwater, Pictor, Honte & Chemical Provider | Aanmelden + Verkeersbeeld + Manoeuvre

445. Botlek de Grote Stern
446. Grote Stern, stand-by
447. Sector Botlek, de Stolt Shearwater, 1e Pet zit in de monding voor lager uit. Over.
448. Ja sector Botlek, begrepen. De eerste opvaart is dan de zeevaart Pictor, een 700 meter beneden de monding van de eerste Pet, door richting Eemhaven. En binnenvaart op een 1500 meter beneden de monding van de eerste Petroleumhaven, die is dan doorgaand richting stad en loopt op dit moment nog een vijf en een halve knoop.
449. Ja dat heeft die stolt shearer meegekregen. Stuurboord-stuurboord met die eerste zeevaart en dan met die binnenvaart kijken we even aan.
450. Ja, ja die zit wel al MID-vaarwater dus in verband nog stuurboord-stuurboord afspraak uitvaart Oude Maas.
451. Ja in dat geval ook nog stuurboord-stuurboord met die binnenvaart
452. Ja begrepen, dan daarachter is het voorlopig vrij voor u.
453. Voor de Pictor Botlek over
454. Pictor meegeluisterd hoor, stuurboord-stuurboord met die uitvaart eerste Pet
455. Dank u vriendelijk. Honte sector Botlek over
456. Hi, stuurboord-stuurboord met die uitvaart eerste Pet
457. Ja positief, positief, die gaat in de afvaart. Dank u wel.
458. Voor de Stolt Shearwater voor u dan tweemaal stuurboord-stuurboord akkoord.
459. Stolt Shearwater meegekregen, bedankt voor de medewerking.
460. Voor de Chemical Provider, sector Botlek, dan is de uitvaart eerste Petroleumhaven varende en die gaat dan gelijk in de afvaart u gaat binnenkeer?
461. Dat is correct.
462. Ja begrepen dank u.

46:34 – 46:54 | VTSO & Zilvermeeuw | Aanmelden + Verkeersbeeld

463. Botlek de Zilvermeeuw
464. De Zilvermeeuw Botlek over
465. Ja wij hebben de Borax gepasseerd, we zijn bijna in de monding en dan gaan we richting de Oude Maas
466. Ja sector Botlek dat is begrepen, de invarende zeevaart die grondt verder de centrale geul in en dan is de eerste opvaart zeevaart 1500 meter beneden monding Botlek, doorgaand.
467. Ontvangen.

46:57 – 47:10 | Waterboot & Main 21 | Intenties

468. Main 21 voor de waterboot
469. Joooo, zegt u het maar
470. Wat wordt uw bestemming
471. De Boper Voyer?
472. Dat is mooi, wij ook
473. Dat is gezellig

47:16 – 47:35 | VTSO & Kieviet | Aanmelden + Verkeersbeeld + Manoeuvre

474. Sector Botlek, Kieviet
475. Kieviet, Botlek. Over.
476. Komen los aan de binnenkant bij Koole, 1e Petroleumhaven, willen in de opvaart.

477. Ja, verzoek dan even te wachten komt zeevaart uit de eerste Petroleumhaven, die gaat in de afvaart. Die houdt hem voorlopig even aan de zuid.
478. Ja ik zie het koppie doorkomen

47:47 – 47:52 | Stolt Shearwater & Husky | Overig
479. Husky, bedankt van die Stolt Shearwater, fijne dag verder
480. Graag gedaan en dankje

48:32 – 49:15 | VTSO, SPA1 & Stolt Shearwater | Aanmelden + Verkeersbeeld
481. Sector Botlek, de SPA1 is losgekomen van de Honte, en die gaat dan rond over stuurboord en dan naar de Welplaathaven
482. Ja dat is begrepen. Douane vaart uit de monding Botlek die gaat de Oude Maas in en opvarende zeevaart aan de scheurkade die is doorgaand richting de 1e Petroleumhaven. Ehh de zeevaart uit de eerste Petroleumhaven gaat dan door in de afvaart richting zee.
483. Ja hoor, bedankt.
484. Voor de Stolt Shearwater, bunkerboot is losgekomen bij die tegenliggende binnenvaart en die duikt dan de Botlek in.
485. Stolt Shearwater begrepen.
486. En u wou nog voorlangs die opvarende zeevaart aan de Scheurkade he SPA1?
487. Ja hoor dan ga ik na de douanevaart nog even richting de dam
488. Ja begrepen

50:08 – 50:45 | VTSO & Treembos 4 | Aanmelden + Verkeersbeeld
489. Sector Botlek Treembos 4 (?)
490. Sector Botlek over
491. Treembos 4, los in de monding 3e Pet, lager uit.
492. Waar zit u in de monding 3e Pet, want ik zie u nog niet bewegen?
493. Tegenover de Koolesteiger, LBC
494. Ja dat is begrepen. Nou voor dan nog uitvaart aan de Welplaathaven de duikt de Geulhaven in, zeevaart aan de voormalige Helingen die gaat door naar de eerste Pet en bunkerboot aan de dam Geulhaven voor de welplaat.
495. Ja hoor dank u wel.

50:57 – 51:20 | VTSO & Greta | Afmelden
496. Sector Botlek, de Greta
497. Sector Botlek over
498. Ja goedemiddag, ik wilde ff afmelden. We zijn klaar met de werkzaamheden, wij deden hier bodemonderzoek bij de het koppie van de 1e Petroleumhaven
499. Ja dat is begrepen, bedankt voor de melding
500. Jo graag gedaan!

51:23 – 52:02 | VTSO, Albatros & SPA 1 | Aanmelden + Verkeersbeeld
501. Sector Botlek Albatros
502. Albatros sector Botlek over
503. Goedemiddag, uit de kleine Geulhaven richting de Oude Maas
504. Ja Albatros, Botlek, dat is begrepen. Opvarende zeevaart dwarsmonding Botlek die is doorgaand, afvarende bunkerboot aan de dam Geulhaven voor de centrale geul bestemd. Dan komt er nog binnenvaart uit de 3e Pet, die gaat in de afvaart.
505. Meegekregen bedankt
506. SPA 1, Botlek, de Albatros die komt uit de kleine Geulhaven en die gaat in de opvaart
507. Ja begrepen hoor

52:03 – 53:12 | VTSO, Anvisa 2, Treembos 4 & Zeeland | Aanmelden + Verkeersbeeld + Manoeuvre

508. Sector Botlek, de Anvisa 2
509. De Anvisa 2, sector Botlek
510. Ja de Anvisa 2, we zitten aan de Borax en dan richting Geulhaven voor een ligplaats
511. Ja sector Botlek begrepen, er is nog eenmaal uitvaart uit de kleine Geulhaven, die draait in de opvaart, uitvarende binnenvaart 300 meter binnen de monding van de 3e Petroleumhaven voor de afvaart bestemd over.
512. Okay stand-by
513. Laat u die even voorgaan?
514. Wie bitte?
515. Die ausfahrt dritte Pet kann vor ihnen passieren?
516. Ja das ist mögelich, ich fahre ein bisschen langsam an, das ist gut.
517. Ja danke. Nou Treembos 4, die uitvaart aan de Borax doet het dan even rustig aan voor u, dan nog opvarende binnenvaart aan de scheurkade, niet gehoord over.
518. Okay stand-by
519. Zeeland, Botlek
520. Jaa ik kwam er niet tussen, wij zijn bestemd voor de 2e Werkhaven
521. Ja sector Botlek dat is begrepen. Voor u tweemaal uitvaart, de eerste monding 3e Pet, die gaat in de afvaart en uitvaart aan de Borax voor de Geulhaven bestemd
522. Ja allebei een normale passage hoor
523. Ja dank u wel. Voor de Treembos 4, dat komt mooi uit die opvaart aan de scheurkade voor de 2e Werkhaven
524. Ja hoor meegekregen

53:15 – 53:26 | VTSO & Fairplay 21 | Aanmelden + Verkeersbeeld
525. Sector Botlek de Fairplay 21, uit de west tak naar de eerste Werkhaven
526. De 21 naar de 1e, dat is begrepen. Geen invaart voor de 3e Pet.
527. Dank u

53:28 – 53:51 | VTSO & Ambiteux | Aanmelden + Verkeersbeeld
528. Sector Botlek de Ambiteux
529. Ambiteux, sector Botlek over
530. Afvarend over de Delta Hotel, en ik heb bestemming de Oude Maas.
531. U bet voor de Oude Maas bestemd, dat is begrepen. Tegenliggende zeevaart uh bijna aan de monding van de Oude Maas, die is doorgaand. Voorlopig geen uitvaart Oude Maas.
532. Begrepen bedankt.

53:52 – 54:35| VTSO, Main 9 & Holland Diving 1 | Aanmelden + Verkeersbeeld + Manoeuvre
533. Botlek Main 9
534. Main 9, Botlek over.
535. Aan de scheurkade, tweede Werkhaven.
536. Voor de tweede Werkhaven dat is begrepen, binnenvaart voor u ook voor de tweede Werkhaven bestemd over.
537. Ja okay hoor
538. Holland Diving 1 over
539. Holland Diving 1 luistert
540. Goedemiddag, wat wordt uw bestemming
541. Wij gaan door naar Vlaardingen
542. U gaat door naar Vlaardingen, dat is begrepen. Bunkerboot monding Botlek die is doorgaand richting de welplaat, tweemaal opvaart aan de scheurkade bij bestemd voor de 2e Werkhaven
543. Ja hoor, kunnen wij met die tweemaal opvaart aan de scheurkade stuurboord-stuurboord doen?

544. Uhhhh, nou ja als u gelijk oversteekt naar de eigen wal dan kunnen hun gewoon normaal naar binnen draaien.
545. Gaan we doen

55:25 – 55:43 | VTSO & Cansu Y | Aanmelden + Verkeersbeeld
546. Sector Botlek, de Cansu Y over.
547. Cansu Y, sector Botlek
548. Sector Botlek de Cansu Y gaat Leensvaart Laurenshaven over stuurboord zwaaien en dan overstuur naar de BTT Noord over.
549. Ja dat is begrepen, er is geen uitvaart achterin gemeld voor u.
550. Sector Botlek, Cansu Y, dat is begrepen.

56:15 – 56:40 | VTSO, Fairplay 21 & Zeeland | Verkeersbeeld
551. Voor de Fairplay 21, Botlek. Centrale geul is vrij, opvaart een 300 meter beneden de monding Botlek die draait dan naar binnen voor de 2e Werkhaven.
552. Ja de 21 hoort. Nou dan doe ik er een klapje bij en dan zijn wij weg.
553. Ja hoor begrepen dank je wel. Dan voor de Zeeland. Sleepboot uit de monding van de 3e Petroleumhaven schiet voor u langs naar de 1e Werkhaven over.
554. Ja okay hoor

56:46 – 57:12 | VTSO, Holland Diving 1 & Ambiteux | Verkeersbeeld + Manoeuvre
555. Voor de Holland Diving 1, de Botlek over
556. Holland Diving 1 luistert
557. Er is nog afvarende binnenvaart op 600 meter boven de Oude Maas, die is daarvoor bestemd, die verzoekt dan stuurboord-stuurboord over.
558. Ja stuurboord-stuurboord akkoord
559. Dankjewel. Voor de Ambiteux sector Botlek, uitvaart monding Botlek, richting stad mag u stuurboord-stuurboord mee varen. Geen uitvaart Oude Maas, over.
560. Ja Ambiteux meegekregen, stuurboord-stuurboord is goed.

57:42 – 57:49 | VTSO & Zeeland | Overig
561. Ja Zeeland ik denk dat je het ook al ziet maar die sleepboot trekt wel goede kuilen hoor
562. Ja komt wel goed hoor

58:53 – 59:13 | VTSO, Chemical Provider, Husky & Somnium | Verkeersbeeld
563. Voor Chemical Provider, sector Botlek, er is geen uitvaart eerste Pet gemeld, dan uh bij het achterschip, die in de zeevaart aan de Koole 1 wordt nog geëgaliseerd door de Husky.
564. Ja dank je wel
565. Sector Botlek, Somnium
566. Stand by. De Husky, Botlek. Zeevaart 400 meter beneden de monding 1e Pet, die draait dan naar binnen.
567. Ja Husky ontvangen
568. Somnium Botlek
569. Ja zitten afvarend beneden het Delta Hotel, en dan straks voor de Botlek achter in de centrale geul
570. Wat wordt de bestemming in de centrale geul?
571. Naar de wachtpalen achterin
572. U gaat naar de wachtpalen, dat is begrepen. Voor u nog tegenliggende binnenvaart aan de scheurkade, nog niet gehoord. Stand-by
573. Ja okay.

B2. Overview of content in Conversations

			Targets				
C	ToC	Observing vessel	T1	T2	T3	T4	T5
1	A	Sten Fjell					
1	TI	Sten Fjell	Bunga Lavender	Roeiers 52			
1	M	Sten Fjell	Roeiers 52				
2	A	Anversa					
2	TI	Anversa	Bunga Lavender	Sten Fjell			
3	A	Main 21					
3	TI	Main 21	Sten Fjell	Anversa			
3	M	Main 21	Sten Fjell				
4	M	Sten Fjell	Main 21				
5	A	Spica					
5	TI	Spica	Sten Fjell	Main 21	Anversa		
6	A	Valburg					
6	TI	Valburg	Bella Vita	Roeiers 52			
7	A	Eiltank 24					
7	TI	Eiltank 24	Sten Fjell				
8	A	Annabel					
9	A	Hydrovat 10					
9	TI	Hydrovat 10	Main 21	Sten Fjell			
10	M	Main 21	Roeiers 52				
11	A	Renata					
11	TI	Renata	Sten Fjell				
11	M	Renata	Sten Fjell				
12	A	Fiona					
12	TI	Fiona	Spica	Renata			
12	M	Fiona	Renata				
13	A	Superiority					
14	A	Eiltank					
14	M	Eiltank	Renata				
15	A	Spaarneplus					
16	A	Holland Diving 1					
17	I	VTSO	Main 21				
18	A	Bunga Lavender					
18	TI	Bunga Lavender	Anversa				
19	A	Annabel					
19	TI	Annabel	Renata	Nancy			

19	I	Anversa	Bunga Lavender				
20	A	Nancy					
20	TI	Nancy	Fiona	Annabel			
20	M	Nancy					
21	A	Denzo					
21	TI	Denzo	Nancy	Annabel			
22	A	Aquisala					
22	TI	Aquisala	Bunga Lavender				
23	I	VTSO	Flava				
23	TI	Flava	Aquisala				
24	I	Calandula 12	Barones				
24	M	Calandula 12	Barones				
25	A	Charlotte					
25	TI	Charlotte	Flava	Aquisala			
26	I	Tristan	Main 21				
27	A	Beghera					
27	TI	Beghara	Superiority				
28	A	Clean Seas 1					
28	TI	Clean Seas 1	Husky				
28	M	Clean Seas 1	Husky				
29	TI	Matricaria	Clean Seas				
30	A	Barones					
30	TI	Barones	Nancy	Annabel	Spica		
30	TI	Calandula 12	Superiority	Nancy	Annabel	Spica	Denzo
30	M	Calandula 12	Nancy				
30	M	Calandula 12	Annabel				
30	M	Calandula 12	Spica				
30	M	Calandula 12	Denzo				
30	M	Denzo	Superiority				
30	TI	Superiority	Denzo	Barones	Calandula 12		
30	M	Superiority	Calandula 12				
30	TI	Denzo	Charlotte	Waterbuffel			
31	A	Trivels					
31	TI	Trivels	Barones	Calandula 12	Superiority	Baghera	
32	A	Flava					
32	TI	Flava	Charlotte	Denzo	Superiority	Calandula 12	
32	M	Flava	Denzo				
32	M	Flava	Calandula 12				
32	M	Charlotte	Denzo				
32	M	Charlotte	Calandula 12				
32	M	Charlotte	Superiority				
33	A	Odessy					
33	TI	Odessy	Aquisala				

34	A	Richel					
35	I	VTSO	Jacobina				
35	TI	Jacobina	Trifels				
36	TI	Trivels	Charlotte	Flava			
36	M	Trivels	Charlotte				
36	M	Trivels	Flava				
37	TI	Aquisala	Odessy				
38	A	Calamus					
38	TI	Calamus	Barones	Baghera	Charlotte		
39	TI	Aquisala	Calandula 12				
39	TI	Calandula 12	Aquisala				
40	-						
41	Af	Matricaria					
41	M	Matricaria	Barones				
42	M	Calamus	Charlotte				
42	TI	Calamus	-				
43	A	Main 21					
43	TI	Main 21	Richel				
44	A	Cansu Y					
44	TI	Cansu Y	Honte				
45	A	Pictor					
46	A	Honte					
46	TI	Honte	Cansu Y				
46	M	Cansu Y	Honte				
47	M	Main 21	Richel				
47	TI	Richel	Cansu Y	Honte			
48	TI	Honte	Cansu Y	Pictor			
48	M	Honte	Cansu Y				
49	A	Grote Stern					
49	TI	Grote Stern	Achar B				
50	A	Odessy					
50	TI	Odessy	Richel	Main 21			
51	A	Lady Hestia					
51	TI	Lady Hestia	Pictor	Cansu Y	Honte		
52	A	Disponible					
53	A	Invotus 7					
53	TI	Invotus 7	Faryskar	Husky			
54	A	Aloha					
54	TI	Aloha	Richel	Invotus 7	Husky		
55	A	Stolt Shearwater					
55	TI	Invotus 7	Stolt Shearwater				
56	TI	Pictor	Stolt Shearwater				
57	A	Main 21					

57	TI	Odessy	Main 21				
57	M	Odessy	Main 21				
58	M	Invotus 7	Husky				
59	A	Waterboot 12					
59	TI	Waterboot 12	-				
60	TI	Faryskar	Pictor	Honte + SBH 1	Aloha	Octopus	
60	M	Faryskar	Richel				
60	TI	Pictor	Faryskar	Aloha			
60	M	Faryskar	Pictor				
60	TI	Aloha	Faryskar	Pictor	Octopus		
60	M	Aloha	Pictor				
60	A	Octopus					
60	TI	Octopus	Faryskar	Aloha	Honte	Pictor	Lady Hestia
60	M	Octopus	Faryskar				
60	TI	Cansu Y					
61	A	Chemical Providor					
61	TI	Chemical Providor	Stolt Shearwater				
62	A	Anvisa 2					
63	TI	Aloha	Octopus				
63	M	Aloha	Octopus				
63	TI	Lady Hestia	Faryskar	Aloha	Octopus	Acher B	
63	TI	Acher B	Faryskar	Aloha	Lady Hestia		
63	TI	Honte	Octopus	Lady Hestia	Chemical Provider		
63	M	Octopus	Lady Hestia				
64	A	Stolt Shearwater					
64	TI	Stolt Shearwater	Pictor	Honte			
64	M	Stolt Shearwater	Pictor				
64	M	Stolt Shearwater	Honte				
64	TI	Chemical Provider	Stolt Shearwater				
65	A	Zilvermeeuw					
65	TI	Zilvermeeuw	Cansu Y	Chemical Provider			
66	I	Waterboot	Main 21				
67	A	Kieviet					
67	TI	Kieviet	Stolt Shearwater				

67	M	Kieviet	Stolt Shearwater				
68	-						
69	A	SBH 1					
69	TI	SBH 1	Zilvermeeuw	Chemical Provider	SBH 1		
69	TI	Stolt Shearwater	SBH 1				
69	M	SBH 1	Chemical Provider				
70	A	Crane Barge 4					
70	TI	Crane Barge 4	Anvisa 2	Chemical Provider	SBH 1		
71	Af	Greta					
72	A	Albatros					
72	TI	Albatros	Chemical Provider	SBH 1	Crane Barge 4		
72	TI	SBH 1	Albatros				
73	A	Anvisa 2					
73	TI	Anvisa 2	Albatros	Crane Barge 4			
73	M	Anvisa 2	Crane Barge 4				
73	TI	Crane Barge 4	Anvisa 2	Zeeland			
73	A	Zeeland					
73	TI	Zeeland	Crane Barge 4	Anvisa 2			
73	M	Zeeland	Crane Barge 4				
74	A	Fairplay 21					
74	TI	Fairplay 21					
75	A	Ambitieux					
75	TI	Ambitieux	Chemical Provider				
76	A	Main 9					
76	TI	Main 9	Zeeland				
76	I	VTSO	Holland Diving				
76	TI	Holland Diving	SBH 1	Zeeland	Main 9		
76	M	Holland Diving	Zeeland				
76	M	Holland Diving	Main 9				
77	A	Cansu Y					
77	TI	Cansu Y					
78	TI	Fairplay	Zeeland				
78	M	Fairplay	Zeeland				
79	M	Holland Diving 1	Ambitieux				
79	TI	Ambitieux					
80	-						
81	TI	Chemical Providor	Husky				

81	TI	Husky	Chemical Provider				
81	A	Somnium					
81	TI	Somnium	Volharding 9				