The effects of anti terroristic measures on the traffic situation in the Port of Rotterdam

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THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

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Preface

This is the report of my Master Thesis with the title “The effects of anti terroristic measures on the traffic situation in the Port of Rotterdam”. This Master thesis is done as the final project for the Master Transport, Infrastructure and Logistics at the Technical University of Delft.

This research is carried out for ARCADIS Nederland B.V. for the division Mobility, department Traffic and Transportation, Advise group Strategy and Policy. In this report the effects of anti terroristic measures, which must be taken in case of a raised terroristic threat, on the traffic situation in the Port of Rotterdam are described and the negative effects are tried to minimize with mandatory reroutings.

First of all I would like to thank my Master Thesis commission. The formal chairman of the commission is Dr. Ir. Serge Hoogendoorn and my daily supervisors are Dr. Ir. Hans van Lint and Dr. Ir. John Baggen of the Technical University of Delft and Ir. Esther Heijink of ARCADIS. During this research, they give me valuable, critical and constructive advice.

Next to that I want to thank my family, especially my mother. She supports me during my entire study, especially the last four years and give me advise about everything, even over my master thesis. Also I want to thank my brother who checked this report on grammatical mistakes and my sister for her sociability during the project, especially the last few weeks!

At last I want to thank my father, who unfortunately can’t witness my graduation. His last wish for me motivated me during the last four years of my study and during my Master Thesis. That is why I want to dedicate this report to my father!
Summary

Since the terrorist attacks of 9/11 in 2001 port security is a hot item. Directly after the attacks on the World Trade Centre, the 22nd conference of the International Maritime Organization (IMO) was held (in November 2001). During this conference decisions are made to develop new measures to ensure the safety of ships, ports and terminals. Among other things the implemented measures contain the development of the International Ship and Port facilities Security code (ISPS code). This ISPS code uses three security levels. In case of a higher risk on a security incident the level will scaled up to an higher level. In that case port facilities must take extra security measures to resist terrorist attacks. Measures that will take at the entrances of the terminal could lead to extra congestion on the road network in the Port of Rotterdam. In this research the effects of anti terrorist measures that must be taken in case of a raised terrorist threat are studied with the following main research question:

What are the effects of the anti terrorist measures on the traffic situation on the road network around the Port of Rotterdam and how can the negative effects be minimized?

To answer this question several threat scenarios are developed. Per scenario the security measures that will be taken by the terminals and the Port of Rotterdam are described. Scenarios must be developed for two reasons. The first one is the diversity of possible threat situations, the second one the confidentiality of the information about the security measures. Before the scenarios can be developed a list with the most critical harbours of the Port of Rotterdam in respect with the traffic situation and the ISPS related terminals must be identified. The five harbours in the Port of Rotterdam are scored on seven criteria, like number of ISPS related terminals, amount of traffic that enters the harbour and the risk outlines of the terminals. These criteria are scored based on an area analysis, which exists of a description of the Port of Rotterdam and its harbours and a traffic analysis. The most critical harbour in the Port of Rotterdam is the Botlek which will be used to determine the effects of the anti terrorist measures that must be taken in case of a raised ISPS level for that harbour.

Different scenarios are developed for the Botlek harbour. In the first scenario all ISPS related terminals in the Botlek are threatened, in the second just one or a few and in the last terminal the Botlek tunnel is threatened. To determine the effects of the security measures each scenario is scored on three different criteria. The first one is the average delay on the road network in the Port of Rotterdam. This criterion is used as a network performance indicator. The other two criteria are travel time and congestion on the A15. Each scenario is scored for the morning peak and an off peak period.

To determine the effects of the security measures, all scenarios are simulated in the Microscopic traffic model Vissim. First the current situation is studied followed by all scenarios for the morning peak and off peak periods. By comparing the current situation with the scenarios, based on the criteria, the effects of the anti terroristic measures could be
identified. When these effects are clear, some mandatory reroutings are developed to decrease the negative effects.

The average delay of all vehicles will increases for each scenario during the morning peak and off peak period. The increase during the morning peak is much higher than during the off peak period. For both periods, the difference between the average delay of the current situation and all scenarios is significance. This means that the difference can be attributed to the extra anti terroristic measures with a reliability of 95%.

The congestion during the morning peak on the A15 around the Botlek harbour increases in most of the scenarios. These congestions are caused by the waiting queue before the threatened terminals that reaches the A15. The longest traffic jam occurs during a threat on the Botlektunnel, followed by the threat on all terminals in the Botlek. The difference between the congestion in the current situation and the scenarios are all significance. During the off peak period no congestion will occur.

The last criterion is the travel time between the beginning of the Port of Rotterdam and the Maasvlakte. As a result of the congestion that occurs, also the travel time will increases significantly. Another reason of the increase of the travel time is the lower speed on the A15, which is a result of the terroristic threat. The increase of the travel time during the morning peak is much higher than during the off peak period.

For scenario 1, when all ISPS terminals in the Botlek are threatened two possible mandatory reroutings are introduced to decrease the negative effects of the anti terroristic measures. Both reroutings decreases the negative effects. During rerouting 1 (where traffic to the Botlek must take an earlier off ramp) the extra congestion occurs much later than in the situation without rerouting and during rerouting 2 (where the traffic to the Botlek must take a later off ramp) no extra congestion occurs.

There can be concluded that during a terroristic threat on the Botlek a lot negative effects occur. Congestion on the A15 occurs very quickly and the length of this congestion will increase enormously. This results in a longer travel time between the beginning of the Port of Rotterdam and the Maasvlakte and more delay for the traffic. Mandatory reroutings can decrease the negative external effects. It is necessary to develop these reroutings for all scenarios, also for the other harbours in the Port of Rotterdam.
Samenvatting

Sinds de aanslagen van 9/11 in 2001 haven beveiliging een belangrijk onderwerp. Direct na de aanslagen op het World Trade Centre is de 22e conferentie van de Internationale Maritieme Organisatie (ISO) gehouden (in november 2001). Tijdens deze conferentie zijn beslissingen genomen om nieuwe maatregelen te treffen om de veiligheid van schepen, havens en terminals te garanderen. Deze maatregelen bevat onder andere de ontwikkeling van de International Ship and Port facilities Security code (ISPS code). De code bestaat uit drie security niveaus. In het geval van een verhoogd risico op een security incident het niveau zal opgeschaald worden naar een hoger level. In dat geval moeten terminals extra security maatregelen treffen om de terroristische aanslag te voorkomen. De maatregelen die bij de ingang van een terminal genomen worden kunnen tot extra congestie leiden op het wegennet van de Rotterdamse haven. In dit onderzoek worden de effecten van anti terroristische maatregelen die moeten worden genomen ten tijde van een terroristische dreiging onderzocht met de volgende onderzoeksvraag:

Wat zijn de effecten van anti terroristische maatregelen op de verkeerssituatie op het wegennet van de Rotterdamse haven en hoe kunnen de negatieve effecten worden gemanipuleerd?

Om deze vraag te beantwoorden worden er meerdere dreigingsscenario's ontwikkeld. Per scenario worden de security maatregelen die door de terminals and the Rotterdamse haven genomen worden beschreven. Deze scenario's zijn om twee redenen ontworpen. De eerste reden is de verscheidenheid van alle mogelijke dreigings situaties die zich kunnen voordoen, de tweede vertrouwelijkheid van de informatie van de anti terroristische maatregelen. Voordat de scenario's ontwikkeld kunnen worden zal er een lijst gemaakt worden met de meest kritieke havengebieden van de Rotterdamse haven. Deze lijst is gebaseerd op verkeerssituatie rond de havengebieden en de ISPS gerelateerde terminals. De vijf verschillende havengebieden zullen gescoord worden op zeven criteria, zoals het aantal ISPS terminals, hoeveelheid verkeer dat het havengebied in gaat en de risicocontouren van de ISPS terminals. Deze criteria zullen worden gescoord op basis van een gebiedsanalyse, die bestaat uit een beschrijving van de Rotterdamse haven de vijf havengebieden en een veerkeersanalyse. Uit alle scores blijkt de Botlekhaven het meest kritieke havengebied is en zal gebruikt worden om de effecten van de anti terroristische maatregelen te berekenen.

Na deze gebiedsanalyse zijn verschillende scenario's voor de Botlekhaven ontwikkeld. In het eerste scenario worden alle ISPS gerelateerde terminals in de Botlek bedreigd, in de tweede slechts een of enkele terminals en in het derde scenario wordt de Botlektunnel bedreigd. Om de effecten van de anti terroristische maatregelen te berekenen is elk scenario gescoord op drie verschillende criteria. Het eerste criterium is de gemiddelde vertraging van alle voertuigen in de Rotterdamse haven. Dit criterium wordt gebruikt als netwerk prestatie indicator. De andere twee criteria zijn de reistijd tussen de A15 en de Maasvlakte en de congestie op de A15. Daarnaast worden de effecten per scenario berekend voor de ochtendspits en een periode buiten de spits.
Om de effecten van de anti terroristische maatregelen te berekenen zullen alle scenario's worden gesimuleerd in het microscopische verkeersmodel Vissim. Als eerste zal de huidige situatie zonder extra security maatregelen bekeken worden waarna alle scenario's voor de ochtend spits en buiten de spits om bekeken zullen worden. Door de huidige situatie te vergelijken met de verschillende dreigingsscenario's, gebaseerd op de criteria, de effecten van de anti terroristische maatregelen kunnen geïdentificeerd worden. Als de exacte effecten bekend zijn zullen enkele reroutings ontwikkeld worden om de negatieve effecten te minimaliseren.

De gemiddelde vertraging van de alle voertuigen zal tijdens alle scenario's zowel gedurende de ochtendspits als de off spits toenemen. De toename gedurende de ochtendspits is echter een stuk groter. Voor beide perioden is het verschil tussen de huidige situatie en alle scenario significant. Dit betekent dat het verschil met een zekerheid van 95% kan worden toegeschreven aan de anti terroristische maatregelen.

De congestie gedurende de ochtendspits op de A15 rond de Botlekhaven neemt in de meeste scenario's toe. Deze congestie wordt veroorzaakt door de wachtrijen voor de bedreigde terminals die de A15 bereiken. De langste file ontstaat tijdens de dreiging op de Botlektunnel, gevolgd door de dreiging op alle terminals in de Botlek en de Esso Nederland terminal. Het verschil tussen de congestie in de huidige situatie en de scenario's is in alle gevallen significant. Tijdens de periode buiten de spits al geen extra congestie optreden, alleen bij de dreiging op de Botlektunnel.

Het laatste criterium is de reistijd tussen het begin van de Rotterdamse haven en de Maasvlakte. Deze reistijd zal door de extra congestie en de verlaging van de gemiddelde snelheid op de A15 significant toenemen. De toename van de reistijd gedurende de ochtendspits is een stuk groter dan gedurende de off spits periode.

Het meest gemiddelde scenario, gebaseerd op de resultaten, is scenario1 (alle ISPS terminals in de Botlek worden bedreigd). Voor dit scenario zijn twee verschillende reroutings ontwikkeld die de negatieve effecten moeten proberen te verminderen. Tijdens rerouting 1 (waarin het verkeer naar de Botlek een eerdere afrit zal nemen) zal de extra congestie pas op een later tijdstip op de A15 bereiken en gedurende rerouting 2 (waarin het verkeer naar de Botlek een latere afrit zal nemen) de extra congestie zal nagenoeg verdwijnen.

Er kan worden geconcludeerd dat tijdens een terroristische dreiging in de Botlek een hoop negatieve effecten optreden door de inzet van verschillende anti terroristische maatregelen. Congestie ontstaat vrij snel op de A15 en de lengte van deze congestie zal enorm snel toenemen. Dit resulteert uiteindelijk weer in een langere reistijd tussen het begin van de Rotterdamse haven en de Maasvlakte en in meer vertraging voor het verkeer op de A15. Verplichte reroutings kunnen deze negatieve effecten aanzienlijk verminderen. Het is noodzakelijk dat verschillende reroutings voor alle dreigingsscenario's aanwezig zijn, ook voor de andere gebieden. Hierdoor kunnen de reroutings tijdig worden ingezet ten tijde van een terroristische dreiging.
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1 Introduction

Since the terrorist attacks of 11 September 2001 on the World Trade Centre in New York, terrorism suppression is one of the most important parts of the international and national safety policy. Since then, in the Netherlands many organizations have been established which keep themselves busy with the suppression of terrorism. The Nationaal Coördinator Terrorismebestrijding (NCTb) coordinates the cooperation between all these organizations. (Ministerie van binnenlandse zaken, 2008)

1.1 Threat in the Netherlands

On 9 September 2008 the fourteenth Dreigingsbeeld Terrorisme Nederland (DTN14) was published. The DTN, written by the NCT, is published four times a year and describes the progresses of the threat of a terrorist attack in the last quarter of the year. The DTN14 mentions that the threat level of a terrorist attack in the Netherlands stays on the substantial level. This means that the chance of a terrorist attack in the Netherlands is currently realistic at the moment. (NCT, 2008 [2]) In March 2008, the level was scaled up from the limited scale to the current substantial level. This was caused by the increasing international threat for Europe in combination with a high international profile for the Netherlands. This high profile is also an effect of the movie Fitna of Geert Wilders. (NCTb, 2008 [2].

Traditional targets for terrorist attacks are objects that are symbolic for a nation or governments that are seen as anti Islamic, for example embassies, government buildings, military objects or airplanes of airlines of those countries, the so called hard targets. (NCT, 2006, p.16) The last few years also soft targets were used by terrorists. Soft targets are areas or objects with an open public function which are difficult to secure, like hotels and stations. The last kind of objects those are interesting for terrorists are vital infrastructures, like roadways, bridges, tunnels, airports or ports. (NCT, 2006) This research focuses on the terrorist threats for the Port of Rotterdam.

1.2 Port Security Developments

Directly after the attacks on the World Trade Centre the 22nd conference of the International Maritime Organization (IMO) was held (in November 2001). During this conference, some decisions were made to develop new measures to ensure the safety of ships, ports and port

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1 Four threat levels can be distinguished, namely minimal, limited, substantially and critical. (NCT 2008 [1])
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facilities. In December 2002 the measures were implemented by a conference of contracting governments during the International Pact of security of men’s life on sea, also known as the Diplomatic Conference. After this conference the measures were also adopted by the European ordinance 725/2004. This ordinance became effective per 1 July 2004. (Ministerie van Verkeer en Waterstaat, 2008)

Among other things the implemented measures contain adjustments of the SOLAS (Safety Of Life On Sea) pact of 1974. (Commissie van Europese Gemeenschappen, 2003) Next to these changes of the SOLAS also a new international standard for the security of ships and port facilities was made, the so called International Ship and Port facilities Security code, from now ISPS code. (Port of Rotterdam, 2008 [3]) This ISPS code does not have a direct connection with the threat level of the NCTb.

The ISPS code uses three security levels. In case of a higher risk on an incident the level will be scaled up to a higher level. In case of a higher risk the port facilities and ships have to take extra measures to resist terroristic attacks. (Port of Rotterdam, 2008 [3]) These anti terroristic measures could have external effects, such as a negative impact on the traffic situation around the port of Rotterdam.

NEGATIVE EXTERNAL EFFECTS OF ANTI TERRORISTIC MEASURES

The anti terroristic measures following from the ISPS code could have a negative impact on the traffic situation on the road network around the Port of Rotterdam. This is not desirable because of the longer travel time for trucks and employees of terminals which have to pass the up scaled area, while in the current situation traffic congestion is already a problem. This applies for port incoming and outgoing traffic. For example, in case of a raised ISPS level for the Europoort (only the Europoort), measures have to be taken by the terminals in the Europoort. For example, these measurements could lead to congestions on the disclosure roads and on the A15. Congestion on the A15 results in a longer travel time for the traffic to the Maasvlakte (where no up scale ISPS level is). A longer travel time means bigger delays, which will result in an economic loss.

The other way around, the traffic situation on the road network around the Port of Rotterdam could influence the effectiveness of some anti terroristic measures negatively. For example, they might decide to evacuate a part of the harbour. Traffic congestion on the A15/N15 can complicate this. In case of congestion on the road network, the evacuation time will be much longer than in case of a free flow situation. In this project, only the impact of the anti terroristic measures on the traffic situation will be researched. The problem statement of this project is as follow:

Anti terroristic measures are expected to have a negative effect on the traffic situation on the road network around the Port of Rotterdam.

2 “A port facility is a location that is determined by the contracting government or suitable authority where the ship/port interface takes place.” (Commissie van Europese Gemeenschappen, 2003, p.52)
1.4 RESEARCH OBJECTIVE

In this Master thesis the consequences of the anti terroristic measures will be analyzed, which will be taken by port facilities in case of a raised terroristic threat. Furthermore, also the possibilities to minimize the negative effects of the anti terrorism measures will be researched. The research objective for the master thesis project is as follow:

To clarify the effects of the anti terroristic measures on the traffic situation on the road network around the Port of Rotterdam and find possible reroutings to minimize the negative effects.

1.5 RESEARCH QUESTIONS

The main research question of this research is:

What are the effects of the anti terroristic measures on the traffic situation on the road network around the Port of Rotterdam and how can mandatory reroutings minimize the negative effects?

This main question can be split up into a few sub-questions, which will help to answer this main question. The first three sub questions will help to give a general answer to the first part of the main question, namely the effects of the anti terroristic measures. The last two sub question give an answer of the effect minimizing question. The last question generalizes the conclusion of the effects in the Port of Rotterdam. The research sub-questions are:

SQ1: Which harbour, port facilities and road infrastructures will be taken into account and what do they and their surroundings look like?

By a lack of time it is not possible to determine the effects of security measures for the whole Port of Rotterdam. The Port of Rotterdam exists of five different harbours, namely the Maasvlakte, the Europoort, the Botlek, the Vondelingenplaat and the Heijplaat. Only one of these harbours will be used to determine the effects in that harbour.

To study the effects of the port facilities specific measures an exact description of the port facilities that are taken located in the chosen harbour is necessary. The measures per port facility are dependent of the characteristics of the terminal and its surrounding. A good description of the amount of traffic, the number of entrees, the materials and the surrounding is necessary to find the right facility specific measures. This is also the fact for parts of the infrastructure of the road network in the Port of Rotterdam.

SQ2: Which threat scenarios could exist and which anti terroristic measures will be taken in that threat scenario?

Different kind of threat scenarios could exist in the Port of Rotterdam. In every scenario, port facilities will take different security measures and also measures from the Port authority will differ per situation.

To research the effects of the port facilities specific measures, an exact description of these measures per ISPS terminal is necessary. Unfortunately the exact measures per port facility can not be obtained, because of the confidentiality of this information. To overcome this problem, an internal workshop with specialist of ARCADIS will be organized to inventory the possible security measures.
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SQ3: Which criteria should be used to determine the traffic situation on the road network around the Port of Rotterdam?

To find the effects of the anti terroristic measures, the situation in the normal situation will be compared with the situation during a raised ISPS level. To compare these two situations, one or more criteria are necessary.

SQ4: Which reroutings can be developed to minimize the negative effects of the anti terroristic measures?

To improve the traffic situation different kind of Dynamic Traffic Management measures could be taken. To minimize the negative external effects of the anti terroristic measures will chosen to introduce several reroutings. It is expected that rerouting the only effective Dynamic Traffic Management measure is that can reduce the negative effects of the anti terroristic measures. Before the effects of the different reroutings could be determined, these reroutings must be developed and described.

SQ5: What are the effects of the possible reroutings on the traffic situation?

The effects of the reroutings have to be determined to examine how to minimize the negative external effects of the anti terroristic measurements.

SQ6: What are the general effects of anti terroristic measures for the Port of Rotterdam?

The first five sub-questions present the effects of the anti terroristic measures and the mandatory reroutings for only one harbour. This last sub-question will generalize these effects for the total Port of Rotterdam.

READING GUIDE

This report will answer the questions mentioned in the previous section. In the next chapter the developments of the port security will be presented. In that chapter, the ISPS code will be described in more detail. After that, in chapter three an area analysis of the Port of Rotterdam will be done. This analysis is done because of two reasons. The first reason is to gain insight in the current traffic situation in the Port of Rotterdam. The second reason for an area analysis is to create an overview of vulnerable spots. This list will be used to develop several threat scenarios. These scenarios are developed in chapter four. Next to the description of the scenarios also the anti terroristic measures will be presented. In chapter five the experimental setup is presented. In that chapter the traffic model that is used and the analyzing steps will be presented. After the experimental setup, the results of the experiment are presented in chapter six. Based on three criteria, which are also presented in chapter five, the results per scenario are given, followed by the effects of mandatory reroutings and the results for the scenarios in 2020. In the last chapter the conclusions and recommendations are given.
Port security

In this chapter the developments in the port security since September 2001 will be presented. First, the adjustment of the SOLAS pact of 1974, and the ISPS code will be described. In the second paragraph the ISPS code will be presented, based on its parts A and B.

DEVELOPMENTS AND COMPONENTS

Ships and port facilities are interesting targets for terrorists in Europe. The first reason for this is the high potential threats of ships and port facilities. Ships could be used as a weapon, can transport mass destruction weapons and even ships with dangerous cargo can be a threat, in case of the absence of good control measures. A terroristic attack could lead to a lot of victims in case of a passenger ship or a cargo ship around port facilities. In the last case an attack could also lead to an enormous damage of the terminals. (Commissie van Europese Gemeenschappen, 2003) The second reason is the share of the sea transportation in trade of the European Union. Sea transportation is essential for the economic and commercial power of the union. That is why a terroristic attack on a ship or port facility will have a big impact, and is interesting for terrorists. (Commissie van Europese Gemeenschappen, 2003)

As mentioned in the introduction, during a conference of IMO decisions were made to develop new measures to ensure the safety of ships, ports and port facilities. One of the new measurements is an adjustment off the SOLAS (Safety Of Life On Sea) pact of 1974. This adjustment is adopted by the European ordinance 725/2004. The most important change is the security guide for port facilities. Before 2002, SOLAS only have security aspects for ships. On the conference also strictly rules for the facilities are added to the SOLAS pact of 1974. The changes of the SOLAS pact are mandatory. (Commissie van Europese Gemeenschappen, 2003)

Next to this change of the SOLAS also a new international standard for the security of ships and port facilities is made, the so called International Ship and Port facilities Security code, from now ISPS code. (Port of Rotterdam, 2008 [3]) This code exists of two parts. The first part is a mandatory section. In this section detailed security-related requirements for governments, port authorities, port facilities and shipping companies are described. In the second section, the non-mandatory part, some guidelines are presented to meet the requirements of the first part. (Commissie van Europese Gemeenschappen, 2003) In paragraph 2 both parts will be described.

The changes of the SOLAS pact of 1974 and the ISPS code are significant for all the ships with a minimal load capacity of 500 ton and that make international journeys (passengers- and freight ships) and the port facilities that handle these international ships. (Commissie
van Europese Gemeenschappen, 2003) In this report only the port facilities are taken into account. In the Port of Rotterdam are more than 140 ISPS related facilities.

2.2 COMPOSITION OF ISPS CODE

As mentioned in the previous paragraph, the ISPS code exists of two parts, a mandatory and a non mandatory one. In this paragraph both parts will be presented.

2.2.1 PART A

The contracting governments should establish safety levels. The higher the safety level, the higher the risk on a safety incident. (Commissie van Europese Gemeenschappen, 2003) The ISPS code has three security levels. In a normal situation this level has code 1. This means that there is no threat of any terrorist attack. In such a situation the standard security checks have to be made. On this moment the ISPS code in the Port of Rotterdam has level 1. This is presented on the website of the Port Authority, which is shown in figure 1.

![Figure 1: Current ISPS level in the Port of Rotterdam (Port of Rotterdam, 2008 [3])](image)

In case of an increased risk on a terrorist attack the level will be scaled up to code 2, resulting in stricter security measures. The highest level is code 3. In a period with code 3 the chance on a terrorist attack or accident is very plausible. Very strict security measures have to be taken. (Port of Rotterdam, 2008 [3])

In this part also the preventive measures that ISPS related ships and port facilities have to take in case of ISPS level 1 are given. The standard preventive measures that have to be made in case of safety level 1 for port facilities are:

- Take care for the execution of all tasks with regard to the safety of the port facility.
- Control the access of the facility.
- Supervision of the facility, inclusive the quay.
- Supervision of the forbidden areas and take care that only permitted persons can enter these areas.
- Supervision of loading and unloading of the ships.
- Take care for safety communication systems

Furthermore, the port facilities should provide a port facility security plan (psp) for the protection against safety incidents in case of a raised ISPS level. In part B, guide lines are given to implement a psp.
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Other issues that are mentioned in part A are the assessment of the safety of the facility, the safety plans of the facility, the safety officer and practices concerning with the safety of the facility. (Commissie van Europese Gemeenschappen, 2003)

PART B

In part B of the ISPS standard guide lines are given to guarantee the safety of ISPS related ships and port facilities in case of an up scaled ISPS level. Based on these guidelines each port facility can make an own facility based port facility security plan (psp). (Commissie van Europese Gemeenschappen, 2003)

First, the port facilities have to identify possible threats and vulnerable spots of the terminal. Based on these factors, the facility specific measures in case of a raised threat can be made. These measures are split up in a few categories, like access to the port facility, areas inside the terminal for which restrictions apply and cargo handling. Per category specific measures must be given per ISPS level in the psp. For this research, only the category of the access to the terminals will be studied.

The following guidelines are given in this part of the ISPS code for the access to the port facility in case of an ISPS level 2 (Commissie van Europese Gemeenschappen, 2003):

- Confer extra personnel to supervise the access points and to patrol around the fences.
- Limit the amount of access points of the port facility and identify which access point will be closed.
- Increase the frequency of the number of checks of persons, personal belongings and vehicles.
- Forbid the access of visitors who have not a good reason to visit the facility.

In case of security level 3, facilities have to follow the instructions that are given by them who react on the threat of an incident or a safety incident. In the PSP, the safety measures that can be taken through the port facility, in corporation with them who react and the ships, must be given. Guidelines for these measures are given here. (Commissie van Europese Gemeenschappen, 2003)

- Temporary denial of the access to the total port facility, or a part of it.
- Only they who react on the threat of an incident are allowed to enter the facility.
- No movements inside the total facility.
- Increase the number of patrols inside the facility.
- Postpone the activities on the facility
- Evacuate the total or a part of the port facility.

Based on parts A (ISPS levels) and B (guidelines for measurements) of the ISPS code all the ISPS related terminals have to make a Port facility Security Plan. In this plan all the port facility specific measures are given. In chapter 4 measures that can be taken by port facilities are per scenario presented.
2.3 WATER CROSSINGS

The ISPS code is obligatory for terminals and ships with the characteristics which are mentioned above. Parts of the infrastructure around the Port of Rotterdam are not ISPS related. In this report however, the water crossings in the Port of Rotterdam will be taken into account. To determine the weight of the threat on water crossings the ISPS level will be used.

In this chapter the developments of the port security since the terrorist attacks on the World Trade Centre of 9/11 2001 are presented. Based on these developments, ISPS related terminals must make a PSP, in which several anti terrorist measures are presented. In the next chapter an area analysis will be done.
3 Area analysis

In this chapter the problem area, the Port of Rotterdam, will be analyzed. There are two reasons to do this area study. The first reason is to gain insight in the current traffic situation in the Port of Rotterdam. The traffic situation in case of a raised terroristic threat will be compared with this situation. Based on this comparison, the effects of the extra security measures can be determined. The second reason for an area analysis is to create an overview of vulnerable spots. This list will be used to develop several threat scenarios.

The area analysis exists of three parts. In the first part, a description of the Port of Rotterdam will be given. For this description, first the total harbour will be defined, followed by the definition of five different harbours. Based on the descriptions of the Port of Rotterdam and its harbours the second paragraph a traffic analysis will be done of the current traffic situation. Based on this analysis, in the last part a list will be given with the most vulnerable spots in the Port of Rotterdam. These spots will be used to develop the threat scenarios.

3.1 AREA DESCRIPTION

In this paragraph a description of the total port and five harbours is given. First the total harbour will be presented. Some characteristics of the port area, the location of the ISPS related terminals and the highway network will be given. To get a better view of the ISPS related terminals and the underlying road network in the Port of Rotterdam a more detailed description of the port is necessary. That is why the port will be split up into five different harbours.

3.1.1 PORT OF ROTTERDAM

In figure 2 the port area of the Port of Rotterdam is given in respect of the city of Rotterdam. The largest part of the harbour is located on the western side of the city of Rotterdam and on the southern side of the Maas, which is accentuated by the border in the figure.
The total length of the harbour (from West to East) is 40 kilometres. The size of the area is 10400 hectare, of which the half exists of port facilities areas (Port of Rotterdam, 2007). In this area several kind of port facilities are located, of which 140 ISPS related. In figure 3 the locations of these ISPS related terminals in the Port of Rotterdam are presented by the green areas. As can see, these terminals are spread over the whole port area.

The most important highway around the Port of Rotterdam is the A15. The A15, from Rozenburg it becomes the N15, is the only highway that crosses the total harbour from east (Ridderkerk) to west (Maasvlakte). This main road starts officially on the Steenen baakplein, at the beginning of the Maasvlakte. The N15, however, starts earlier on the Maasvlakte, but this part of the road is owned by the Maasvlakte and isn’t a national highway. (Wikipedia, 2008) In figure 2 the A15 is marked with the black line in the middle of the port area.

The A15 has two different functions. The first one is the connecting function for road transport from and to the hinterland. The A15 connects the Port of Rotterdam with the hinterland (Germany) and with other highways which leads to other areas, like the A16 to Belgium. The second function is the disclosing function for the employees of the Port of Rotterdam and for the regional personal traffic from the surrounding communities.
The number of traffic lanes on the A15/N15 differs per part of the trajectory. From the Maasvlakte till Spijkenisse (Hartelkruis) the A15/N15 has a 2x2 profile. On the West to East trajectory, around the Thomassentunnel, a specific part has 3 traffic lanes. From Spijkenisse till the Vaanplein the A15 has a 2x3 profile. Around the Beneluxplein a parallel structure is present. (Rijkswaterstaat, 2008)

On the trajectory of the A15/N15 four water crossings exist. In figure 4 these crossings are presented.

![Figure 4: Tunnels and bridges in the Port of Rotterdam (Google maps, 2008)](image)

The first one is the Botlektunnel (1). This tunnel is the gateway to the Port of Rotterdam and is located between the Vondelingenplaat and the Botlek harbour and crosses the Oude Maas. Traffic with the Botlek harbour, the Europort or the Maasvlakte as destination have to cross the Oude Maas. Next to this tunnel, it is also possible to cross the Oude Maas by the Botlekbrug. This bridge is obligatory for trucks with hazardous goods, but can also be used by other traffic in case of an incident in the Botlektunnel. The second crossing is the Thomassentunnel (2). This tunnel, which is finished in 2004, crosses the Calandkanaal and is used by traffic from or to the Europort or the Maasvlakte. The Calandbrug is an alternative route to cross the Calandkanaal, and must be used by the traffic that leaves the A15 directly after the Calandkanaal. The last two crossings are bridges, just before the Maasvlakte. The first one (3) is the Dintelhavenbrug, the second one the Suurhoffbrug. These two bridges don’t have an alternative route to cross the Dintelhaven access canal (3) or the Hartelkanaal (4). This fact makes these two bridges more vulnerable than the two bridges.

Around the city of Rotterdam the square of Rotterdam (the ring road around Rotterdam) is located. The square exists of the A4, A20, A15 and A16 and disclosed the traffic around Rotterdam, among which traffic of the port of Rotterdam as origin. After the square, these highways and the A29 and A13 become connecting roads with the hinterland of the port. The A15/N15 has three intersections with other highways around Rotterdam. The first one is Ridderkerk, located on the east side of Rotterdam, where the A15 meets the A16. The following intersection is Vaanplein, where the A15 crosses with the A29. The last one, located between the Heijplaat and the Vondelingenplaat, the A4 comes together with the A15.

Next to the N15/A15 a few smaller N-roads are present in the region of the port. These roads could be used as connecting or disclosing roads. They connect different smaller town located on Voorne with each other, but these roads also disclosed these towns to the A15. Examples of these N-roads are the N57 (to the south), N218 (parallel to the N15/A15) and
the N493. In case of emergency the N218 could be used for port related traffic to avoid the A15.

3.1.2 HARBOURS

After the description of the total port, the Port of Rotterdam can be split up into five separate harbours. These harbours are the Maasvlakte 1 (1), the Europoort (2), the Botlek (3), the Vondelingenplaat (4) en the Heijplaat (5) (from west to east). In figure 5 the harbours are presented in a map of the Port of Rotterdam.

Figure 5: Location harbours (Google maps, 2008)

Per harbour the most important ISPS related terminals will be described, based on the terminal type and its risk outlines. Six different kinds of port facilities exist in the Port of Rotterdam. In figure 6 these different kinds of terminals in the Port of Rotterdam are presented. The biggest part of the ISPS related port facilities handle wet bulk, like oil and Chemic. Also container and dry bulk terminals are mostly ISPS related.

Figure 6: Different kinds of terminals (Port of Rotterdam, 2008 [1])

Based on the risk card of the Province of South Holland, the risk outlines of the terminals in the different harbours are given. A risk outline (a tied risk) shows the death chance in the surrounding through an incident with a risk source. A tied risk is the determined chance that a person dies because of the effects of an incident with a risk source and is based on the chance that an incident occurs and the chance that a person really dies. In a risk card the outlines are based on a tied risk of 10^{-6}, which means that the chance that a heavy incident
takes place is one on a million. The bigger the risk outline of a terminal, the bigger the effects distance of a terminal. (Provincie zuid Holland, 2008)

Next to the descriptions of the terminals on the specific harbour, also the underlying road network per harbour is given. This description is based on the off ramps that are located in the harbour and the route possibilities for vehicles after the off ramp. The terminals are connected with the off and onramps of the A15/N15 by the underlying network. In case of extra security measures at a port facility, the traffic on these roads will experience the effects first. In case of a short distance between the entrances of a terminal and the off ramp, the effects could also reach the traffic on the A15/N15. In this section, the off ramps and the underlying network per harbour will be presented. In figure 7 all the off ramps on the A15 are given. Also one off ramp on the A4 is given, namely number 17.

In appendix A a detailed map of all the off ramps in the Port of Rotterdam is given, together with a description of the possible routes and the underlying road network, which will be presented below. In the description of the underlying road network per harbour, the numbers of the off ramps mentioned in the figure above will be used.

Maasvlakte 1
The first harbour is the Maasvlakte 1. This part of the Port of Rotterdam is the most western area, nearby the North Sea and has a surface of 40 km². In figure 8 the exact location of the Maasvlakte is shown (left), the areas of the ISPS related port facilities on the Maasvlakte 1 (middle) and the risk outlines of all terminals on the Maasvlakte (right).
The most important terminals are the Europees Massagoed Overslagbedrijf (EMO, 1a), ECT Delta Terminal (1b), APM Terminal Rotterdam (1c), the Maasvlakte Olie Terminal (MOT, 1d), E.ON (1e) and Lyondell – Bayer (1f). In appendix B the total list with ISPS terminals in this area is given. The risk card makes clear that EMO and E.ON don’t have a risk contour, while ECT and APM have the biggest ones.

The N15 (Europaweg)/A15 has a connecting function between the Maasvlakte and the other harbours in Rotterdam and the square around Rotterdam. The position of the Maasvlakte takes care for a long travel time over this highway for trucks and cars between this area and the exit (the square) of the Port of Rotterdam. This makes this area sensible for delays by congestion on the N15/A15 before the Maasvlakte. To reach the Maasvlakte the traffic has to cross two tunnels (the Botlektunnel and the Thomassentunnel) and two bridges (the Suurhoffbrug and the Dintelhavenbrug). Another connecting link could be the N218, a regional road that crosses Voorne.

The terminals on the Maasvlakte are disclosed by a few small roads that are owned by the Port of Rotterdam. (van Schuylenburg, 2008) These roads have a direct crossing with the Europaweg. On the Maasvlakte, vehicles can take four different off ramps. The first one (off RAMP 7) leads to the Distribution Park Maasvlakte, followed by the Missouriweg (off ramp 6) which discloses EMO and the Coloradoweg (off ramp 5) for the E.ON, ECT and APM terminal. Not taking one of these off ramps means automatically that vehicles will follow the Europaweg till the end to Lyondell – Bayer and the Maasvlakte Olie Terminal. The last off ramp is a crossing on the same level with the N15/Europaweg. The traffic to the Maasvlakte comes from the A15 or the N218. The N218 crosses the N15 on the Steenenbaakplein, which is off ramp number 8.

Europoort

The second harbour is the Europoort. This is a large chemical harbour, directly on the East side of Maasvlakte 1 with oil refineries, petrol terminals and ore transhipments and has a surface of 36 km². In figure 9 the position of the Europoort in the port of Rotterdam is shown (left), the ISPS related terminals in this harbour (middle) and all risk outlines in this harbour (right).
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Figure 9: Position, terminals and risk outlines of the Europoort (Port of Rotterdam, 2008 and Provincie Zuid Holland 2008)

The largest ISPS related terminals in the Europoort are the BP Raffinaderij Rotterdam (2a), EECV (2b), the Shell Europoort Terminal (2c) and the Kuwait Petroleum Europoort (2d), Caldic and Exxon Mobil (both in 2e) and Lyondell (2f). In appendix B the total list with ISPS terminals in this area is given. It is remarkable that next to the Kuwait Petroleum, Caldic, Exxon Mobile and Lyondell also some smaller ISPS terminals around these terminals have large risk outlines. This result in several overlapping contours, in a relative small area.

The N15/A15 takes care for the connection between the Europoort and the square around Rotterdam and the other parts of the Port of Rotterdam. In contrast to the Maasvlakte 1, the traffic for the eastern part of the Europoort only crosses the two tunnels that are located more to the east. Traffic for the BP Raffinaderij Rotterdam B.V. terminal (the most western terminal of the Europoort) must still cross the Dintelhaven bridge) The Suurhoff bridge will not be used by Europoort traffic. Next to the A15, also the N218 (for the western part of the Europoort) and the N57 (for the eastern part of the Europoort) can be used as connecting links. The underlying road network that is owned by the Port of Rotterdam (van Schuylenburg, 2008) discloses the Europoort. The terminals are disclosed by a road that is parallel with the N15/A15. This parallel road is linked to other road that goes to the port facilities.

In the Europoort four off ramps exists. The first one is off ramp number 9 and is located just before the Suurhoff Bridge. This off ramp discloses the BP Raffinaderij on the South side and the EECV and Vordian terminal on the North side. The second off ramp (number 10) is just before the Dintelhavenbrug. Just like off ramp 9, vehicles can take a road on the South side, which discloses P&O/Ferries and some smaller terminals, and a road on the North side, which disclose also the P&O/Ferries, the Team terminal, the Shell Europoort and the Caldic terminal. The next off ramp is number 11. Off ramp 11 lies between the Dintelhavenbrug and the Thomassentunnel, and is responsible for the disclosure of the West side of Kuwait Petroleum Europoort, the Caldic Terminal and Exxon Mobil. The last off ramp is number 12, directly after the Thomassentunnel. Traffic that takes this off ramp from the east side can’t enter the port area, but only go to Voorne by using the N57. Traffic that comes from the east that has Vopak or MET as destination, have to leave the A15 by off ramp 13 and make use of the Caland Bridge. The traffic that comes from Voorne over the N57 however has the opportunity to enter the port. This traffic has the possibility to go to the MET and Vopak terminals (on the north) or to the most eastern part of the Botlek (on the south west). Traffic that takes the off ramp from the west side can go to the Vopak and MET terminal.
Botlek
The third harbour is the Botlek. The Botlek is just like the Europoort a large chemical harbour and lies in the eastern of the Europoort and on the western side of the Oude Maas and has a surface of 25 km². In figure 10 the exact location of the Botlek harbour in the Port of Rotterdam is shown (left), the terminals with an ISPS code (middle) and the risk contours of the terminals (right).

Figure 10: Position, terminals and risk outlines of the Botlek (Port of Rotterdam, 2008 and Provincie Zuid Holland 2008)

The biggest terminals in the Botlek harbour are the Esso Nederland (3a), the Vopak Zuid (3b) and Odjell (3c). In appendix B the total list with ISPS terminals in this area is given. Odjell has the largest risk outline of the area, but also Esso and Vopak has such a contour. On the south side of the A15, a lot of terminals exist with all a risk outline. The most of these terminals are not ISPS obligatory.

The A15 takes care for the connection between the Botlek and the square around Rotterdam and the other parts of the harbour. The traffic with the Botlek harbour as destination or origin only has to pass the Botlek tunnel. So, the two bridges and the Thomassen tunnel are not been used anymore. Next to the A15 the Botlekweg (parallel to the A15) could be used as a connecting link. This road doesn’t make use of the Botlek tunnel but of the Botlek Bridge. Nowadays, this road is used by trucks with dangerous products. Next to this parallel road also the N218/N493 could maybe be used as a connecting road. In the Botlek also a parallel to the A15 underlying road disclose the terminals. This parallel road is connected with the roads that go to the terminals. In figure 11 the Botlek is presented.

Also four off ramps disclose the Botlek harbour. Off ramp 13 is the first one, located just before the Thomassen tunnel. This off ramp is used by traffic with the most eastern part of the Eurooppoort (Vopak and MET), as mentioned above, or Rozenburg as destination. (Only the traffic which goes to Rozenburg is counted, because the traffic to Vopak and MET is counted by off ramp 12). The next off ramp (14) discloses also Rozenburg, the North West part of the Botlek and the most western part of the Botlek. Off ramp 15 is located on the south side of the large Esso Nederland terminal and discloses next to this terminal also the Vopak zuid (on the North side of the off ramp) and the South West part of the Botlek (on the South side). The last off ramp (16) is the disclosure off Spijkenisse (by the Hartel Bridge on the south), Esso Nederland and Vopak zuid (on the West side) and the East side of the Botlek (on the East side).
Vondelingenplaat
The fourth harbour is the Vondelingenplaat. This place, which has a surface of 18 km², is also a chemical harbour and is located on the eastern side of the Oude Maas, directly beside the square of Rotterdam. In figure 11 the exact location of the Vondelingenplaat in the Port of Rotterdam is shown (left), in the middle the right side the ISPS related terminals and on the right side the risk outlines in the harbour.

![Figure 11: Position, terminals and risk outlines of the Vondelingenplaat (Port of Rotterdam, 2008 and Provincie Zuid Holland 2008)](image)

There are only two very big terminals on the Vondelingenplaat, namely the Shell Nederland Raffinaderij (exists of two terminals) and the Shell Chemie (exists of two terminals). Both terminals are located in area 4a. In appendix B the total list with ISPS terminals in this area is given.

Just like the other harbours, which are described above, the A15 has a connecting function for the Vondelingenplaat. When the A15 is used as the connecting road, the traffic is not using any tunnel or bridge anymore. Next to the A15, also the A4 has a direct connecting function for the Vondelingenplaat. In that case, the traffic has to pass the Nieuwe Maas by the Benelux tunnel. The Vondelingenweg is the road that lies parallel to the A15. This road has a connection with the A15 and A4. This road discloses the Vondelingenplaat to the A15 and A4 with the help of smaller roads that crosses that way.

The Vondelingenplaat is disclosed by two off ramps, number 17 on the A15 and number 17 on the A4. The off ramp on the A15 discloses the whole Vondelingenplaat to the A15, while the off ramp on the A4 the same function has fore the traffic on the A4. Both off ramps enters the Vondelingenplaat on the same Next to these two off ramps, also an off ramp for the Botlekbrug exists, which is used by trucks with hazardous goods.

Heijplaat
The last harbour is the Heijplaat and is the most Western part of the Port of Rotterdam. The Heijplaat, which is located in the square of Rotterdam, close to the city of Rotterdam, has a surface of 15 km² and has container terminals and other terminals. In figure 12 the exact location of the Heijplaat in the Port of Rotterdam is shown (left), the ISPS related terminals (middle) and on the right side the risk outlines of the terminals in this harbour.
In the harbour not much large terminals are located. There are only four terminals which are relatively large, namely Interforest (5a), the ECT and RSC (both in number 5b) and the Uniport terminal (5). In appendix B the total list with ISPS terminals in this area is given. The first three terminals have also a risk outline, but these are not very large.

The Heijplaat has the same connecting infrastructure as the Vondelingenplaat. The A15 and the A4 take care for this function. If the traffic makes use of the A4, it has to cross the Nieuwe Maas by the Benelux tunnel. In case of using the A15 mo tunnel or bridge have to be taken. The Heijplaat is disclosed by a main road, the Waalhavenweg, and a few smaller roads that go to the terminals. The Waalhavenweg has a connection with the A15 and, via a detour, A4. In appendix A the disclosing roads of the terminals on the Heijplaat are given.

3.2 CURRENT TRAFFIC SITUATION

In the previous paragraph a clear description of the Port of Rotterdam and its harbours is given. Based on these descriptions, in this paragraph a traffic analysis is done of the current traffic situation on the road network around the Port of Rotterdam. The current traffic situation is used by determining the most vulnerable harbour and terminals in the Port of Rotterdam. The traffic analysis is done for the morning peak and the non peak period during the noon. During the morning peak lot home-work traffic will go to the terminals. In that case, extra security measures are used to have more effect on the traffic situation than in a non peak period or in the evening peak (when the home-work traffic leaves the terminals instead of entering). First, a study of the traffic situation on the A15/N15 will be done, followed by the traffic situation on the underlying, disclosing roads to the terminals.

3.2.1 A15/N15

In the Netherlands, intensity and speed are important variables to measure the traffic situation on highways. The intensity is the amount of vehicles that passes a road segment per time unit, measured in vehicles per hour. The speed is the average speed of all vehicles on a road segment per time unit. These two variables will be used to determine the current traffic analysis.

First in table 1 the intensities on the A15 in the direction of the Maasvlakte are presented. The values in this table are obtained by the MoniCa induction loops. In the first column the intensity before an off ramp is given, followed by the amount of A15 outgoing vehicles per off ramp. The intensity minus the amount of outgoing vehicles is the traffic that not leaves.
the A15 and passes the off ramp on the A15. The higher the amount of traffic that passes a harbour the more traffic could be hindered by the traffic jam that could occur by the extra security measures when this traffic jam reaches the A15. The traffic jam could reach the A15 more quickly in case of a higher amount of A15 outgoing traffic. The amount of passing vehicles plus the number of entering vehicles resulted in the intensity after the off ramp. All values are given in vehicles per hour.

| Table 1: Intensities on A15 and outgoing and entering vehicles (Vehicles/hour) |
|-------------------------------|-----------------|-----------------|---------------|-----------------|
| Off ramp 8                   | 1047            | 168             | 879           | 296             | 1174            |
| Off ramp 9                   | 1307            | 165             | 1142          | 30              | 1172            |
| Off ramp 10                  | 1391            | 157             | 1235          | 73              | 1307            |
| Off ramp 11                  | 1.561           | 318             | 1.243         | 148             | 1.391           |
| Off ramp 12                  | 1.718           | 367             | 1.352         | 204             | 1.555           |
| Off ramp 13                  | 2.063           | 322             | 1.741         | x               | 1.741           |
| Off ramp 14                  | 2.663           | 663             | 2.000         | 86              | 2.086           |
| Off ramp 15                  | 3153            | 1.002           | 2.151         | 85              | 2236            |
| Off ramp 16                  | 4263            | 2.929           | 1.334         | 1.819           | 3153            |
| Botlek                       | 4.391           | 220             | 4171          | x               | 4.171           |
| On 17                        | 3670            | x               | 3670          | 737             | 4407            |
| On Ben                       | 2415            | x               | 2415          | 1.255           | 3670            |
| Off 17                       | 3371            | 956             | 2414          | x               | 2415            |
| Off Ben                      | 5637            | 2.266           | 3371          | x               | 3371            |
| Off ramp 18                  | 4.513           | 123             | 4.390         | 1.106           | 5.497           |

From this table can be concluded that the highest intensity on the A15 occurs around off ramps 16, Botlek and Benelux. Next to that can be concluded that the off ramps 15 and 16 have the largest amount of A15 outgoing vehicles. Traffic that leaves the A15 at off ramp 16 can enter the Botlek harbour or Spijkenisse. Traffic that makes use of off ramp 15 can only enter the Botlek harbour. In case of extra security measures around these two off ramps a lot of traffic could be hindered by the congestion that can occur. This makes off ramp 15 and 16 vulnerable. The last conclusion from this table is that the amount of passing vehicles is the highest around off ramp 18 and Botlek.

The intensities mentioned above do not tell anything about the congestion on the A15. With the average speed on a road segment a speed contourplot can be made. A speed contourplot indicates the location of congestion and how this congestion will be changed during a given time period. In figure 13 the speed contourplot for the A15 in the direction of the Maasvlakte for the morning peak is given.

---

3 Off ramp Benelux lead to the A4 and not directly to any terminal. So the amount of A15 outgoing traffic is not interesting for this research.
Figure 13: Speed contourplot A15 direct km Maasvlakte (Speed in km/hour)

In this plot the yellow/orange areas indicate a low speed and the green areas a free flow situation. During approximately one hour (from 30 minutes till 90 minutes) a traffic jam of 4 kilometres occurs between hectometre 46 and 50. This is between off ramp 16 (Spijkenisse and the Botlek) and the Beneluxplein. On this trajectory the Botlektunnel is located. This corresponds with daily traffic jam that occurs around the Botlektunnel.

In table 2 the average speed per hour during the morning peak is given. The values are lower than can be concluded from the figure above. This is because the average is determined over the three peak hours during the morning peak. These values will be used to determine the most vulnerable harbour.
The effects of anti terroristic measures on the traffic situation in the Port of Rotterdam

Table 2: Speed per location on the A15 to the Maasvlakte (km/hour)

<table>
<thead>
<tr>
<th>Between off ramps</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
</tr>
<tr>
<td>12-11</td>
<td>102.91</td>
</tr>
<tr>
<td>13-12</td>
<td>100.47</td>
</tr>
<tr>
<td>14-13</td>
<td>97.85</td>
</tr>
<tr>
<td>15-14</td>
<td>88.86</td>
</tr>
<tr>
<td>16-15</td>
<td>80.46</td>
</tr>
<tr>
<td>Botlek - 16</td>
<td>70.06</td>
</tr>
<tr>
<td>17 - Botlek</td>
<td>68.02</td>
</tr>
<tr>
<td>Ben - 17</td>
<td>70.47</td>
</tr>
<tr>
<td>17 - Ben</td>
<td>83.40</td>
</tr>
<tr>
<td>18 - Ben</td>
<td>81.32</td>
</tr>
</tbody>
</table>

The average speed is also measured by the MoniCa induction loops. These loops are located till off ramp 11. The Port of Rotterdam, who collects traffic information after off ramp 11, does not collect the speed of the passing vehicles. That is why no information about the speed after off ramp 11 is available.

UNDERLYING ROAD NETWORK

3.2.2

In the previous paragraph the traffic situation on the A15/N15 till the Steenen baakplein is presented. In this paragraph the traffic situation on the most important underlying roads in the Port of Rotterdam are presented.

After the off ramps several underlying roads discloses the terminals. Here, a list is given with the most important underlying roads with their intensities. This list exists of the roads to the entrances of the most important terminals, which are mentioned in appendix C. The intensities are given in the tables 3, 4 and 5 and are vehicles per hour, for the morning peak, and off peak period during the day. In appendix A the maps of the road networks around the off ramps are given.

Table 3: Intensities Moezelweg (vehicles per hour) (Port of Rotterdam and Witteveen+Bos, 2008)

<table>
<thead>
<tr>
<th>Moezelweg (Europoort)</th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trajectory</td>
<td>Morning</td>
<td>Noon</td>
</tr>
<tr>
<td>West of off ramp 10</td>
<td>103</td>
<td>80</td>
</tr>
<tr>
<td>Between off ramp 10</td>
<td>Near off ramp 10</td>
<td>21</td>
</tr>
<tr>
<td>10 and 11</td>
<td>Near off ramp 11</td>
<td>97</td>
</tr>
<tr>
<td>Between off ramp 11</td>
<td>Near off ramp 11</td>
<td>73</td>
</tr>
<tr>
<td>11 and 12</td>
<td>Near off ramp 12</td>
<td>76</td>
</tr>
<tr>
<td>East of off ramp 12</td>
<td>nk</td>
<td>nk</td>
</tr>
</tbody>
</table>

nk: Not known
Table 4: Intensities Botlekweg (vehicles per hour) (Port of Rotterdam and Witteveen+Bos, 2008)

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>WEST</th>
<th></th>
<th>EAST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Noon</td>
<td>Morning</td>
</tr>
<tr>
<td>North of off ramp 14</td>
<td>659</td>
<td>323</td>
<td>218</td>
</tr>
<tr>
<td>North</td>
<td>Droespolderweg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>Droespolderweg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between off ramp 14 and Theemsweg</td>
<td>127</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>Near off ramp 14</td>
<td>72</td>
<td>109</td>
<td>64</td>
</tr>
<tr>
<td>Near Theemsweg</td>
<td>259</td>
<td>211</td>
<td>69</td>
</tr>
<tr>
<td>Near Welplaatweg</td>
<td>193</td>
<td>86</td>
<td>73</td>
</tr>
<tr>
<td>Between Theemsweg and Welplaatweg</td>
<td>115</td>
<td>80</td>
<td>161</td>
</tr>
<tr>
<td>Near Welplaatweg</td>
<td>261</td>
<td>103</td>
<td>110</td>
</tr>
<tr>
<td>Near Hartelbrug</td>
<td>62</td>
<td>97</td>
<td>426</td>
</tr>
</tbody>
</table>

East of Hartelbrug

Table 5: Intensities Vondelingenweg (vehicles per hour) (Port of Rotterdam and Witteveen+Bos, 2008)

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>WEST</th>
<th></th>
<th>EAST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Noon</td>
<td>Morning</td>
</tr>
<tr>
<td>West of Digna Johannaweg</td>
<td>273</td>
<td>140</td>
<td>152</td>
</tr>
<tr>
<td>Between D. Johannaweg and the Petroleumweg</td>
<td>nk</td>
<td>nk</td>
<td>nk</td>
</tr>
<tr>
<td>Near Johannaweg</td>
<td>nk</td>
<td>nk</td>
<td>nk</td>
</tr>
<tr>
<td>Near Petroleumweg</td>
<td>220</td>
<td>162</td>
<td>115</td>
</tr>
<tr>
<td>Between Petroleumweg and connecting road</td>
<td>251</td>
<td>157</td>
<td>95</td>
</tr>
<tr>
<td>Near Petroleumweg</td>
<td>430</td>
<td>142</td>
<td>64</td>
</tr>
<tr>
<td>Near connecting road</td>
<td>606</td>
<td>345</td>
<td>294</td>
</tr>
<tr>
<td>Near Hoefsmidstraat</td>
<td>nk</td>
<td>nk</td>
<td>nk</td>
</tr>
<tr>
<td>East of Hoefsmidstraat</td>
<td>nk</td>
<td>nk</td>
<td>nk</td>
</tr>
</tbody>
</table>

nk: Not known

The busiest underlying road is Botlekweg, on the North side of off ramp 14, which is located in the North part of the Botlek around the small village Rozenburg, followed by the Vondelingenweg around off ramp 17. More traffic will be hindered in case of extra security measures in the surrounding of these roads.
VULNERABLE SPOTS

After the presentation of the current traffic situation on the road network a list will be made with the most vulnerable harbours in the Port of Rotterdam. The lists with the weak harbours of the port will be used to develop several scenarios. Each harbour will be scored on the every criterion. These scores are based on the description of the Port of Rotterdam and the harbours in paragraph 1 and the traffic analysis in paragraph 2. Based on these scores, the most vulnerable harbour can be determined. Below the five harbours are scored on several different criteria.

A. Amount of traffic that enters the harbour
This criterion determined the total amount of vehicles that enter the harbour. The higher the number of vehicles, the more vehicles can be hindered by the extra security measures. Harbours with a high amount of entering vehicles will be more vulnerable than harbours with a low number of vehicles. For this criterion only the entering traffic that comes from Rotterdam is taken into account. Per harbour the average amount of vehicles per hour during the morning peak is presented:

<table>
<thead>
<tr>
<th>Harbour</th>
<th>Morning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botlek</td>
<td>2707 vehicles</td>
</tr>
<tr>
<td>Maasvlakte 1</td>
<td>1097 vehicles</td>
</tr>
<tr>
<td>Vondelingenplaat</td>
<td>956 vehicles</td>
</tr>
<tr>
<td>Eurooport</td>
<td>639 vehicles</td>
</tr>
<tr>
<td>Heijplaat</td>
<td>61 vehicles</td>
</tr>
</tbody>
</table>

B. Amount of traffic that passes the harbour over the A15
In case of extra security measures, a blockage on the access roads to the terminals could exist. When these traffic jams are very close to an off ramp, also a blockage on the A15 could arise. A harbour which is passed by a large amount of vehicles is more vulnerable than harbours with a small amount of passing vehicles. The number of vehicles that are presented below is the sum of the passing vehicles per off ramp per harbour (for example, for the Botlek harbour, the amount of passing vehicles that passes the off ramp 16, 15, 14 and 13 are counted up)

<table>
<thead>
<tr>
<th>Harbour</th>
<th>Morning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botlek</td>
<td>13786 vehicles</td>
</tr>
<tr>
<td>Eurooport</td>
<td>6455 vehicles</td>
</tr>
<tr>
<td>Heijplaat</td>
<td>6179 vehicles</td>
</tr>
<tr>
<td>Vondelingenplaat</td>
<td>4901 vehicles</td>
</tr>
<tr>
<td>Maasvlakte 1</td>
<td>2766 vehicles</td>
</tr>
</tbody>
</table>

C. Speed between off ramps
The average speed on the A15 is a indicator of a possible traffic jam. For this criterion the average speed on the A15 during the morning peak (which takes three hours) around the different harbours are presented. This speed could not be determined after off ramp 11, so no information of the average speed around the Maasvlakte is available. Based on the list with the daily congestions can be concluded that no traffic jam will be occurred between off ramp 11 and the Maasvlakte. That is why an average speed of 100 km/hour will be taken for that location.
THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

D. Number of off ramps
The amount of off ramps per harbour determines the possibilities of alternative routes in case congestions. The higher the amount of off ramps, the more possibilities are present and the less a harbour is vulnerable.

1) Europoort: 4 off ramps
2) Botlek: 4 off ramps
3) Maasvlakte I: 3 off ramps
4) Vondelingenplaat: 2 off ramps
5) Heijplaat: 1 off ramp

E. Number of ISPS related terminals
The number of ISPS related terminals in a specific harbour influence the total effects of the extra security measures. Each ISPS related terminal has to take extra security measures, which can effect the traffic situation. In case of a large amount of ISPS terminals, also a large amount of extra measures will be taken. In this research not all 140 ISPS related terminals will be taken into account. Only the most important and largest terminals are analyzed.

1. Europoort: 15 ISPS terminals
2. Botlek: 15 ISPS terminals
3. Heijplaat: 8 ISPS terminals
4. Maasvlakte 1: 7 ISPS terminals
5. Vondelingenplaat: 3 ISPS terminals

F. Type of terminals in a harbour

1. Maasvlakte 1: Oil, dry bulk and container terminals
2. Europoort: Oil, chemical, dry bulk and container terminals
3. Botlek: Oil and chemical terminals
4. Vondelingenplaat: Oil terminals
5. Heijplaat: Container and other terminals

G. Risk contours ISPS related terminals
On the risk card the risk outlines of all terminals in the Port of Rotterdam are given. Not every terminal has an outline and every contour has a different dimension. A lot of outlines and a large size of these contours lead to a more vulnerable place. This is because the large impact of a terroristic attack on these harbours (a large risk outlines means a bigger chance on a fatally security incident). In this criterion only the risk outlines of the ISPS related terminals are taking into account.

1. Europoort: 7 risk outlines with a total dimension of 8,29 km²
2. Maasvlakte 1: 4 risk outlines with a total dimension of 11,22 km²
3. Botlek: 4 risk outlines with a total dimension of 6,61 km²
4. Heijplaat: 2 risk outlines with a total dimension of 1,03 km²
5. Vondelingenplaat: 0 risk outlines

Ranking
In table 6 the scores for every harbour are given. A multi criteria analysis (MCA) will be used to determine the most vulnerable harbour in the Port of Rotterdam. A MCA is a
comparison method which is used to select and/or compare different alternatives (in this case different harbours). The MCA is the most suitable method to determine the most critical harbour because it is possible to compare different variables with different units. Each harbour is scored per criterion based on the values of the criteria, which are presented above. The harbour with the highest value per criterion is scored with 5 points. The other values are determined proportionally (if value 4 gets a score of 5 points, value 2 gets a score of 2.5). All criteria are just as important. In the last column the total score per harbour is given. Based on this score, the most vulnerable harbour can be determined. From the table can be concluded that the Botlek harbour is the most vulnerable harbour. For this harbour, several threat scenarios will be developed.

<table>
<thead>
<tr>
<th>Harbour</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G1*</th>
<th>G2*</th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maasvlakte I</td>
<td>2.03</td>
<td>1.36</td>
<td>2.46</td>
<td>3.75</td>
<td>2.33</td>
<td>3.5</td>
<td>2.86</td>
<td>5</td>
<td>23.29</td>
</tr>
<tr>
<td>Europoort</td>
<td>1.18</td>
<td>2.35</td>
<td>2.89</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5.69</td>
<td>30.11</td>
</tr>
<tr>
<td>Botlek</td>
<td>5</td>
<td>5</td>
<td>4.17</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>2.86</td>
<td>2.95</td>
<td>32.98</td>
</tr>
<tr>
<td>Vondelingenplaat</td>
<td>1.77</td>
<td>1.67</td>
<td>5</td>
<td>2.50</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td>0</td>
<td>13.44</td>
</tr>
<tr>
<td>Heijplaat</td>
<td>0.11</td>
<td>3.04</td>
<td>4.22</td>
<td>1.25</td>
<td>2.67</td>
<td>2</td>
<td>1.43</td>
<td>0.46</td>
<td>15.18</td>
</tr>
</tbody>
</table>

* G1 is number of risk outlines, G2 the size of these outlines

### 3.3 FUTURE DEVELOPMENTS

In the area analysis the current situation of the Port of Rotterdam is presented. A description of the current state of the harbour is given, based on the present port facilities and the road network. This is done for the total port and for five separated harbours. Next to that, the current traffic situation is presented. Based on this analysis the effects of the extra security measures on the traffic situation will be determined. In the near future different developments for the Port of Rotterdam are planned, like the construction of the Maasvlakte II and the expanding of the number of road lanes of the A15. After the realisation of these developments, the traffic situation on the road network around the Port of Rotterdam will be different than in the current situation. That is why the effects of the security measures also will be studies in that future situation. The developments of the Port of Rotterdam will be presented now.

#### Construction of the Maasvlakte II

The Port of Rotterdam has an urgent need of extra area for new large scale activities. With the current port area it is not possible for the Port of Rotterdam to growth. To overcome this problem, in September 2008 the construction of the Maasvlakte II is started. This new harbour has a surface of 10 km² which is intended for port facilities, which is a expanding of the current port area of 20%. The first ships will be anchor in 2013, while the total construction of the Maasvlakte II will be finished yet in 2030. (Port of Rotterdam, 2007)

#### Expanding number of road lanes of the A15/N15

A good disclosure of the Port of Rotterdam is essential for a good functioning harbour. The A15/N15 is, as mentioned before, the only highway that crosses the Port of Rotterdam from west to east and is the most important disclosing road in the harbour. The traffic on the A15 has grown a lot the last few years and also the coming year a lot more traffic is expected
through the construction of the Maasvlakte II. Through the growth of the amount of vehicles, the capacity of the A15/N15 is not sufficient anymore, which endanger the accessibility of the Port of Rotterdam. (Eurlings, C. and Baljeu, J., 2008)

In the oncoming years the A15/N15 will be expanded. These extensions have to improve the accessibility and safety of the Port of Rotterdam and have enough capacity till 2020. After that year, possible capacity problems can occur. (Eurlings, C. and Baljeu, J., 2008)

The expanding can be split up into two regions. The first one is between the Maasvlakte and the Beneluxplein. On this trajectory the N15 (between Maasvlakte and the connecting with the N57) will be rebuild onto a city highway. Next to that the number of road lanes on the A15 (between the connection with the N57 and the Beneluxplein) will be enlarged. The Botlekbrug will be renewed to a 2x2 highway by which it becomes a better alternative for the Botlekbrug. The second region is between the Beneluxplein and the Vaanplein. This part of the A15 will be expanded to a 2x3 and 2x2 road structure. The 2x2 road lanes are parallel roads for off going vehicles. (Eurlings, C. and Baljeu, J., 2008)

In this chapter the most critical harbour of the Port of Rotterdam for this research is presented. Based on an area description and a traffic analysis the Botlek harbour is the most critical harbour. For the Botlek the effects of the anti terroristic measures will be determined. In the next chapter several scenarios will be developed for this harbour.
As mentioned in chapter one, to determine the effects of extra security measures in case of a raised terroristic threat, several threat scenarios will be developed. Per scenario, a specific threat situation will be described followed by the anti terroristic measures that can be taken in that specific situation. The reason to use scenarios is the uncertainty about threat situations that can occur. Several situations can take place in the future, which can not be precisely forecasted. Another reason to use threat scenarios is the confidential character of the anti terroristic measures. The measures taken by ISPS related terminals are not available, because of their confidential character. Based on possible threat scenarios, several security measures will be developed.

A scenario is a tool to forecast a possible future. It outlines a view of a situation that possibly can occur in the future, without linking a probability to that view. (Enserink et al, 2004) These scenarios represent different possible threat situations that can occur. The development of the scenarios in this report is globally based on the process of Enserink and is done with the help of four specialists of ARCADIS. During a brainstorm session a list of different variables are thought. Each variable could have several conditions, which has firstly a general characteristic. By combining the general conditions of all variables (one condition per variable) a scenario frame will be created. After combining all variables a list with several scenario frames exists. From this list a selection must be made of a few frames, because not all scenario frames will be used in this project. This is because it is not appropriate and useful to work with a large amount of different scenarios. (Enserink et al, 2004) To measure the effects of the anti terroristic measures, specific scenarios are needed. These scenarios are obtained by concretising the general conditions of the variables based on the list with critical spots in the Port of Rotterdam.

In each scenario several security measures will be taken. During the brainstorm session, also a list with possible security measures is made. These measures are linked to the scenarios, whereby the measures per scenario become clear. In the description of the concretized scenarios, also the relevant measures will be presented.

In this chapter the scenarios are developed and finally described. First of all in section 1 the variables with their possible conditions and all combinations between these variables will be presented. After that the scenario frames will be presented in section 2, followed by the choice of the frame works that will be analyzed in section 3. Before concretizing the frame works into specific scenarios in section 5 the list with possible security measures will be given in section 4.
4.1 VARIABLES, CONDITIONS AND COMBINATIONS

In this section the variables with their general conditions will be described. Per condition an example of a concretizing is given to clarify the variable and its conditions. Furthermore, some restrictions and demarcations of combinations of variables with each other are made.

ISPS level

The first factor is the height of the threat level. The ISPS code has three possible threat levels which determine the probability of the possible security incident. Per scenario one of these levels can be chosen.

Security level 1: This security level is the normal situation (business as usual) in which no higher threat occurs. The minimal security measures will be taken, that has been tightened up since 1 July 2004.

Security level 2: In a situation with security level 2, it is more likely that an attack will occur. This will result in more and stricter measures.

Security level 3: In this situation, a security incident is very plausible. In this case, the measurements of level 2 will be intensified.

Only level 2 and level 3 will be used to create scenarios. The standard ISPS level 1 will not be used, because no extra measures will be taken in that case.

Location of threat

The ISPS level can be increased in the whole Port of Rotterdam or in separate parts of the port. In the first case, it is not sure where a possible security incident will occur. This is a very unsure situation, which result in more and more general measures when a specific location is known.

The exact position of the threat will influence the effects for the traffic of the extra security measures. Extra measures on the Maasvlakte will have less influence than measures around the Botlek. This is because of the amount of traffic that passes the Botlek and the Maasvlakte.

Next to the distinction between the whole port and separate parts also a distinction can be made between the numbers of terminals that is threatened in a part of the harbour. It is possible that only one port facility is threatened. In that case, terminal specific measures will be taken.

Object that is threatened

In the Port of Rotterdam two different kinds of objects can be threatened. The first group are the ISPS related terminals. In Rotterdam, more than 140 terminals are obliged to handle the ISPS code and take security measures in case of a raised threat level. All these terminals can be threatened alone (for example the ECT Delta terminal), but it is also possible that a small group of terminals is endangered (for example all Shell terminals).

Next to the terminals also the road infrastructure in the Port of Rotterdam can be endangered. The most likely parts of this structure that will be threatened are the bridges (for example the Suurhoffbrug) and tunnels (for example the Botlekbrug), because of the possible economic and social effects of an attack and their importance for the traffic on the A15.

Also a terroristic threat with an unknown target can occur. In that case, the scenario will be very general. A large scope of measures has to be taken in that case.
Origin of threat
It is important to know from where an object is threatened. There are three possible origins of the threat. The first origin is the landside. In this case, the extra security measures must be taken on the road entrance of the terminals or on the road infrastructure. The other two possibilities are the waterside of the harbour and through the air. For this variable a demarcation is made. In case of a threat from the waterside of the Port of Rotterdam, measures will be taken on the quays of the terminals (e.g. extra control of the cargo which is deposited on the terminal), or measures onboard of the ships. It is not likely that these measures will have a big impact on the traffic situation on the road network around the Port of Rotterdam. That is why this condition will not be taken into account.
Also the threat from the air will not be take into account. An attack form the air can not be stopped by measures that influence the road network. The only effective measure is a total evacuation of the threatened area. In other scenarios, this measure will also come back. That is why scenarios with a threat from the air will not be analyzed. These two reasons have as a result that the variable origin of the threat is assumed as a constant, with condition number 11, a threat from the landside.

Kind of threat
The last uncertainty that is relevant in this study is the kind of threat. Several kinds of threats can exist, like explosions, gas attacks and so on. For this variable also a demarcation is made and is a result of the previous demarcation. The anti terroristic measures that will be taken are independent of the kind of threat. In all cases only measures will be taken into account that has a direct effect on the traffic situation. These measures are not influenced by the type of threat. That is why this variable will not be taken into account.

In table 7 all the variables with their possible conditions are given. After the demarcations for the variables origin of threat (D) and kind of threat (E) only one standard condition for these variables will be used. These variables will not be mention anymore and are not placed in table 7. For the variable threat level condition level 1 will be denied and not mentioned anymore.
Table 7: Characteristics of the threat scenarios with their possible conditions

<table>
<thead>
<tr>
<th>Factor</th>
<th>Conditions per factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISPS level</td>
<td>Level 2</td>
</tr>
<tr>
<td></td>
<td>Level 3</td>
</tr>
<tr>
<td>Location of threat</td>
<td>Whole Port of Rotterdam</td>
</tr>
<tr>
<td></td>
<td>Specific harbour</td>
</tr>
<tr>
<td></td>
<td>Specific terminal</td>
</tr>
<tr>
<td></td>
<td>Specific part of the infrastructure</td>
</tr>
<tr>
<td>Object</td>
<td>Object not known</td>
</tr>
<tr>
<td></td>
<td>Terminal</td>
</tr>
<tr>
<td></td>
<td>(Road) Infrastructure</td>
</tr>
</tbody>
</table>

Based on the different conditions of the variables in table 7 24 \(2^2 \times 4 \times 3\) combinations can be made. To reduce this amount of possible combinations some restrictions are made. It is not always possible to combine every condition with each other because of their contradicting character. The following combinations are not possible:

*Object not known with specific terminal and specific infrastructure:*
In case of a situation with an unknown object, it is not possible that a specific terminal or part of an infrastructure is known.

*Specific terminal with (road) infrastructure and specific infrastructure and terminal:*
In case of a situation where the object is known, it is not possible that a specific other objects is threatened.

Next to these restrictions it is also not possible to combine two conditions of a variable. Table 8 shows the combinations between conditions that are not possible.

Table 8: Restrictions for combinations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conditions</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Port</th>
<th>Harbour</th>
<th>Spec. term.</th>
<th>Spec. infra</th>
<th>Object</th>
<th>Terminal</th>
<th>Infra</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISPS level</td>
<td>Level 2</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level 3</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of threat</td>
<td>Whole Port</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific harbour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific terminal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object</td>
<td>Object not known</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>(Road) Infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After the restrictions sixteen possible combinations between conditions of the variables are remained. In table 9 the remaining combinations are given. These combinations will be used as the scenario frames which will be concretized in section 5.
Table 9: Remaining combinations/scenario frames

<table>
<thead>
<tr>
<th>Combination/Scenario frames</th>
<th>ISPS level</th>
<th>Location of threat</th>
<th>Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Level 2</td>
<td>Whole Port of Rotterdam</td>
<td>Object not known</td>
</tr>
<tr>
<td>B.</td>
<td>Level 3</td>
<td>Whole Port of Rotterdam</td>
<td>Object not known</td>
</tr>
<tr>
<td>C.</td>
<td>Level 2</td>
<td>Whole Port of Rotterdam</td>
<td>Terminal</td>
</tr>
<tr>
<td>D.</td>
<td>Level 3</td>
<td>Whole Port of Rotterdam</td>
<td>Terminal</td>
</tr>
<tr>
<td>E.</td>
<td>Level 2</td>
<td>Whole Port of Rotterdam</td>
<td>(Road) Infrastructure</td>
</tr>
<tr>
<td>F.</td>
<td>Level 3</td>
<td>Whole Port of Rotterdam</td>
<td>(Road) Infrastructure</td>
</tr>
<tr>
<td>G.</td>
<td>Level 2</td>
<td>Specific harbour</td>
<td>Object not known</td>
</tr>
<tr>
<td>H.</td>
<td>Level 3</td>
<td>Specific harbour</td>
<td>Object not known</td>
</tr>
<tr>
<td>I.</td>
<td>Level 2</td>
<td>Specific harbour</td>
<td>Terminal</td>
</tr>
<tr>
<td>J.</td>
<td>Level 3</td>
<td>Specific harbour</td>
<td>Terminal</td>
</tr>
<tr>
<td>K.</td>
<td>Level 2</td>
<td>Specific harbour</td>
<td>(Road) Infrastructure</td>
</tr>
<tr>
<td>L.</td>
<td>Level 3</td>
<td>Specific harbour</td>
<td>(Road) Infrastructure</td>
</tr>
<tr>
<td>M.</td>
<td>Level 2</td>
<td>Specific object</td>
<td>Terminal</td>
</tr>
<tr>
<td>N.</td>
<td>Level 3</td>
<td>Specific object</td>
<td>Terminal</td>
</tr>
<tr>
<td>O.</td>
<td>Level 2</td>
<td>Specific object</td>
<td>(Road) Infrastructure</td>
</tr>
<tr>
<td>P.</td>
<td>Level 3</td>
<td>Specific object</td>
<td>(Road) Infrastructure</td>
</tr>
</tbody>
</table>

In figure 14 the remaining possible scenarios frames from the table above are schematically presented. Each last rectangle is a scenario frame, which can have ISPS level 2 and 3. In the following section these frames will be described in more detail.

![Figure 14: Remaining scenarios](image-url)
SCENARIO FRAMES

In this paragraph a description of all scenario frames will be given. Frames with the same object and location, but with a different ISPS level will be described together. First all scenarios with a threat in the total Port of Rotterdam will be described, followed by the scenarios for specific harbours. Finally the scenarios with a specific object that is threatened will be presented.

**Port of Rotterdam**

For the first scenario frames the total Port of Rotterdam will be threatened. During these scenarios different objects could be threatened, which are spread over the total Port.

*Scenario frame A and B: Threat on an unknown object in the whole Port of Rotterdam*

In this scenario the total harbour experiences a raised ISPS level, but the exact object is not known. This results in a very big threatened area, without any knowledge about the object.

*Scenario frame C and D: Threat on a terminal in the whole Port of Rotterdam*

In this case, a terminal is endangered but information about the exact location of this terminal is not available, through which the exact location of the threat is not known. In this situation, every terminal has to take extra security measures to secure itself against a security incident.

*Scenario frame E and F: Threat on a infrastructure in the whole Port of Rotterdam*

In this case, a part of the infrastructure is endangered but information about the exact location of this part is not available, through which the exact location of the threat is not known. In this situation, every part of the infrastructure must be protected to secure it against a security incident.

**Specific harbour**

During the following scenario frames only a specific harbour, which are presented in the previous chapter, is threatened. During these scenarios different objects could be threatened, which are located spread over the total specific harbour.

*Scenario frame G and H: Threat on a random object, but in a specific part of the Port of Rotterdam*

In this scenario a specific part of the Port of Rotterdam is endangered. This could be one of the five harbours (presented in chapter xx) or little fraction of these harbours. It is still unsure which object is threatened, so measures must be taken that secure all the terminals and infrastructure in the specific area.

*Scenario frame I and J: Part of the Port of Rotterdam*

In this situation the location of a possible security incident is defined. This result in a more exact threat area, with a clear description of the present ISPS related terminals and more specific security measures. This scenario can occur for the five separated harbours, which are mentioned in chapter 3, or smaller parts of these harbours.

*Scenario frame K and L: Part of the Port of Rotterdam*

In this situation the location of a possible security incident can be defined more surely than in the scenario above. This results in a more exact threat area, with a clear description of the present parts of the infrastructure and more specific security measures. This scenario can
occur for the five separated harbours, which are mentioned in chapter 3, or smaller parts of these harbours.

**Specific object**
In the last frames a specific object in threatened. This results also in a specific harbour. During these frames a specific terminal or infrastructure could be threatened.

**Scenario frame M and N: Specific terminal(s)**
In contrast to the previous scenarios, the exact location of the threatened terminal(s) in this situation is familiar. It is possible that on of the 140 ISPS related terminals is endangered, but also 2 or three terminals can be threatened (for example, all the three ECT terminals).

**Scenario O and P: Specific part of the infrastructure**
In contrast to the previous scenarios, the exact location of the threatened part(s) of the infrastructure in this situation is familiar. It is possible that each part of the infra is endangered, but also 2 or three parts can be threatened (for example, both tunnels in the Port of Rotterdam).

### 4.3 SCENARIO SELECTION

As mentioned before, the scenarios, which are mentioned above, must be concretized to get specific information. The specified scenarios will be used to measure the effects of anti terroristic measures. Before the scenarios will be concretized, five scenarios frames will be chosen. Not all the scenarios frames will be analyzed in this report; only several scenarios will be chosen which are relevant for this project. This is done because it is not appropriate and useful to work with a large amount of different scenarios (Enserink et al, 2004). The choice of the scenario frames are based on two criteria on which all scenario frames will be scored. Both criteria have four different values which all scenario frames could have, based on the conditions of the factors mentioned in section one. By combining both criteria a matrix, with both criteria on the axis, can be made. All scenario frames can be placed in this matrix. Finally, five frames will be selected based on the locations of all frames in the matrix. In this section, first the criteria on which the choice is based and their possible values are presented, followed by the matrix and finally the choice of the five scenarios.

### 4.3.1 CRITERIA: COMPLETENESS OF INFORMATION AND SEVERITY

The choice of the analyzing scenarios in this report is based on two possible criteria; the completeness of the available important information and the severity of the threat. Both criteria have four different values. The criteria and their values will be described now.

**Completeness of available important threat information**
The availability of important information about the threat determines the completeness of this threat. In case of a threat with incomplete information, important data about some factors (given in table 7 above) is missing. This results in an incomplete threat where more general measures are necessary. The other side of this direction is the complete threat, where very specific information is available. In this case more specific measures could be used. The following values in which scenarios could be placed are possible for this direction:
THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

Incomplete threat situation
In the most complete threat scenario for all factors the most doubtful condition will be used. This means that no specific information is available.

Semi incomplete threat situation
In this case, information of one factor is available, but the other two factors are just not known.

Semi complete threat situation
For a semi complete threat situation it is necessary that the object and the location are identified. It is not necessary to know the specific terminal or infrastructure, but information about the part of the Port of Rotterdam in which the object is located is important.

Complete threat situation
In this situation, all necessary information is available. The specific terminal or infrastructure is known, just like the kind of threat.

Severity of threat
The type of threat stipulated how violent the situation is. During an extreme threat the most radical measures will be taken. The effects of these measures on the traffic situation shall be larger than in case of a smaller threat. The seriousness of a threat will be determined by the threat level, the terminals and infrastructure that are endangered and the size of the area where these terminals or infrastructures are located. The following values in which scenarios could be placed are possible for this direction:

Extreme threat situation
In the most extreme situation, the total port of Rotterdam will be threatened, in such a way that the ISPS level has code 3. In this situation, all the objects in the harbour are endangered. It is not sure that in this situation the port activities will continue and one of the measures could be evacuation.

Semi extreme threat situation
In this situation, some of the factors mentioned above (threat level, kind of terminal/infrastructure or the size of the area) must be extreme, but not all of them.

Semi non extreme threat situation
A semi small threat situation can occur in case of ISPS level 3 in case of a threat for a single terminal or infrastructure, which are not critical*, or in a situation with level 2 in a larger area.

Non extreme threat situation
In this case, a small threat exists. This could only be the case with an ISPS level 2 in a small area for non critical terminals or infrastructure.

In figure 15 a matrix is presented with both criteria on an axis. All scenarios can be placed into the matrix by which a distinction occurs between the scenarios.

* Critical terminal: Chemical terminal. Critical infrastructure: Bridges and tunnels

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THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

<table>
<thead>
<tr>
<th>Completeness of information about threat situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
</tr>
<tr>
<td>Non Extreme</td>
</tr>
<tr>
<td>Semi non extreme</td>
</tr>
<tr>
<td>Semi extreme</td>
</tr>
<tr>
<td>Extreme</td>
</tr>
</tbody>
</table>

Figure 15: Scenario-matrix with criteria

Each scenario mentioned above is located in this matrix. The severity of the scenarios M, N, O and P is not known. It is depending on the characteristics of the specific terminal or infrastructure. A threat on the Botlektunnel is more heavy threat than a threat on a small road to a small terminal.

4.3.2 SCENARIO CHOICE

Enserink et al give no procedure to choose several scenarios that are placed in the scenario-matrix. There are only three restrictions: Each scenario has to have an own characteristic, must be realistic, and all the scenarios together must be representative for the spectrum of all possible future situations. (Enserink et al, 2004) Every scenario in the matrix satisfies the first two restrictions. By choosing the scenarios in such way that every part of the matrix is represented by one or more scenarios, the last restriction is also satisfy. Keeping this in mind the following scenarios are selected.

Scenario 1: Frame I Terminal in a specific harbour with ISPS level 2
Scenario 2: Frame N Specific terminal with ISPS level 3
Scenario 3: Frame P Specific road infrastructure with ISPS level 3
Scenario 4: Frame G Unknown object in a specific harbour with ISPS level 2
Scenario 5: Frame B Unknown object in the whole Port or Rotterdam with ISPS level 3

In the following paragraph the anti security measures that terminals take are presented. In the last paragraph the scenarios will be concretized, based on the area analysis, that is made chapter 3. In the description of the concretized scenarios also the scenario specific measures will be presented.

4.4 SECURITY MEASURES AND SCENARIOS

In this section a short description per security measure is given. First, in sub-section 1 several possible measures will be described. These measures are also thought during the internal workshop with the specialists of ARCADIS. In sub section 2, the measures will be linked to the chosen scenarios.
4.4.1 ANTI TERRORISTIC MEASURES

In this section a description of some possible security measures will be given. In this description will be described why this measures will be taken and how this is done.

More and stricter control at the entrance
The most simple security measure is to intensify the control at the ports of the terminals. Possible actions during this measure are control of the cargo of the trucks, extra control of the personal data of the drivers, extra control of the truck company and so on. Also personal cars that enter the terminal must be checked carefully.

The result of the extra and longer controls at the entrances of threatened ISPS related terminals could lead to longer waiting queues, which could reach the underlying road network. After a while, these queues could also get to the off ramps to the A15 and create congestion on that highway.

Closes entrances of terminals
In case of a threat on a terminal, the amount of entrances of the terminals could be decreased. A decreased number of entrances can result in a better overview of vehicles and persons that enter the terminal. Another reason to do this is the availability of security employees. When more and stricter controls are done by the entrance, more security guides are necessary. These guides are not always (directly) available. By closing an entrance, the security people that work by that access could help by other entrances.

By closing entrances of terminals more vehicles have to enter the terminal via fewer entrances. This could lead to longer waiting queues, especially in case of longer and extra controls at the entrances, which is described above.

Inspection of all the traffic to identify the shady vehicle
During this measure all the vehicles that enter the Port of Rotterdam or a part of the harbour will have an inspection to identify the shady vehicle. During a threat when a specific car is search, every car must be controlled very quickly by which the shady vehicle could be discovered in case that car enters the threatened area. This control leads also to a long waiting queue before the control post and finally to congestion.

Extra supervision
This security measures means that around the road network and the terminals in the endangered area extra supervision is present. Actions that can take are snipers, armoured cars and extra police or army. These actions lead to a lower speed on the surrounding roads. This is because of the inferring character of these anti terrorist measures (it could be compared with a situation with a crash on a highway. In most of the times, also congestion occurs on the contradicting road lane. This congestion is occurred by "watchers").

Split up traffic flows
In this measure different kind of vehicle flows are separated. So, separated road lanes for trucks and cars exist. The exact excepted effects of this measure are not known, but it could lead to lower speed or even congestion on specific road lanes.
Evacuation (people or the source)
This is a very heavy security measure. Two different forms of evacuation exist. The first one is to evacuate all people who are present in the threatened area (a terminal, part of the harbour or the total Port of Rotterdam). This will lead to a lot of extra (port) outgoing traffic on the road network. Another kind of evacuation is to abandon the source of the threat (e.g., a container with explosives in it).

Only primary tasks
During a terrorist threat on a terminal it could be decided that only the primary tasks of that terminal are continued. In that case, all the office employees should leave the terminal, and are not allowed to come back before the end of the threat.

(Partly) Close roads (parallel), areas, off and on ramps, bridges and tunnels
In case of emergency, some infrastructural components could be closed. In general, these measures will be used during an ISPS level 3. The effects of a measure like this on the traffic situation could mostly be very big. It depends of the exact location which part will be closed. It is also a possibility to close some roads for certain vehicles, like the freight transportation.

Control on a distance
Another way of controlling vehicles that have to enter the threatened area is to control these vehicles on a distance of the Port of Rotterdam or terminal. The exact ISPS level determines the exact control at these posts, and which vehicles must be checked.

The first six measures that are described will influence vehicles directly. The last three measures do not influence the traffic situation around the Botlek directly. These measures will not be taken into account. In figure 16 the first six possible effects of the anti terroristic measures are presented in a flow diagram. The measures are split up into two categories, namely general measures and terminal specific measures. In this diagram the effects of the evacuation are not presented. The other five anti terroristic measures are presented in the red rectangles.
In this sub-section all anti terroristic measures which have directly influence on the traffic situation are presented. In the following sub-section these measures are linked to the scenarios.

**SCENARIOS LINKED WITH SECURITY MEASURES**

In the previous sub-section all anti terroristic measures that have a direct influence on the traffic situation are presented. In this sub-section these measures will be linked with the scenario frames. This is also done with the help of the four specialists of ARCSDIS. In table 10 per scenario the extra security measures are given.
During the workshop with the four specialists of ARCADIS the measures are linked to the scenarios. In case of a threat on one or more ISPS terminals, scenario 1, 2 and 4, always stricter and more controls at the entrance will be taken and some entrances will be closed. With these measures the change that the terroristic threat enters the terminals decreased. During all scenarios, except scenario 5, extra supervision will take place. This is done to have an overview over the threatened area and identify shady vehicles or persons. Another measure take will be taken in every scenario is the split up of the traffic flows. This is done to separate trucks and personal vehicles. During scenario three and four, in which the Botlektunnel is threatened, all traffic will be controlled/scanned before the tunnel. By doing this the shady vehicle could be identified.

4.5

**CONCRETIZE SCENARIOS FRAMES**

Because of the general characteristic of the conditions, scenarios are not concretized. Based on the list with critical spots in the Port of Rotterdam the scenarios will be concretized, which results in specific scenarios. This is done based on the area analysis, which is presented in chapter 3.

In the first four scenarios, a specific part of the Port of Rotterdam is threatened. As mentioned before in the area analysis, five separated harbours could be identified, which all could be endangered. In this research only one of these harbours will be analyzed. Based on the analysis, the most critical harbour is defined, namely the Botlek Harbour. The Botlek will be used to determine the effects of extra security measures.

**Scenario 1: Threat on an unknown terminal, in the Botlek harbour with ISPS level 2.**

In this scenario all terminals in a specific harbour are threatened with ISPS level 2. In this situation, all terminals in the Botlek harbour will suffer a higher risk on a security incident, with an ISPS level 2. During this situation, extra security measures must be taken. First of all, all ISPS related terminals have to take terminal specific measures. This report focuses, as mentioned before, only on the security measures that will be taken on the landside of the terminal. In section
4.4 all possible measures that could be taken by the terminals are given. The most important measures that can be taken by the terminals are more and stricter controls at the entrances. In this scenario, with threat level 2, each vehicle will have a longer control at the entrance of the terminal. As mentioned in the previous section, trucks will suffer an extra control of five minutes and personal cars of two minutes. In figure 16 the entrances of the ISPS terminals are presented by the black circles. Before these entrances the extra security measures will be taken by the terminals. For the second terminal specific measure entrances of terminals will be closed. The only terminal in the Botlek with more than one entrance is the Esso Nederland terminal. The entrance of the Esso Nederland terminal that will be closed is presented by a red circle, the entrance that stays open with a blue circle in figure 17.

![Figure 17: Entrances of ISPS related terminals in the Botlek](image)

For the last terminal specific measure two traffic flows will be created before the entrances of the terminals. Separated waiting queues will be created, one for trucks and one for normal vehicles. Next to the terminal specific measures also a general measures will be taken. Around the Botlek harbour more supervision is created. This supervision leads to lower speed on the A15.

**Scenario 2: Threat on (a) specific terminal(s) with an ISPS level 3.**

This scenario exists of three parts. In the first part (scenario 2a) some terminals that are located at the Oude Maasweg in the Botlek will be threatened. The rest of the Botlek harbour is not threatened. In figure 18 the entrances of the threatened terminals are presented by the circles.
The same anti security measures as in scenario 1 will be taken by the ISPS related terminals on the Oude Maasweg. The only difference is the longer extra control time of the entering vehicles because of the higher ISPS level.

In the second part (scenario 2b) only the terminal with the most entering traffic will be threatened. In the scenario 5b the Esso Nederland terminal, located on the Botlekweg and the Welplaatweg will be threatened. In figure 19 these entrances are presented by the blue and red circles. The red entrance will also be closed in this scenario and the blue one will be the only entrance to this terminal. Also here the same measures will be taken as during scenario 1 and 2a.
In the third part (scenario 2c) of this scenario, scenario 2c, only the most northern terminals on the Welplaatweg are threatened. These terminals are located after the right turning corner and are presented by the circles in figure 20. Also in this scenario the same measures will be taken as during the scenarios above.
Scenario 3: Threat on the Botlektunnel with ISPS level 3.
In the third scenario only the Botlektunnel is threatened, with an ISPS level 3. This already happened once, during a bomb alarm on the Botlektunnel in September 2001. In figure 21 a photo of that situation is presented. Only one road lane was available before entering the tunnel. In 2001, a clear description of the shady vehicle was given. In that case all vehicles have to pass a control post, will be quickly scanned/controlled and only the vehicle with the characteristics of the shady vehicles will be controlled very carefully. Next to that also extra supervision around the Botlek will be commenced and must all trucks drive over the Botlekbrug instead of the Botlektunnel.

![Bomb alarm Botlektunnel September 2001](image)

Scenario 4: Threat on an unknown object in the Botlek harbour with ISPS level 2.
In this scenario the exact location of the threatened area is known. In this situation, the Botlek harbour is threatened with an ISPS level 2. Contradicting with the first three scenarios the exact object of the threat is not known, so all terminals and parts of the infrastructure are possible targets for an incident. All anti terrorist measures that were presented in the first scenarios will also be taken in this situation.

Scenario 5: Threat on an unknown object in the whole port of Rotterdam, with an ISPS level 3.
The last scenario is the heaviest situation that can occur in the Port of Rotterdam. This is because the highest ISPS level is present, there is uncertainty about the object that is threatened and the uncertainty about the location of the threat. In this situation, the total Port of Rotterdam will be evacuated, because of the very serious situation.

In this chapter the threat scenarios are presented. These scenarios will be simulated in a traffic model to determine the effects of the anti terrorist measures. In the following chapter the experimental setup will be described in which the traffic model and the criteria will be presented.
Experimental setup

In this chapter the experimental setup of the research will be presented. In figure 22 all components of the experiment are given in a flow diagram.

Figure 22: Experimental steps

This chapter describes these components in sequential order. In the previous chapter the scenarios with anti terroristic measures are described and presented. These scenarios with
measures are the input of the traffic model that will be used to simulate the threat situations. For this research the microscopic software packet Vissim is used. An existing Vissim model of the Port of Rotterdam will also be used as the input for the finally model. In section one will be explained how these external inputs will be used to develop the Vissim model. Also other building steps of the Vissim model will be presented in that section. Next to the traffic model also criteria are necessary to determine the effects of the anti terrorist measures on the traffic situation. The traffic situation is based on several criteria. These criteria will be presented in section two. The Vissim model and the criteria are used as input for the experiment. This experiment exists of two phases. The first phase is the determination of the effects of the threat scenarios and the second phase is the determination of the effects of some mandatory reroutings for the most average scenario. In section three these phases will be described.

5.1 TRAFFIC MODEL

In this section the traffic model that is used to analyze the traffic situation will be presented. As mentioned in the introduction of this chapter the microscopic traffic model Vissim will be used. In the first sub-section the choice for this kind of model will be explained. In the second sub-section the construction and adjustment of the chosen model will be explained followed by the description of the routes and amount of traffic in the model. To ensure that a correct model is used, in sub-section four the model is validated. In this validated model the anti terroristic measures must be added. In sub-section five this will be described. The last two steps of the model construction are the determination of the amount of runs and the description of the duration of one simulation run.

5.1.1 MODEL CHOICE

As mentioned in the introduction of this chapter, a Vissim model will be used to analyze the effects of several anti terroristic security measures. In this sub-section will be explained why this model is chosen. A choice must be made between three different kinds of traffic models exist, namely the micro-, macro- and mesoscopic models. A macroscopic model simulates the traffic as a homogeneous flow, in which no individual vehicles can be distinguished. All vehicles are the same and show the same behaviour. A microscopic model considers each vehicle separate as a black-box with its own driving behaviour. The interaction between the separate vehicles becomes intelligible by the use of such a model. Mesoscopic models are a mixture of the macro- and microscopic models. The behaviour of small packets or groups of vehicles will be simulated. This type of model, which is relatively new, will be used to simulate larger areas with a higher detail level than macroscopic models.

For this research a microscopic traffic model will be used to simulate the traffic situation in the Port of Rotterdam. The most important reason for this is the availability of a Vissim model of the Port of Rotterdam. An earlier research to the traffic situation in the Port of Rotterdam, done by Jop Vlaar, was done with the help of the microscopic software packet Vissim. In this packet, the Port of Rotterdam was modelled. Another reason to choose a microscopic model is that a microscopic model can simulate the exact location, duration and length of any congestion very clearly and the interaction between the vehicles becomes clear.
5.1.2 MODEL ADJUSTMENT

As mentioned in the previous sub-section the Vissim model of the Port of Rotterdam of Jop Vlaar serve as a basis for the simulation model for this research. In figure 23 this model is presented.

This existing Vissim model of the Port of Rotterdam that will be used must be adjusted for this research. First of all, the underlying road network of the Botlek harbour and the entrances of the terminals must be added to the model. In the existing Vissim model only the most important roads of the Port of Rotterdam are included, like the A15 and the A4, the N218/ Groene Kruisweg (which is located on the south of the Port of Rotterdam and runs parallel to the A15) and the port route, which exists of the Vondelingenweg, Botlekweg and Moezelweg. To simulate a situation with a raised ISPS level in the Botlek area, the Welplaatweg and the Oude Maasweg must be added. These roads are the most important disclosure roads in the Botlek to several terminals. Also the entrances of these terminals must be modelled to get insight into the situation at the entrances during a raised terroristic threat.

Next to this extension, also a simplification of the model will be made for the region on the south side of the Port of Rotterdam. The Vissim model is based on the Regionale VerkeersMilieu Kaart (RVMK). This card splits the region of the Port of Rotterdam into several zones. All these zones are split up into several sub zones. Transfer of different types of vehicles takes place between all the (sub) zones. In figure 24 all the zones are presented.
The Port of Rotterdam exists of the zones 15, 16, 17, 18 and 32. In the model, zone 16 is split up into the different sub zones by adding the underlying roads, as mentioned above. In the Vissim model of Jop Vlaar the zones on the South side of the Port of Rotterdam (21, 22, 23, 33, 34, 35, 36 and 45) are partly split up. Per zone, a few sub zones are created that will be used as an origin and destination. For this research, these zones will not be split up. Each zone will be used as an origin and destination and generates all the traffic that departs from that zone. This is done to decrease the amount of origins and destinations and the amount of route decisions. The zones are connected with the N218/ Groene Kruisweg.

 ROUTES AND TRAFFIC

In the previous step, the structure of the Vissim model was adjusted to the demands of this project. Now, the route decisions and the traffic assignment will be added to the model. As mentioned before, the region around the Port of Rotterdam is split up into several zones. The road network connects all (sub) zones with each other, which resulted in several possible routes between the areas. In the Vissim model only one route between the zones is added, based on a route planner (ANWB, 2009). This route, which is the most probable, will be taken by all the traffic between the two zones. This is done to decrease the amount of possible routes which will reduce the amount of work to add all routes into the model.

Next to the route decision, also the traffic assignment must be added to the Vissim model. The zones are used as the origins and destinations in the Origin – Destination matrix, which
comes from the RVMK. This OD-matrix clarifies the amount of traffic between the (sub) zones. Based on this matrix, the amount of traffic that departs from an origin and the fraction of the departing traffic that goes to a specific destination become clear. This information, which will be added to the Vissim model, differs per part of the day. That is why two different models will be made, one for the morning peak and one for an off-peak period.

5.1.4 MODEL VALIDATION

After adding the route decisions and the traffic assignment to the Vissim model, the model must be validated. It is not necessary to make an exact copy of the reality, but the model must create a traffic situation that can occur on a random day during the given time period. To check if this condition is satisfied the results of the Vissim model will be compared with the real traffic data, which are obtained through the MoniCa counting points. In figure 25 the speed-contour plot of the A15 from Rotterdam to the Maasvlakte for the morning peak for the MoniCa data is given. In figure 26 the same plot is given for the Vissim data.

Figure 25: Speed contourplot MoniCa data
THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

In the plots the yellow/orange areas are the congested periods and locations. From the plots can be concluded that the period (between 15 and 90 minutes) and the location (between hectometre 44 and 50) of the congestion are approximately the same. Next to the yellow congestion area in the plot two remarkable issues need some attention. The first one is the blue line around hectometre 37 in the plot of the MoniCa data. This blue line indicates a higher speed for a distance of 300 meters. The counting points that measure the speed for this location are located in the Thomassentunnel, after the descent into the tunnel. This descent takes care for a higher speed, and is not added into the Vissim model.

The other issue is the higher speed during the free flow periods in the MoniCa plot. This could be a result of the method of determining the average speed. The average speed that is used is a so called "pointed average speed", which measured the average speed on a specific location. This mean speed is more influenced by faster vehicles, which passed the location more often than slower vehicles and resulted in a higher average speed. In Vissim, the determined average speed will be corrected for this disadvantage. This is not the case for the MoniCa data, which clarifies the difference between the average speed for the Vissim data and the MoniCa data. Generally, the Vissim model will be correspond with the real situation on the A15. In the next sub-section the anti terrorist will be modeled in the Vissim model.

5.1.5 ANTI TERRORISTIC MEASURES IN VISSIM MODEL

In the previous chapter several anti terrorist measures are described that could be taken in case of a terroristic threat. All these measures have directly influence on the traffic situation.
In this sub-section will be described how these measures will be implemented into the Vissim model.

**More and stricter controls at the entrances**

In the previous sub-section the entrances of all terminals in the Botlek are added to the Vissim model. The entrances for the ISPS related terminals are split up into two rows, one for trucks and one for normal vehicles. Both rows get an own traffic light, which is red during the control time and will be green for just one second, so only one vehicle can pass the traffic light. The exact control times of truck or personal cars are not found. That is why an assumption must be made of the extra control time in case of a raised ISPS level. In table 101 the assumed control times per vehicle type and per ISPS level are given. These times are the extra control times compared with the normal control situation at an entrance during ISPS level 1.

**Table 11: Extra control time at the entrances per ISPS level**

<table>
<thead>
<tr>
<th></th>
<th>Control time during ISPS level 2</th>
<th>Control time during ISPS level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks</td>
<td>5 minutes</td>
<td>7.5 minutes</td>
</tr>
<tr>
<td>Personal cars</td>
<td>2 minutes</td>
<td>4 minutes</td>
</tr>
</tbody>
</table>

**Close some entrances of ISPS related terminals**

Only in case of the Esso Nederland terminal more than one entrance exists. During the threatened periods only one entrance is open for the traffic. In section 4.5 the closed and open entrance of the Esso Nederland terminal are presented in the description of scenario 1 and 2b. In the Vissim model all routes to the closing terminal will be applied to the open entrance by which no traffic goes to the closed entrance.

**Inspection of all traffic**

This anti terrorist measure will be taken during a threat on the Botlektunnel. Only a few vehicles, which have the same characteristics as the shady vehicle, will be controlled very carefully, the rest of the vehicles must pass the control post before the tunnel and will be scanned/controlled very quickly. In the Vissim model only one road lane will be opened before the tunnel on which a maximum desirable speed of 15 km/hour apply.

**Extra supervision**

As mentioned in the previous chapter the average speed on the A15 will be decreased by the presence of extra supervision in and around the Botlek. For the reduction of the average speed an assumption is made. In the Vissim model the speed on the A1 around the Botlek is decreased from 100 km/hour to 65 km/hour.

**Split up traffic flows**

Before each entrance two separate waiting queues are modelled to split up the traffic flows of trucks and normal vehicles. This is done by two road lanes to the entrances of the terminals, one for the trucks and one for the normal cars. Both vehicle groups have their own routes to the right entrance road lane.

In case of scenario 3 the traffic flows of the trucks and personal cars will also be split up. All trucks have to pass the Oude Maas via the Botlekbrug and all cars via the Botlek tunnel. In the Vissim model the routes for all trucks are applied via the Botlekbrug and that of the cars via the tunnel.
Evacuation

The last anti terroristic measure is the evacuation of the threatened area. During scenario 5, (whole Port of Rotterdam is threatened with an ISPS level 3) the whole port must be evacuated. To simulate such evacuation a total other Vissim model must be made than the described model and other information is needed as input. By a lack of time, such a model will not be made and this scenario will not be simulated in the report.

Before the model can be used, in the next subparagraph the required number of runs will be presented.

5.1.6

NUMBER OF RUNS

The traffic flow off the model is determined by the amount of origins and destinations, the number of routes between these origins and destinations and the driving behaviour of the individual vehicles. The first two factors are constant in the used Vissim model; the last one differs per simulation run. This variable behaviour takes care for a variable traffic flow and because of that, changing outcomes per simulation run. To overcome these changing outcomes several simulation runs must be done, each with another random seed. The number of runs can be determined by the following formula (Muller, 2004):

\[
n \cdot t_{n-1, \alpha/2}^2 \cdot (1 + \frac{1}{n}) \cdot \frac{X^2}{X^2}
\]

\(X\)

The sample Standard Deviation

\(X_a\)

The accepted deviation

\(\alpha\)

The reliability

\(X\)

The abscise of the normal distribution attainability value

\(t\)

Value from the Student-distribution

For the criteria “average delay”, “total congestion” and “travel time between the A15 and the Maasvlakte”, which will be described in section two of this chapter, this formula is used to determine the amount of runs that is needed to get reliable results for these criteria from the Vissim model. The total congestion and the travel time are measured each five minutes. Per time period of five minutes the amount of runs must be calculated. In the table 12, per criterion the time period that needs the largest amount of runs is given. The average delay is measured for the total simulation run and not per five minutes.

Table 12: number of runs needed for the Vissim model

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Time period</th>
<th>Average</th>
<th>Accepted SD</th>
<th>SD</th>
<th>t-value (95%)</th>
<th>Amount of runs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total congestion</td>
<td>20</td>
<td>1067 meters</td>
<td>106.7</td>
<td>908.03</td>
<td>1.64</td>
<td>690</td>
</tr>
<tr>
<td>Travel time *</td>
<td>125</td>
<td>25.71 minutes</td>
<td>2.57</td>
<td>1.89</td>
<td>1.64</td>
<td>5.15</td>
</tr>
<tr>
<td>Average delay</td>
<td>x</td>
<td>4.08 minutes</td>
<td>0.41</td>
<td>0.08</td>
<td>1.64</td>
<td>1</td>
</tr>
</tbody>
</table>

* A15 - Maasvlakte

x: This criterion is determined for the whole simulation run
Based on this table, 690 runs must be made to determine the total congestion with a reliability of 95%. For this project only five simulation runs will be done because of a lack on time.

### 5.1.7 DURATION OF SIMULATION RUNS

The effects of the extra security measures will be determined for the morning peak and an off peak period in the afternoon. The morning peak is generally between 6.00 am and 9.00 am, so the simulation run takes three hours. To compare the situation during the morning peak and the off peak period, the off peak period will also take three hours.

In both situations, the simulation run starts with a warming up period of 15 minutes. This is necessary to get vehicles into the model. Otherwise, an empty road in the beginning will influence the results in a positive way.

### 5.2 CRITERIA

All scenarios will be scored on three criteria. Based on these scores scenarios can be compared with the current situation, with each other and with the same scenario with a mandatory rerouting. The criteria will be presented now in this subparagraph.

**Average delay**

The first criterion is the average delay of all vehicles on the road network of the Port of Rotterdam. By comparing all scenarios with this criterion, the network performance can be identified.

**Length of congestion**

The second criterion is the length of congestion that will occur. The length of congestion will be measured at four different places on the A15 in the direction of the Maasvlakte. This is to get a good view of the exact location of the congestion. The locations of the congestion measures are given in figure 27.

![Figure 27: Location of the congestion detecting points (google.maps.nl)](image)

1. Before off ramp 15: Off ramp just before the Welplaatweg
2. Before off ramp 16: Off ramp just before the Oude Maasweg
3. Off ramp Botlek: Off ramp just before the Botlekbrug
4. Before off ramp 14: Just before the Botlekweg
The locations 1 and 2 are located near the off ramp to the threatened areas in scenario 4 and 5. Traffic with a threatened terminal as a destination will make use of one of these off ramps. The traffic jam that can occur before the entrance of the terminals will reach the A15 first around these off ramps. Location 3 is located just before the Botlek tunnel and Botlek off ramp. In case of scenario 8, the Botlek tunnel is threatened and congestion will occur before the tunnel. The last location, number 4, will be interesting for the scenarios with a rerouting.

Travel Time
The last criterion is the average travel time of vehicles from a specific origin to a destination. Travel time is a resultant of the congestion and the average speed on the A15. This means that this criterion is influence by the congestion and the speed on the A15. For several trajectories the average travel time could be measured. The most important trajectory is between the beginning of the A15 and the Maasvlakte. Vehicles that take this route must pass the threatened area over the A15 and can be interrupted by the effects of the extra security measures in the Botlek.

ANALYZING STEPS

After defining the criteria, now the experimental steps will be presented. These steps will be used in chapter six to present the results of the simulation runs.

Step 1: Compare current situation with scenarios
First of all, all scenarios will be compared with the current traffic situation on the road network. By comparing these results the difference between the situations can be obtained. These differences will be checked on their significance. In case of a significant difference between the current situation and the situation in a scenario the difference can be attributed to the extra security measures. The significance level will be determined with a Paired Sample T test. This test compares the means and the standard deviations of both situations in the analytic software program SPSS.

Step 2: Analyze the effects of mandatory reroutings
Step 1 determines the effects of the anti terrorist measures per scenario. All scenarios are scored on the criteria, which are mentioned in the previous section. From the results of these steps the most average and interesting scenario could be identified. During this scenario, negative effects of the anti terrorist measures occur, but not the heaviest ones. For this scenario the negative effects of the anti terrorist measures will be tried to minimize with the help of some mandatory reroutings. These reroutings are based on the traffic situation during the threat situation. When a waiting queue reaches the A15 via a specific off ramp, this off ramp will be closed and another, further located off ramp will be used for the traffic to the threatened terminals. First, these routes will be presented. Secondly, the situation with the rerouting is scored on the three criteria mentioned above.

Step 3: Analyze the effects of extra security measures in the future
In the last step in this experiment the scenarios are compared with the situation in 2020. By now, the construction of the Maasvlakte II has already started and also the adjustment of the A15 between the Maasvlakte and the Vaanplein is going ahead. In 2020 both projects will almost be finished and a total new situation occurs. That is why it is interesting to analyze the effects for that future situation.
To analyze the situation in 2020 a new Vissim model for that situation must be made. By a lack of time this model is not build. However, some conclusions will be made based on the results of the first two steps in the next chapter and the

In this chapter the experiment setup was presented. With the Vissim model and the criteria the effects of the anti terroristic measures will be determined. In the following chapter the results of the simulation runs of the scenarios will be presented.
6 Results

In the previous chapter the experimental setup of the project is presented. In this chapter the results of the experiment will be described. First, each scenario will be scored on the criteria (which are mentioned in the previous chapter) and compared with each other and the current situation. This is done for the morning peak and an off peak period. The difference between the current situation and the scenario will also be tested on its significance. In case of a significant difference between the situations, this difference can be attributed to the extra security measures that will be taken in case of a specific scenario. If the difference is not significant, the difference could be coincidence.

After comparing the different scenarios with each other and the current situation in paragraph 1, the effects of some obligatory reroutings will be analyzed by comparing the most average scenario with normal routes with the same scenario with a mandatory rerouting. This is done in the second paragraph. In the last paragraph the effects of the anti terrorist measures in 2020 will be presented.

6.1 SCENARIOS COMPARED WITH CURRENT SITUATION

In this paragraph the effects of the anti terrorist measures will be presented based on the criteria which are mentioned in the previous chapter. First, the network performance indicator average delay of all vehicles will be presented, followed by the congestion on the A15 around the Botlek and the travel time between the beginning of the A15 and the Maasvlakte.

Before the results of all scenarios will be presented a demarcation is made about scenario 4. This scenario is a combination of scenario 1 and 3. Especially scenario 3 has enormous negative effects (the longest traffic jam occurs). By combining these scenarios the negative effects will be heavier as during the effects during the scenarios apart. The Vissim model can not handle the enormous congestion, by which the model will stagnate. That's why this scenario is not taken into account.

6.1.1 AVERAGE DELAY

The first criterion is the average delay of all vehicles and tells something about the road network performance. In table 13 the average delay per scenario during the morning peak is presented.
Table 13: Average delay per scenario in minutes and its significance level during morning peak

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average delay (minutes)</th>
<th>Significance level*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current situation</td>
<td>4.09</td>
<td>x</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>10.43</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 2a</td>
<td>6.14</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 2b</td>
<td>12.17</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 2c</td>
<td>4.31</td>
<td>0.03</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>30.07</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* Significance level for the difference between the current situation and the scenario

Based on this table can be concluded that the average delay of all vehicles increases and by that the network performance decreases for each scenario during the morning peak. During scenario 3 the biggest delay occurs, followed by scenario 2b and 1 while scenario 2a and 2c have smaller increases. All differences have a significance level smaller than 0.05. This means that the difference can be attributed to the extra anti terrorist measures with a reliability of 95%.

In table 14 the average delay per situation during an off peak period is presented.

Table 14: Average delay per scenario in minutes and its significance level during off peak

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average delay (minutes)</th>
<th>Significance level*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current situation</td>
<td>1.18</td>
<td>x</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>2.69</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 2a</td>
<td>2.36</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 2b</td>
<td>1.52</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 2c</td>
<td>1.19</td>
<td>0.29</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>24.73</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* Significance level for the difference between the current situation and the scenario

The average delay of the current situation during the off peak period is much lower than during the morning peak. This is also the case for all scenarios. The difference of the average delay of the current situation and the scenarios are, just like in the morning peak, significance, except for scenario 2c. So, the raised average delay can be attributed to the extra security measures.

The extra average delay of all vehicles could be an indication that extra congestion occurs during the threat scenarios. In the next sub-section the congestion on the A15 around the Botlek will be given.

CONGESTION

After the presentation of the total network performance indicator, in this sub-section the congestion on the A15 around the Botlek will be presented. First, for each scenario a speed contourplot will be presented. Based on these plots can be concluded if congestion occurs during the scenarios. After the presentation of the speed contourplots also the total length of the traffic jam and the significance level will be presented.
In figure 28 for the current situation and all scenarios a speed contourplot is given. The red/orange areas represent the congested areas, while the light green areas show the free flows area.

During scenario 1 the daily congestion just before the Botlektunnel increases and after approximately one hour congestion occurs around hectometre 42, just before off ramp 15. This extra congestion, which is caused by the waiting queue before the threatened ISPS related terminals that reaches the A15, increases directly from that moment and an enormous traffic jam occurs.

During scenario 2a, the daily congestion will be continued during the whole morning peak. Next to that, the length of this congestion increases a little bit and the average speed of all vehicles around the Botlek decreases till around 60 kilometres per hour. A very heavy
congestion will not occur, which indicates that the waiting queue of the ISPS terminals on the Oude Maasweg will not reach the A15.

For scenario 2b approximately the same situation occurs as during scenario 1. The increase of the normal congestion before the Botlektunnel and the extra congestion just before off ramp 15 have the same characteristics. The only difference is the earlier moment that the extra congestion just before off ramp 15 occurs during scenario 2b. The waiting queue of the Esso Nederland terminal reaches the A15 faster than the waiting queues of all terminals on the Welplaatweg. This could be a result of the longer control time at the entrance of Esso Nederland because of the higher ISPS level.

Scenario 2c is almost the same as the current situation. Just before the Botlektunnel congestion occurs, but after 90 minutes this congestion will disappear. The only difference is the lower speed on the A15 around the Botlek harbour during the whole morning peak, which is caused by the extra supervision of the whole harbour. Extra congestion do not occur.

During the last scenario, directly after the beginning of the threat on the Botlektunnel an enormous traffic jam occurs. Directly after the control post the congestion disappear and the average speed will increase till the allowable speed of 100 kilometres per hour.

From the speed contourplot the length of the congestion can not be recognized. The plots are just made for the A15 till hectometre 54, while the congestion could much longer than that. Next to that also the moment that the extra congestion occurs and the moment that the difference between the congestion during the scenarios and the current situation is significant will be presented more precisely.

The length of the congestions will be determined with the help of the queue counters. In the Vissim model four queue counters are placed on the A15 around the Botlek. The total congestion around the Botlek is the sum of the congestion length at the four counters. In table 15 the total length of the congestion per scenario is presented in the first column. In the second column the moments that the extra congestion with respect to the current situation occurs are given. In the last column the significance level of the difference between the normal situation and the scenarios is given.

### Table 15: Length of congestion and occurring moment during morning peak

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total length</th>
<th>Extra congestion occur after</th>
<th>Significance after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>3 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>14 km*</td>
<td>30 minutes</td>
<td>50 minutes</td>
</tr>
<tr>
<td>Scenario 2a</td>
<td>4 km</td>
<td>10 minutes</td>
<td>155 minutes</td>
</tr>
<tr>
<td>Scenario 2b</td>
<td>14 km*</td>
<td>30 minutes</td>
<td>55 minutes</td>
</tr>
<tr>
<td>Scenario 2c</td>
<td>3 km</td>
<td>No congestion</td>
<td>No significance difference</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>11 **</td>
<td>0 minutes</td>
<td>5 minutes</td>
</tr>
</tbody>
</table>

* Maximum congestion that can occur in the Vissim model before off ramp 15
** Maximum congestion that can occur in the Vissim model before the Botlektunnel

During the scenarios 1, 2b and 3 traffic jams of more than 10 kilometres occur. The difference between these scenarios and the current situation becomes significance within one hour, for scenario 3 already after 5 minutes. During scenario 2a and 2c almost no extra congestion occurs.
In table 16 the length of the congestion is presented and the moment that the extra congestion occur during the off peak period.

### Table 16: Length of congestion and occurring moment during off peak

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total length</th>
<th>Extra congestion occur after</th>
<th>Significance after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>No congestion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>1 kilometres</td>
<td>130 minutes</td>
<td>Non difference</td>
</tr>
<tr>
<td>Scenario 2a</td>
<td>No congestion</td>
<td>No congestion</td>
<td>Non difference</td>
</tr>
<tr>
<td>Scenario 2b</td>
<td>&lt; 1 kilometre</td>
<td>160 minutes</td>
<td>Non difference</td>
</tr>
<tr>
<td>Scenario 2c</td>
<td>No congestion</td>
<td>No congestion</td>
<td>Non difference</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>11 kilometres*</td>
<td>0 minutes</td>
<td>5 minutes</td>
</tr>
</tbody>
</table>

* Maximum congestion that can occur in the Vissim model before the Botlektunnel

Based on this table can be concluded that only in case of scenario 3 a significant longer congestion occur. During the other scenarios almost no congestion takes place. That is why no speed contourplots of these situations will be presented.

The extra congestion on the A15 during the morning peak and the decrease of the allowable maximum speed on the A15 causes for longer travel times. In the following section the travel time between the beginning of the A15 and the Maasvlakte will be presented for all scenarios and the current situation.

### 6.1.3 TRAVEL TIME A15 - MAASVLAKTE

The last criterion is the travel time between the beginning of the A15 and the Maasvlakte. The travel time increases by the reduction of the maximum allowable speed and the presence of congestion on the A15. In figure 29 the travel time per scenario over the time is given during the morning peak.
This figure corresponds with the congestion on the A15, presented above. The travel time of scenario 3 increases immediately. The travel time for scenario 1 and 2b rises just after more than one hour, which is later than the congestion on the A15 occur. This is a result of the method how the travel time is determined, which is mentioned in the previous chapter. The travel time of the scenario 2a and 2c is just a little bit higher than in the current situation and is a result of the lower maximum speed.

In figure 30 the travel time per scenario during the off peak period is given. Also these travel times corresponds with the congestion results. Only scenario 3 had a enormous increase of the travel time, while during the other scenarios the travel time only increases by the lower maximum speed.
Figure 30: Travel Time A15 – Maasvlakte per scenario during the off peak

From the results that are presented in this section can be concluded that during every scenario negative effects occur. The biggest negative effects occur during scenario 1, 2a and 3, while during the other scenario hardly effects happen. Another difference can be recognized between the morning peak and the off peak periods. During the morning peak more negative effects occur than during the off peak period.

From the results above can be concluded that during every scenario negative effects occur by the introduction of anti terroristic measures. During the morning peak in almost all scenarios congestion is created by the waiting queues. This congestion and the reduction of the speed cause for a longer travel time between the A15 and the Maasvlakte. The most average scenario is scenario 1. In the next section for this scenario will be tried to minimize the negative effects by the introduction of two different mandatory reroutings. This is only done for the morning peak, because during the off peak period no congestion on the A15 occur.

**MANDATORY REROUTINGS**

In the previous section the effects of the anti terroristic measures are presented based on three criteria. In this section the effects of two different mandatory reroutings on the traffic situation during scenario 1 will be presented. The goal of the reroutings is to decrease the congestion on the A15 and by that to reduce the hindrance for vehicles that have to pass the Botlek harbour over the A15. The two reroutings determines new routes for the traffic that have the Botlek (Welplaatweg and Oude Maasweg) as their origin, while the traffic to the Europoort and the Maasvlakte still make use of the normal route over the A15. First the effects of rerouting 1 will be presented, followed by the results of rerouting 2.
6.2.1 REROUTING 1

The first rerouting leads the traffic to the Welpaartweg via off ramp 16 and via the underlying road that is parallel to the A15 instead of off ramp 15. Off ramp 15 will be closed for the traffic to the Welpaartweg through which they have to take the earlier off ramp. Also the traffic to the Oude Maasweg has to take an earlier off ramp by which the new route leads via the Botlekbrug. The traffic must be informed in time about these new routes, which will be done by the Drip's above the highway and extra traffic signs. In figure 31 the normal and new routes are presented by the black respectively red lines and arrows.

Figure 31: Rerouting 1

First of all the average delay of the current situation, scenario 1 without and with rerouting 1 will be compared. In table 17 the average delay for each situation is presented.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average delay (minutes)</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current situation</td>
<td>4.09</td>
<td>x</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>10.43</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 1 reroute 1</td>
<td>9.36</td>
<td></td>
</tr>
</tbody>
</table>

The average delay of the situation with the rerouting 1 decreases a little bit with respect to the scenario without rerouting. Compared with the current situation the average delay is still five minutes higher, which is a significant difference. Also the difference between the situation with and without the rerouting is significant.

After the presentation of the network performance the congestion on the A15 between the three situations will be compared, based on the speed contourplots of the situations. In figure 32 these plots are given.
From this figure can be concluded that the daily congestion on the A15 occur on the same moment and on the same place. After one hour the average speed before off ramp 16 decreases and after 150 minutes this speed is reduced to 20 kilometers per hour. The congestion occurs just before off ramp 16 and indicate that the waiting queue has reached the A15. The waiting queue of the terminals on the Oude Maasweg doesn’t reach the A15, so the rerouting is good enough for that terminals. In table 18 the total length of the congestion per scenario is presented in the first column. In the second column the moments that the extra congestion with respect to the current situation occurs are given. In the last column the significance level of the difference between the normal situation and the scenarios is given.

Table 18: Length of congestion and occurring moment

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total length</th>
<th>Extra congestion occur after</th>
<th>Significance after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>3 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>14 km*</td>
<td>30 minutes</td>
<td>50 minutes</td>
</tr>
<tr>
<td>Scenario 1 rerouting 1</td>
<td>8 km</td>
<td>75 minutes</td>
<td></td>
</tr>
</tbody>
</table>

From this table can be concluded that also with the rerouting 1 a traffic jam occur of eight kilometers. This congestion occurs, which is also found in the speed contourplot, 45 minutes later than in the situation without rerouting 1.
The last criterion is the travel time between the A15 and the Maasvlakte. In figure 33 the travel time for the current situation, scenario 1 without rerouting 1 and scenario 1 with rerouting 1 are presented.

Figure 33: Travel time A15 - Maasvlakte with and without rerouting 1

The travel time will not be as bad as during the situation without the rerouting, but will also rise enormously after 90 minutes.

Compared with the situation without rerouting, this new situation is overall much better. The congestion caused by the waiting queue however occurs on a later moment and on an earlier place on the A15 and the length of the congestion is smaller. On the other hand, the total congestion is not being denied and on a large part of the A15 around the Botlektunnel the speed is decreased. Next to that the waiting queues of the terminals on the Welplaatweg are still reaching the A15, which is not desirable and the travel time will also increase. That is why another rerouting will be made to try to decrease the negative effects furthermore.

6.2.2 Rerouting 2

For the second rerouting the traffic to the Welplaatweg must take another route than mentioned in rerouting 1. The route to the Oude Maasweg was good enough, so will not be changed. The second rerouting leads the traffic to the Welplaatweg not via off ramp 15 but via off ramp 14. By doing this, the length of the underlying road to the threatened terminals is much longer than in the normal situation and in the situation with rerouting 1. Off ramp 15 will be closed for the traffic to the Welplaatweg through which they have to take the following off ramp. The traffic must be informed in time about these new routes, which will be done by the Drip's above the highway and extra traffic signs. In figure 34 the normal and new routes are presented by the black respectively red lines and arrows.
First the network performance will be scored based on the average delay of all vehicles. In table 19 the average delay is given for the current situation and scenario 1 without reroutings and with rerouting 1 and 2.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average delay (minutes)</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current situation</td>
<td>4.09</td>
<td>x</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>10.43</td>
<td>0.00</td>
</tr>
<tr>
<td>Scenario 1 rerouting 1</td>
<td>9.36</td>
<td></td>
</tr>
<tr>
<td>Scenario 1 rerouting 2</td>
<td>6.20</td>
<td></td>
</tr>
</tbody>
</table>

The new rerouting for the traffic to the Welplaatweg causes a decrease of the average delay of three minutes. The new delay is still higher than in the current situation, but this is caused by the waiting queue before the threatened terminals. The differences between the situation with reroute 2 and the current situation and the rerouting 2 are significant.

After the network performance the speed contourplots of all situations will show the congestion on the A15 during each situation. In figure 35 these plots are presented.
From this figure can be concluded that the most heavy congestion disappear by introducing the new rerouting. Only the daily congestion remain and just before the end of the morning peak a small traffic jam occur before off ramp 14. From this can be concluded that the waiting queue doesn’t reach the A15 within three hours. On the other hand, this queue is no located on the underlying road. The speed around the Botlek decreased, but that is caused by the lower maximum allowable speed. In table 20 the length of the congestion and the occurring moment are given.

**Table 20: Length of congestion and occurring moment**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total length</th>
<th>Extra congestion occur after</th>
<th>Significance after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>3 km</td>
<td>30 minutes</td>
<td>50 minutes</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>14 km*</td>
<td>75 minutes</td>
<td></td>
</tr>
<tr>
<td>Scenario 1 rerouting 1</td>
<td>8 km</td>
<td>150 minutes</td>
<td></td>
</tr>
<tr>
<td>Scenario 1 rerouting 2</td>
<td>2.5 km</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The length of the traffic jam that will occur before off ramp 14 will only growth till 2.5 kilometers and takes place after 150 minutes. The congestion that occurs during scenario 1 without rerouting can be eliminated by using rerouting 2.

The last criterion is the travel time between the A15 and the Maasvlakte. In figure 36 this travel time over de time per scenario is given.
The travel time between the A15 and the Maasvlakte during rerouting 2 is decreased to the level of the current situation. The vehicles that are hindered by the congestion that occur after 150 do not reach the Maasvlakte, so there travel time is not measures yet. This means that the travel time will rise a little bit at the end of the morning peak.

Compared with the situation without rerouting and with rerouting 1, the situation with rerouting 2 could eliminate most of the negative effects. The congestion occurred by the waiting queues is removed and the travel time between the A15 and the Maasvlakte will not rise anymore. However, it is important to recognize that the waiting queue is no located on the underlying road between the off ramp 14 and the Welplaatweg and between off ramp Botlek and the Oude Maasweg.

FUTURE RESULTS

In chapter three the future developments of the Port of Rotterdam and its road network are presented. On this moment the construction of the Maasvlakte II and the expansion of the A15 are already started. These developments could influence the effects of the anti terroristic measures in the future. To determine these effects in 2020 a traffic model must be made with all these developments. By a lack of time this model is not been build. However, based on the effects of the anti terroristic measures in the current situation some conclusions can be made.

The underlying road network in the Port of Rotterdam will not be chanced. That is why the distance between the threatened terminals and the A15 stays equal to the current situation. The amount of traffic to the terminals in the Botlek increases with 8% compared with the current situation. This could result in a small increase in the waiting queues before the terminals, in more hindered vehicles and minimal the same time that the waiting queue reaches the A15.
On the A15 more traffic will pass the Botlek harbour. This increase is caused by the extra vehicles that go to the new harbour, the Maasvlakte II. These vehicles will be hindered by the waiting queues when these queues reach the A15 and could cause a larger traffic jam on the A15. However, by the expanding of the amount of road lanes of the A15 the capacity will increase. This increase will take care for a better traffic flow and for less hindrance for the passing vehicles. The congestion can be reduced by this increase of the road capacity.

How do these future developments influence the effects of the anti terroristic measures during the different threat scenarios? During the scenarios 1 and 2 the waiting queue will reach the A15 approximately on the same moment compared with the current situation. The exact effects of the waiting queue on the traffic situation on the A15 can not determined precisely. The increase of the capacity should take care for less congestion while the increase in the amount of passing vehicles could lead to more congestion. However, the increase of the capacity is larger than the increase of the number of vehicles, so the traffic jam should decrease in 2020 compared with the scenario during the current situation.

During scenario 3 the congestion on the A15 will be decreased by the construction of the new Botlekbrug. This bridge will increase to a 2x2 road way and will be a good alternative for the Botlektunnel. Almost all traffic could be rerouted via this bridge. This could lead to an enormous decrease of the congestion on the A15.
Conclusions and recommendations

In this conclusive chapter the final conclusions of the research and some recommendations will be given. These conclusions are based on the answer of the following main question:

What are the effects of the anti terroristic measures on the traffic situation on the road network around the Port of Rotterdam and how can the negative effects be minimized?

The answer of the main question exists of three parts. First conclusions will be taken about the effects of the anti terroristic measures in the Botlek harbour. This is the only harbour that is researched for this project. Part two describes the conclusion of the effects of reroutings in the Botlek. The conclusions about the effects of anti terroristic measures and the reroutings will be generalized in the third section for the total Port of Rotterdam. In the last section some recommendations will be presented.

Effects of Anti Terroristic Measures in Botlek

The exact effects of the anti terroristic measures depend of the specific threat situations. Per threat scenario the effects are different. Another difference can be made between the morning peak period and the off peak period. During the non peak periods the effects of the extra security measures are not that big as during the morning peak.

During the threat scenarios the network performance indicator “average delay of all vehicles” decreases for all threat situations with respect to the current situation. The differences between the average delay in the current situation and the scenarios are in all cases, morning- and off peak period, significant. This means that the increase can be attributed to the extra security measures and that these measures take care for a decrease of the network performance. The increase of the delay during the morning peak is much higher than during the off peak period.

During the morning peak, for almost all threat scenarios extra congestion on the A15 occurs compared with the current situation. This congestion happens around and before the Botlek harbour and is caused by the waiting queues before the entrances of the terminals that reach the A15 or the vehicle control before the Botlektunnel. The exact length of the congestion, the occurring moment and the severity of the traffic jam depends of the specific threat scenarios. In case of a threat on all terminals in the Botlek with ISPS level 2, only the Esso Nederland with level 3 and the Botlektunnel with level 2 enormous traffic jams occur. This is because the large amount of traffic that has to go to those terminals or passes the tunnel...
and the short distance between the terminals and the off ramps for some ISPS related terminals. A threat on the terminals on the Oude Maasweg caused for a small congestion on the A15, while during a threat on the northern terminals on the Welplaatweg no extra congestion occurs. In these last situations only a few vehicles go to the threatened terminals and the distance between the threatened terminals and the off ramps of the A15 is relative long. This causes only a short waiting queue before the terminals and it takes much longer before these queues reaches the A15 because of the long distance to the A15.

In the off peak period only extra congestion occurs in case of a threat on the Botlektunnel. In all other situations the waiting queues do not reach the A15 by which the vehicles on the A15 that have to pass the Botlek are not hindered. This is caused by the lower number of vehicles that enters the Botlek and goes to the threatened ISPS related terminals.

The extra congestion and the lower speed on the A15 causes for a longer travel time between the A15 and the Maasvlakte. In each scenario the average speed on the A15 around the Botlek is decreased by the extra supervision in and around the Botlek. This lower speed causes in every situation for a longer travel time between the A15 and the Maasvlakte and, corresponding with this longer travel time, in more delay for the Botlek passing vehicles. The delay by the decreased speed is the same for the morning peak and the off peak.

The congestion on the A15 takes also care for a longer travel time. The exact increase of the time depends of the severity of the congestion. During the morning peak, the travel time will rise more than during the off peak and also between the scenarios a difference can be recognized.

7.2 EFFECTS OF MANDATORY REROUTINGS IN BOTLEK

The negative effects of the anti terroristic measures can be minimized by adding mandatory reroutings into the road network of the Port of Rotterdam. In this research for scenario 1 (all terminals in the Botlek harbour are threatened with ISPS level 2) the effects of two mandatory reroutings are presented. Both reroutings takes care for an enormous decrease of the negative external effects. During rerouting 1, in which the traffic to the Welplaatweg takes an earlier off ramp, the extra congestion occurs on a later moment. The second rerouting, in which traffic that goes to the Welplaatweg takes a later off ramp, almost all extra congestion on the A15 is reduced. The reason of this difference is the longer distance between the threatened terminals and the A15 during rerouting 1. A disadvantage of both reroutings is the congestion that occurs on the underlying road network.

7.3 GENERAL CONCLUSIONS

In the first two sections conclusions for a threat situation in the Botlek harbour are given. In this section these conclusions are generalized for the total Port of Rotterdam.

From the results of the effects in the Botlek can be concluded that the amount of traffic that enters the threatened terminals and the distance between the terminals and the off ramps are crucial factors that influence the effects of the anti terroristic measures. In case of a high number of vehicles the waiting queue will rise very quickly. In case of a short distance between the terminals and the A15 the waiting will reach the A15 earlier.

Most of the terminals in the Port of Rotterdam are located nearby the off ramps to the A15. This means that the waiting queues before the entrances of the ISPS related terminals should not be very long to reach the A15. It depends of the amount of vehicles that go to the terminals how long it exactly takes before the waiting queues reach the A15 and create
congestion. The amount of vehicles that have to pass the threatened area determines the severity of the congestion on the A15. It is very plausible that a threat on any ISPS related terminals in the Port of Rotterdam leads to more congestion on the A15 and a lower average speed.

The congestion and the lower speed, caused by the extra supervision around the threatened area, take care for a longer travel time between the A15 and the Maasvlakte. A threat in the Port of Rotterdam will caused a longer travel time in any case.

Two mandatory reroutings shows that these traffic measures could reduce the negative effects of anti terroristic measures. This is because these reroutings create a longer distance between the terminals and the off ramps. For the other harbour also reroutings can reduce the negative effects because of the presence of different routes to the terminals in spite of the Maasvlakte. These reroutings can minimize the negative effects of anti terroristic measures during any threat but must be added directly after the beginning of the threat situation. That is why it is important that several different reroutings are present for all ISPS related terminals in the whole Port of Rotterdam.

**RECOMMENDATIONS**

In this research several scenarios have been used to determine the effects of the anti terrorist measures. In this scenarios also possible anti terrorist measures are presented, that are based on an internal workshop at ARCADIS. These anti terrorist measures are thought by four specialists and will approach the real measures. However, in reality, other or more security measures can be take to resist a terrorist attack. This can cause other results from the Vissim model. To determine the effects more certain, the exact terminal specific measures must be used in the Vissim model.

Each simulation run has its own outcomes because of the random seed. In chapter five is determined that more than six hundred simulation runs must make to get reliable data. In this report only five runs are made because of the short project time. To get more reliable data, more runs should be made.

In this report only the effects of anti terrorist measures in the Botlek harbour are determined. From these results, some conclusions for the rest of the Port of Rotterdam are made in the previous section. To know the exact effects of security measures in the other four harbours, the anti terrorist measures must be simulated with a new Vissim model. With this new model, also some effective reroutings could be developed for the different situation per harbour.

In the chapter three the developments of the Port of Rotterdam are presented. On this moment the construction of the Maasvlakte II and the increase of the A15 are already started. These developments will influence the effects of the anti terrorist measures. To determine these new effects another Vissim model must be made with the developments. By a lack of time this model is not build. However, based on the effects in the current situation some conclusions for the future situation are given. To determine the exact effects of the anti terrorist measures in 2020 a new Vissim model must be made.
THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

Literature

Interviews

Ir. E.A.M. Scheerder, Verkeersondememing Rotterdam
Ir. M. van Schuylenburg, project manager modalities Port of Rotterdam
Ing. E. Verschoor, senior advisor, division mobility, ARCADIS
J. de Vries, team leader traffic and ICT, Verkeersmanagement centrale zuid-west Nederland

Publications

http://route.anwb.nl/routeplanner/?iad=homepage.navigatie.middenkolom.routeplanner uitgebreid


http://www.minbzk.nl/onderwerpen/veiligheid/terrorisme

http://www.verkeerenzewaterstaat.nl/onderwerpen/goederenvervoer/beveiliging/wet- en_regelgeving/#alinea1

Muller, T.H.J (2004). Determining sample size. Faculty of Civil Engineering and Geosciences. Delft


http://www.nctb.nl/wat_is_terrorisme/Actueel_dreigingsniveau/index.aspx
THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM


Appendix A: Off ramps

In this appendix a map of all the off ramps with the disclosing roads from the specific off ramp on the A15/N15 are given. Also a short description of the possible routes to the adjacent terminals is given.

Off ramp 9
Off ramp 9 is located just before the Suurhoffbrug. Most of the vehicles that make use of this off ramp have BP Raffinaderij Rotterdam, Voridian or EECV as their destination. After leaving the A15 by the off ramp the vehicles can take two different directions. The first one is to the south, by the d’Arcyweg (1). This road leads to the south entrance of the BP Raffinaderij. On the north side (2) are three possibilities. The first one is the Dintelweg to the east (3). This road passes a few small non ISPS related terminals and leads to the Elbeweg, at South of off ramp 10. The second option is the entrance of a terminal on the West side (4). The last option, leads to the BP Raffinaderij, EECV and Voridian by the Markweg (5).

Off ramp 10
The following off ramp is number 10, just before the Dintelhavenbrug and disclosed the P&O/ Ferries, Shell Europoort Terminal, the Team Terminal and some smaller terminals. The A15 leaving vehicles have to different options after the off ramp. The first one is going to the South West, taking the Elbeweg. This road (which crosses the Dintelweg coming from off ramp 9) leads to P&O/ Ferries and some smaller terminals. The other option, taken is the North route. This option has three possible continuation routes. The first route (goes to off ramp 11 (to the East) taking the Moezelweg (parallel to the A15) and passed the Kuwait Petroleum Europoort and the Caldic Terminal. The second route is to the North and discloses the Team and Shell Europoort Terminals. The last direction is to the west (Moezelweg). This road goes also to the P&O/Ferries and the smaller terminals.
Off ramp 11
Off ramp 11 lies between the Dintelhavenbrug and the Thomassentunnel, and is responsible for the disclosure of the West side of Kuwait Petroleum Europoort, the Caldic Terminal and Exxon Mobil. The most of the traffic will go to the North after the off ramp, where three possible routes exist. The first one is the Moezelweg to off ramp 12, which lies east of off ramp 11. This road passes the East side of Kuwait Petroleum Europoort, Lyondell, MET and Vopak. The option to the west, also the Moezelweg, goes to off ramp 11 and disclose west side of Kuwait petroleum Europoort. The last option discloses the north side of the off ramp where the Caldic and Exxon Mobil terminals are located.

Off ramp 12 and 13
Off ramp 12 is located directly after the Thomassentunnel and has a crossing with the regional road N57, which come from Voorne. Traffic that takes this off ramp from the east side can't enter the port area, but only go to Voorne by using the N57 (1). The traffic that
comes from Voorne over the N57, however, has the opportunity to enter the port. This traffic has the possibility to go to the MET and Vopak terminals (on the north, 4) or to the most eastern part of the Botlek (on the south east (5 and 6), or north east (3). Traffic that takes the off ramp from the west side can go to the Vopak and MET terminal.

Figure 40: Road network around off ramp 12 (Google maps, 2008)

As mentioned before, traffic that comes from the east has to leave the A15 before the Thomassentunnel by off ramp 13 to go to the MET and Vopak terminals. This traffic doesn’t make use of the tunnel but of the Calandbrug. For vehicles which transport hazardous goods it is forbidden to make use of the Thomassentunnel and have to take the Calandbrug. This traffic enters the Europoort in number 7. In figure 20 this traffic passes number 2. The rest of the traffic that takes off ramp 13 has the opportunity to go to Rozenburg by numbers 3 and 4, or to the western part of the Botlek harbour, taking number 4 to direction 5.

Figure 41: Road network around off ramp 13 (Google maps, 2008)

Off ramp 14
This off ramp is located in the middle of the Botlek harbour and discloses the North surface off the East and West side of the Botlek harbour and the small town Rozenburg. Vehicles that go to Rozenburg have to take route number 3, which also leads to the North side of the eastern area of the Botlek, with terminals as Steinweg, Keppel Verolme and Vopak. Number
THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

4 could lead to Maassilo, EBS and Vopak. Number 5 and 6 goes to the western part of the Botlek, with terminals RCT, Steinweg and Lyondell.

Figure 42: Road network around off ramp 14 (Google maps, 2008)

Off ramp 15
This off ramp discloses the South side of the Botlek. Direction 2 (and further on 6, 7 and 8) discloses the Distripark Botlek, Lyondell and Steinweg. These last two terminals are also disclosed by off ramp 14. Taking number 1 goes to the Esso Nederland (number 3), Vopak zuid (5) and Maassilo (4).

Figure 43: Road network around off ramp 15 (Google maps, 2008)

Off ramp 16
This is the last off ramp after the Botlektunnel, which discloses the city of Spijkenisse. Next to that city, also the most eastern part of this sub harbour is disclosed. Taking number 4 goes to Esso Nederland and number 3 to Odfjell, Aluchemie and AVR. Transport with hazardous goods is not allowed to take the Botlektunnel, but have to take the Botlekbrug. This traffic
also makes use of this off ramp and comes from direction 7. Hazardous goods take have to go to the East of the Oude Maas have to take direction 6.

Figure 44: Road network around off ramp 16 (Google maps, 2008)

Off ramp Botlekbrug
As mentioned above, traffic with hazardous is not allowed take the Botlektunnel. To go to the Botlekbrug traffic has to take direction 1.

Figure 45: Road network around off ramp Botlekbrug (Google maps, 2008)

Off ramp 17 (A15 and A4)
These off ramps are responsible for the disclosing of the Vondelingenplaat and the cities of Hoogvliet and Pernis. Both off ramps enters the on the West side of the A4. As can see in figure 25, direction one leads to Hoogvliet, 2 to the Shell Raffinaderij, number 3 to Shell Chemie and number 4 to the East side of the harbour. Number 5 goes to the city of Pernis and the most eastern sub harbour Heijplaat.
Off ramp 18
The last off ramp discloses the Heijplaat (1) and the Distripark Eemhaven (2).
Appendix B: Important terminals

In this appendix a list of the most important ISPS related terminals per sub harbour is given. Per terminals, also the type is given, based on the possibilities given in figure 6.

### Maasvlakte

<table>
<thead>
<tr>
<th>Terminal Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maasvlakte Olie Terminal (MOT)</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Lyondell – Bayer</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>DFDS Tor Line</td>
<td>Container terminal</td>
</tr>
<tr>
<td>E.ON</td>
<td>Remaining terminal</td>
</tr>
<tr>
<td>APM</td>
<td>Container terminal</td>
</tr>
<tr>
<td>ECT</td>
<td>Container terminal</td>
</tr>
<tr>
<td>Europees Massagoed Overslagbedrijf</td>
<td>Dry bulk (Coal and iron ore)</td>
</tr>
</tbody>
</table>

### Europoort

<table>
<thead>
<tr>
<th>Terminal Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP Raffinaderij Rotterdam B.V.</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Eastman Chemical Europoort B.V.</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>Ertsoverslagbedrijf Europoort C.V.</td>
<td>Dry bulk (Coal and iron ore)</td>
</tr>
<tr>
<td>European Bulk Services (EBS)</td>
<td>Dry bulk (Coal and iron ore)</td>
</tr>
<tr>
<td>P&amp;O/Ferries</td>
<td>Remaining terminal</td>
</tr>
<tr>
<td>Shell Europoort Terminal</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Team Terminal</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Welplaat B.V.</td>
<td>Dry bulk (Sand and grit)</td>
</tr>
<tr>
<td>Kuwait Petroleum Europoort</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Caldic</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>Exxon Mobil</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Micro Chemie</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>Lyondell</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>Vopak (Europoort)</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Maatschap Europoort Terminal</td>
<td>Wet bulk (Oil terminal)</td>
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### Botlek

<table>
<thead>
<tr>
<th>Terminal Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotterdam Car Terminal (RCT)</td>
<td>Remaining terminal</td>
</tr>
<tr>
<td>Lyondell</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>Steinweg</td>
<td>Wet bulk</td>
</tr>
<tr>
<td>European Bulk Service (EBS)</td>
<td>Dry bulk (Coal and iron ore)</td>
</tr>
<tr>
<td>Keppel Verolme</td>
<td>Remaining terminal</td>
</tr>
<tr>
<td>Steinweg</td>
<td>Wet bulk</td>
</tr>
<tr>
<td>Maassilo</td>
<td>Dry bulk (Grains terminal)</td>
</tr>
<tr>
<td>Maastank</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Rio Tinto Minerals Rotterdam</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>Vopak zuid</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Vopak noord</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Esso Nederland</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>Odfjell</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
</tbody>
</table>
### THE EFFECTS OF ANTI TERRORISTIC MEASURES ON THE TRAFFIC SITUATION IN THE PORT OF ROTTERDAM

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>14) Aluchemie Rotterdam</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td>15) AVR</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td><strong>Vondelingenplaat</strong></td>
<td></td>
</tr>
<tr>
<td>1) Van Bentum</td>
<td>Remaining terminal</td>
</tr>
<tr>
<td>2) Shell Nederland Raffinaderij</td>
<td>Wet bulk (Oil terminal)</td>
</tr>
<tr>
<td>3) Shell Chemie</td>
<td>Wet bulk (Chemical terminal)</td>
</tr>
<tr>
<td><strong>Heijplaat</strong></td>
<td></td>
</tr>
<tr>
<td>1) Interforest</td>
<td>Container terminal</td>
</tr>
<tr>
<td>2) ECT</td>
<td>Container terminal</td>
</tr>
<tr>
<td>3) RST</td>
<td>Container terminal</td>
</tr>
<tr>
<td>4) Steinweg</td>
<td>Container terminal</td>
</tr>
<tr>
<td>5) Barge Center Waalhaven</td>
<td>Container terminal</td>
</tr>
<tr>
<td>6) WHT</td>
<td>Container terminal</td>
</tr>
<tr>
<td>7) Uniport</td>
<td>Container terminal</td>
</tr>
<tr>
<td>8) Hanno</td>
<td>Container terminal</td>
</tr>
</tbody>
</table>
Appendix C: Underlying road network

In this appendix the most important disclosing roads in the Port of Rotterdam are given. Per road, which is categorized per sub harbour, the closest off ramp and the adjacent terminals are given.

Maasvlakte

<table>
<thead>
<tr>
<th>Number</th>
<th>Road Name</th>
<th>Off ramp</th>
<th>Terminal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Europaweg</td>
<td>non</td>
<td>Maasvlakte Olie Terminal</td>
</tr>
<tr>
<td>2</td>
<td>Australiaweg</td>
<td>Off ramp 3</td>
<td>Lyondell – Bayer</td>
</tr>
<tr>
<td>3</td>
<td>Antarticaweg</td>
<td>Off ramp 4</td>
<td>DFDS Tor line</td>
</tr>
<tr>
<td>4</td>
<td>Coloradoweg</td>
<td>Off ramp 5</td>
<td>E.ON, APM and ECT</td>
</tr>
<tr>
<td>5</td>
<td>Missouriweg</td>
<td>Off ramp 6</td>
<td>Europees Massagoed, Overslagbedrijf</td>
</tr>
</tbody>
</table>

Europoort

<table>
<thead>
<tr>
<th>Number</th>
<th>Road Name</th>
<th>Off ramp</th>
<th>Terminal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>d'Arcyweg</td>
<td>Off ramp 9</td>
<td>BP Raffinaderij Rotterdam</td>
</tr>
<tr>
<td>2</td>
<td>Markweg</td>
<td>Off ramp 9</td>
<td>Eastman Chemical, Europoort and EECV</td>
</tr>
<tr>
<td>3</td>
<td>Elbeweg</td>
<td>Off ramp 10</td>
<td>EBS and P&amp;F/Ferries</td>
</tr>
<tr>
<td>4</td>
<td>Rijn(dwars)weg</td>
<td>Off ramp 10</td>
<td>Shell Europoort terminal, Team Terminal and Welpaakt</td>
</tr>
<tr>
<td>5</td>
<td>Merwedeweg</td>
<td>Off ramp 11</td>
<td>Caldic, Exxon Mobil and Micro Chemie</td>
</tr>
<tr>
<td>6</td>
<td>Moezelweg</td>
<td>Off ramp 11</td>
<td>Kuwait Ptoleum Europoort</td>
</tr>
<tr>
<td>7</td>
<td>Moezelweg</td>
<td>Off ramp 12 (13)</td>
<td>Lyondell, Vopak and MET</td>
</tr>
</tbody>
</table>

Botlek

<table>
<thead>
<tr>
<th>Number</th>
<th>Road Name</th>
<th>Off ramp</th>
<th>Terminal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Merseyweg</td>
<td>Off ramp 14</td>
<td>Rotterdam Car Terminal</td>
</tr>
<tr>
<td>2</td>
<td>Prof Gerbrandyweg</td>
<td>Off ramp 14</td>
<td>Keppel Verolme, Steinweg</td>
</tr>
<tr>
<td>3</td>
<td>Theemsweg</td>
<td>Off ramp 14/ 15</td>
<td>Lyondell, Steinweg, EBS and Maassilo</td>
</tr>
<tr>
<td>4</td>
<td>Welplaatweg</td>
<td>Off ramp 15</td>
<td>Maastank, Rio Tinto, Vopak zuid en Vopak noord</td>
</tr>
<tr>
<td>5</td>
<td>Botlekweg</td>
<td>Off ramp 16</td>
<td>Esso Nederland</td>
</tr>
<tr>
<td>6</td>
<td>Oude Maasweg</td>
<td>Off ramp 16</td>
<td>Odfjell, Aluchemie and AVR</td>
</tr>
</tbody>
</table>

Vondelingenplaat

<table>
<thead>
<tr>
<th>Number</th>
<th>Road Name</th>
<th>Off ramp</th>
<th>Terminal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vondelingenweg</td>
<td>Off ramp 17</td>
<td>Shell Nederland Raffinaderij</td>
</tr>
<tr>
<td>2</td>
<td>Vondelingenplaat</td>
<td>Off ramp 17</td>
<td>Van Bentum</td>
</tr>
<tr>
<td>3</td>
<td>Petroleumweg</td>
<td>Off ramp 17</td>
<td>Shell Chemie</td>
</tr>
</tbody>
</table>