Climate change and inland waterway transport: impacts on the sector, the Port of Rotterdam and potential solutions

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Leading authors:
Drs. A.H. Krekt[1]
Ir. T.J. van der Laan[1]
Ir. R.A.E. van der Meer[2]
Ir. B. Turpijn[3]
Dr. O.E. Jonkeren[4]
Ir. A. van der Toorn[5]
Dr. ir. E. Mosselman[6]
Drs. J. van Meijeren[7]
Drs. T. Groen[7]

(1) ARCADIS
(2) Port of Rotterdam
(3) Ministry of Infrastructure and the Environment
(4) VU University of Amsterdam
(5) Delft University of Technology
(6) Deltares
(7) TNO – mobility and logistics

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Content

Preface

After Al Gore's wake up call in 'An inconvenient truth', that climate is changing and we are part of the problem, life will never be the same. But we can react in different ways. Some people start to reduce our contribution to the climate change by CO_2-reduction, other people starts to deny the direct link between our CO_2-producing activities and climate change and a third group accepts that anyhow there will be some climate change so wants to invest in how to deal with it.

This report is the result of a research project in the third direction and will focus on the consequences of climate change for the inland navigation on the river Rhine and possible solutions. Because the consequences of climate change and the possible solutions are rather divers, the research group was multidisciplinary composed. Port of Rotterdam and Ministry of Infrastructure and Environment played an important role as initiators and owners of part of the problem. Several research and knowledge institutes joined their efforts during the two years of research.

Illustrative for this fruitful approach nearly every member of the group came up with its 'own' solution. Economist expects that if transport capacity will be less, prices become higher and so will attract more transport capacity. At their turn logistic experts suggests different changes in the logistic chain, like more stock, other shipping routes, other transport modalities, etc. River managers try to find solutions in optimization of dredging activities, more accurate and actual information for the inland navigation. Hydraulic engineers believe in a canalized Rhine, with undisturbed navigation in times of normal discharge and some delays in 'dry times' (but still maximum loading capacity!). Ship designers have developed lighter, broader or longer vessels, all with less draught or suggest temporary buoyancy only at critical passages.

It was this multidisciplinary approach that adds value to the problem analysis as well as to the solutions. The interaction between this different approaches makes this product special. Now all parties involved in this research project will have a much broader view at climate change, which will never be the same as before!

Summary

The main advantage of the Port of Rotterdam is unobstructed access for vessels from the North Sea and river connections to the hinterland. Climate change will have an impact in the future, which will affect port access and the navigability of inland waterways. Continuing sea level rise will necessitate more frequent closures of the Maeslant storm surge barrier and for a longer period of time. This would prohibit access to a large area of the Port of Rotterdam for seagoing vessels, and will impact on inland waterway traffic. Greater fluctuations in water levels in the rivers will also impact the access of inland waterway transport and particularly in long periods of low water levels.

The Port of Rotterdam is Europe's largest seaport and the main port for inland waterway transport by the Rhine and Meuse rivers. Prior to this study little was known about the consequences of climate change on inland waterway transport. Our study focuses on the effects of climate change and potential solutions for water transport on the Rhine River between the port of Rotterdam and the German hinterland as far as Koblenz. For this study, the W+ climate scenario (KNMI) was used to predict economic growth of the Global Economy (WLO), for up to 2050.

It is expected that discharge of the Rhine River, which is now mainly due to snow melt and precipitation, may be more controlled by rain run-off due to temperature increase and greater fluctuation of precipitation. By 2050, there are three main changes that will impact shipping on the Rhine River system.

The largest problem is expected to be a decrease in river water depth and for considerably long periods of time. Relatively long periods of low river discharge will only allow access of vessels with a shallow draught. Another issue is that sea level rise will result in more frequent closures of the Maeslant storm surge barrier, thus limiting access to the Port of Rotterdam. Furthermore, occasional periods of high water levels will cause incidental problems with the passage of high inland vessels under the bridges.

Transportation costs are expected to increase by 9% to 23% due to increased occurrences of extreme high and low water levels according to the W+ climate scenario. Approximately 7% of the total annual volume of goods cannot be transported by inland waterway due to the impact of low water levels. In the worst case scenario, a 10-day period with the lowest water level, the decrease in transport capacity is up to 28% in all inland navigation to and from the Netherlands. These percentages could be substantially higher on specific corridors between Rotterdam and Germany. Of this decreased capacity, 88% will shift to rail transport and 12% to road transport. A shift from the Port of Rotterdam to other European seaports is expected to be low, except in prolonged dry periods.

The consortium selected some promising solutions and elaborated in four categories. They can be dependent on each other.

1. River management: waterway improvement and canalisation of the Rhine

   Waterway improvement can be carried out by dredging and construction of structures such as groynes, fixed bed layers, bottom vanes, bendway weirs and longitudinal dams. This measure may increase the navigation depth by 10 tot 50 cm and costs approximately € 0.1-10 million. The time to possible realisation is approximately between 2 and 10 years.

   Canalisation of the Rhine is estimated to provide a net-benefit of approximately € 2.5 billion for the whole lifetime of the project. This long term solution is expected to be implemented 20 to 30 years from now.

2. Logistic management: Increasing the resilience and flexibility of the sector by modifying the supply chain.

   This can be accomplished by providing larger stock or storage capacity, alternative routes, other transport modalities, extra cargo handling facilities in ports and terminals. 39 logistic measures have been identified. Two most feasible measures are elaborated: increasing the number of operational hours and investing in additional storage capacity.

   Increasing the number of operational hours per day by waterway carriers will provide a net-benefit of approximately €7.4 million a year. Additional storage capacity for shippers is the most feasible solution for upstream locations. The logistic measures can be implemented from now up to 5 years.

3. Information management: ICT systems for inland shipping and the use of ICT in the waterway (Smart Waterways).

   The use of ICT systems for inland shipping can lead to a better exchange of traffic and cargo information. The systems which are developed from now until approximately 5 years are River Information Services, barge planning and a management information system for inland container shipping.

   Navigability can be improved by providing up-to-date on-line information on current and expected water depths in the shipping route, expected bed topography, as well as real-time draught and trim of the vessel. Use of ICT in the waterway shipping would contribute considerably to managing navigability (approximately 20 cm increase in depth). The total cost for development of the system is about €2 million and can be implemented within 5 to 10 years.

4. Fleet management: Using vessels with a smaller draught.

These vessels can be constructed of light weight materials and or extra (temporary) buoyancy and they may be wider and longer. Vessel modification would be justified when (breakeven point) dry and/or wet periods cover about 60-80% of the time in a year. This solution requires further research to be an effectively implemented and can be implemented when other solutions are not feasible (approximately 20 years from now).

Samenvatting

De haven van Rotterdam is Europa's grootste zeehaven en één van de grootste havens voor binnenvaarttransport over de Rijn en de Maas. Klimaatverandering zorgt voor een temperatuurstijging en grotere verschillen in neerslaghoeveelheden. De verwachting is dat de afvoer van de Rijn in de toekomst meer wordt bepaald door neerslag dan door de huidige combinatie van neerslag en het smelten van sneeuw.

De Rotterdamse haven is gebaat bij een goede scheepvaartverbinding van de Noordzee naar het achterland. Verandering in waterstanden kan een negatieve invloed hebben op de haventoegang en de bevaarbaarheid van de vaarwegen. Zeespiegelstijging zorgt voor een meer frequente sluiting van de Maeslantkering en tevens voor een langere duur van de sluiting. Ook toekomstige grote verschillen in waterstanden van rivieren zorgen voor verslechtering van het functioneren van het scheepvaartverkeer. Lange perioden van lage waterstanden kunnen ertoe leiden dat een deel van het transport van goederen niet meer over water gaat, maar via de weg of het spoor. Hoge rivierafvoeren kunnen problemen opleveren voor scheepvaart bij het passeren van bruggen.

Deze studie spitst zich toe op de effecten van klimaatverandering op het binnenvaarttransport op de Rijn tussen de haven van Rotterdam en het Duitse achterland tot aan Koblenz. In de studie is voor klimaatverandering het W+ scenario van het KNMI en voor de economische groei het Global Economy Scenario (WLO) tot het jaar 2050 gebruikt.

Uit deze studie blijkt dat relatieve lange perioden met lage waterafvoeren van de rivieren voor de grootste problemen voor de binnenvaart zorgen. De stijging van de jaarlijkse transportkosten worden geschat van 9% tot 23% als gevolg van extreem hoge en lage waterstanden. Ongeveer 7% van het totale jaarlijkse transportvolume kan niet getransporteerd worden als gevolg van een periode met extreem lage waterstanden. In het meest ongunstige scenario, een 10-daagse periode met de laagste waterstanden, neemt de transportcapaciteit af tot 28% voor de hele binnenvaart transportsector van en naar Nederland. Dit percentage kan aanzienlijk hoger zijn voor specifieke passages tussen Rotterdam en Duitsland. Deze afname in capaciteit verschuift naar andere modaliteiten, waarbij in 88% van de gevallen gebruik wordt gemaakt van het spoor en 12% van het wegtransport. De verwachting van een verschuiving van het transport naar andere havens in Europa is klein, behalve bij aanhoudende droge periodes.

Een aantal oplossingsrichtingen voor het omgaan met bovenstaande verwachtingen worden voorgesteld in de volgende categorieën:

1. Riviermanagement: onderhoudswerkzaamheden in de vaarweg en kanalisatie van de Rijn.

Onder onderhoudswerkzaamheden vallen baggerwerkzaamheden, het aanbrengen en aanpassen van constructies in de vaarweg zoals het verlengen van strekdammen en verschillende vormen van bodembescherming. Deze werkzaamheden kunnen leiden tot het creëren van een extra waterdiepte van 10 tot 50 cm en de kosten bedragen circa tussen de €0,1 en €10 mln. De werkzaamheden kunnen uitgevoerd worden vanaf 2 jaar van nu tot circa 10 jaar.

De kanalisatie van de Rijn kan een netto baat opleveren van circa €2,5 mld. over de hele levensduur van de maatregel. Dit kan een effectieve oplossing zijn voor de langere termijn en zal over circa 20 tot 30 jaar uitgevoerd kunnen worden.

2. Logistiek management: het vergroten van de flexibiliteit van de binnenvaartsector door een verandering in de transportketen aan te brengen.

Dit kan worden gerealiseerd door te zorgen voor grotere opslagcapaciteit, alternatieve vaarroutes, andere transportmodaliteiten en extra overslagcapaciteit in havens. Hieruit zijn 39 logistieke oplossingen geïdentificeerd. De twee meest haalbare maatregelen zijn verder uitgewerkt: het vergroten van het aantal operationele uren en investeren in extra opslagruimte.

Het vergroten van het aantal operationele uren per dag door binnenvaartschepen kan een jaarlijkse netto baat opleveren van circa €7,4 mln. Bij verladers is extra opslagruimte de meest haalbare oplossing voor bovenstroomse locaties. De logistieke maatregelen kunnen vanaf nu tot circa 5 jaar uitgevoerd worden.

3. Informatiemanagement: ICT voorzieningen voor de binnenvaart en het gebruik van ICT in de vaarweg.

De huidige ontwikkelingen van ICT voorzieningen voor de binnenvaart zijn bijvoorbeeld rivier informatie services, planningsystemen voor duwbakken en management informatiesystemen voor de containervaart. Deze systemen worden verder uitgewerkt en kunnen binnen circa 5 jaar leiden tot een betere uitwisseling van verkeersinformatie en vrachtinformatie.

Het gebruik van ICT in de vaarweg kan leiden tot het inrichten van een complete informatievoorziening voor een combinatie van de huidige en verwachte waterstanden op de scheepvaartroutes, stroomsnelheden en de diepgang van schepen. Het gevolg hiervan is dat schepen kunnen doorvaren tot een extra afname van een waterdiepte van ongeveer 20 cm. De kosten voor deze maatregel zal circa €2 mln. bedragen en kan tussen de 5 en 10 jaar gerealiseerd worden.

4. Vlootmanagement: het gebruik van schepen met een kleinere vaardiepte.

Deze schepen zijn gemaakt van lichter materiaal, hebben extra (tijdelijk) drijfvermogen en zijn mogelijk breder en langer. Het aanpassen van schepen zou gerechtvaardigd zijn bij een droge periode over circa 60-80% van de tijd van het jaar. Om de effectiviteit van deze oplossing beter te kunnen voorspellen is verder onderzoek nodig. De maatregel zal pas ingezet worden als andere oplossingen niet haalbaar blijken, circa 20 jaar vanaf nu.

1 Introduction

1.1 Knowledge for Climate Programme

This research project was carried out in the framework of the Dutch national research programme: Knowledge for Climate (www.knowledgeforclimate.org). This programme is directed to developing a strategy to adapt to the effects of climate change and climate variability, as well as to support sustainable use of available land . The strategy will facilitate decision-making related to climate issues for regional, national and international development for the public and private sectors. This will enhance joint learning between science and practice in coping with climate issues in local, regional and national and international developments for the public and private sectors.

Measures are needed to deal with climate change because of the large impact on a regional and global scale in the immediate future. Although climate change will have an negative impact on Dutch society and economy, it also provides impulse for new opportunities for innovations. To meet this challenge, major investment is required on research on infrastructure and climate change. To respond to this challenge, two research programmes have been initiated and funded in the Netherlands: Climate changes Spatial Planning (CcSP) and Knowledge for Climate (KfC), which started in 2005 and will be completed by 2015

A special feature of both programmes are hotspots. These are places or regions where science and practice meet and collaborate throughout the project cycle from definition phase through the project execution and final evaluation of outcomes in terms of prototyping and implementing climate proof solutions. Selected hotspots include major infrastructural and economic pillars of the Netherlands, such as Schiphol airport, the main rivers and the south-western Delta. The present study is one of the projects on the Rotterdam region.

1.2 Aim of the study

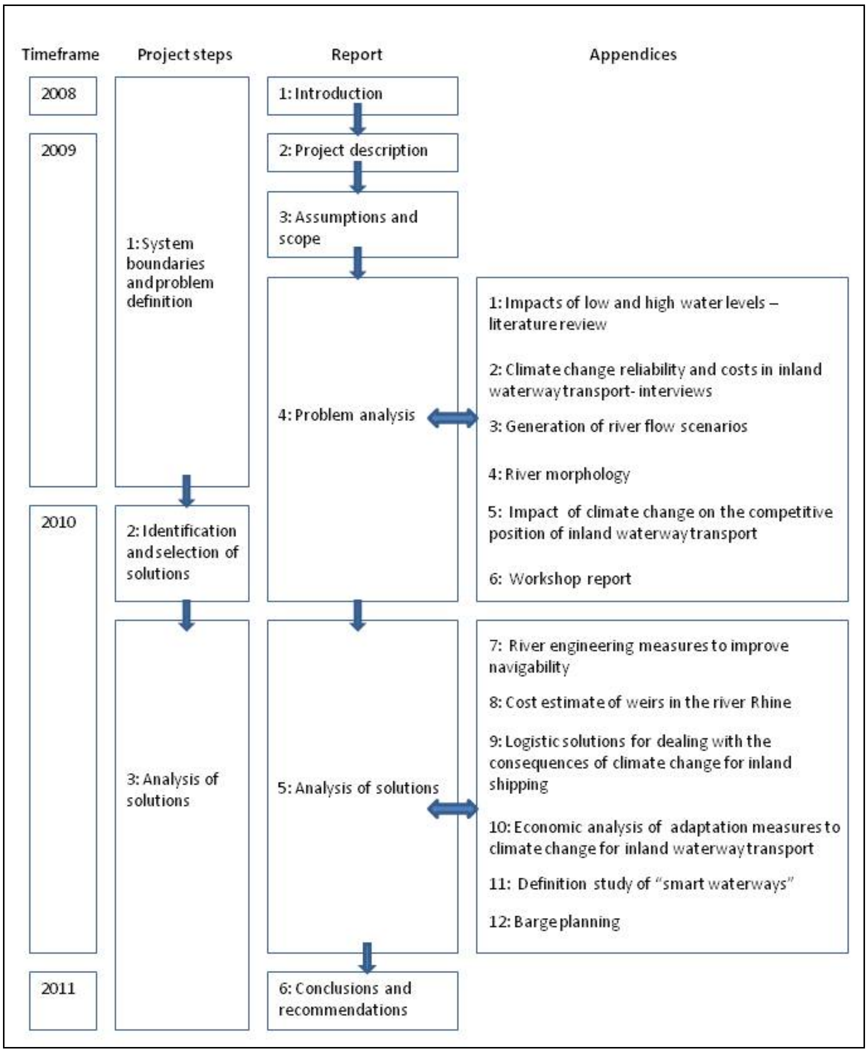
This study investigates the effects of climate change on transport between the Dutch seaports and the Rhine River, which is the main inland waterway connecting the Netherlands with Germany. This investigation was carried out in order to identify potential ways of adapting to the effects of climate. A consortium carried out and self funded this investigation, which followed a holistic approach to define a strategy to adapt to climate change.

Most Knowledge for Climate projects are carried out by a consortium of organisations including universities, governmental organisations, research institutes and private companies.

1.3 Contents of this report

This report summarises the research steps in this project. Various research documents used are presented in a separate appendix report. The overall structure of the project including the timeframe, project steps, content of this report and the appendices is given in Figure 1.

Figure 1: Overall framework of the project



2 Project description

2.1 Objective

The objective of this study is to answer the question: 'How can the adverse effects of climate change on inland transport via Dutch ports, such as the Port of Rotterdam, be reduced or controlled in such a way that:

- Modal split[1] of freight transport by inland waterways will develop as desired by the Port of Rotterdam.

- Inland waterway transport will maintain a reliable mode of transport in the private sector.

The effects of climate change are investigated according to the three aspects:

1. Low river discharge rates.

2. High river discharge rates.

3. Sea level rise and storm surges, which will impact the number of closures of the Maeslant storm surge Barrier.

2.2 Approach

2.2.1 Step 1: System boundary and problem definition

During the workshop and interviews, the problem analysis was discussed with various businesses and stakeholders, which were represented by Vliegasunie, KSV Schuttevaer, DuBarCo, EVO (association of inland waterway transport logistics), EICB (expertise and innovation centre for inland waterway transport) and the Delta programme for Rijnmond - Drechtsteden. International input was provided by the European Federation of Inland Ports (EFIP) and Bundesanstalt für Gewasserkunde (Bafg).

[1] a traffic / transport term that describes the number of trips or percentage of travelers using a particular type of transportation.

This step provides insight to the magnitude of the problem. The research was carried out according to three perspectives on the inland waterway transport sector: the reliability[2], the costs (or damage) and the modal shift[3].

Shippers[4] and carriers were interviewed in order to find out how they would respond to the worst case scenario. The interviews provided an insight into the problems and the competitive position of the Port of Rotterdam.

To get a quantitative impression of the problem, the hydrological model "SOBEK" was used to estimate the impact of climate change on discharge rates and water levels of the Rhine river-system. The inland navigation model "BIVAS" was used to determine the impact of low and high river discharge rates on route selection, changes in loading rate (both resulting in decreased level-of-service) and infeasibility of inland waterway transport (resulting in a decrease of the reliability) due to low water levels. Low and high river discharge rates may have an impact on the competitive position of inland waterway transport (higher transportation costs and modal shift towards road and rail) and the port of Rotterdam (shift of goods towards other seaports). This impact has been estimated with the transportation model "TRANS-TOOLS".

In additional, an analysis was carried out of the impact of climate change on the closing frequency of the storm surge barriers in the Rotterdam area and the consequences for inland waterway transport.

2.2.2 Step 2: Identification and selection of solutions

Possible solutions for low and high river discharge rates were identified and checked that these would allow the position of inland shipping to maintain at the same level in the future.

The selection process was started during a workshop with stakeholders and experts. This workshop had two purposes:

- The stakeholders and experts checked the result of the problem analyses.

[2] The percentage of shipments arriving on time (within a margin) at its destination within a predetermined period (such as a week or a month).
[3] Replacement of a part of the mode of transport by another.
[4] Someone who prepares goods for shipment, by packaging, labelling and arranging for transit, or who coordinates the transport of goods.

- The stakeholders and experts commented on the presented solutions, expressed their preferences, and made suggestions for improvements.

After the workshop the consortium selected the most promising solutions to be researched in the next step.

2.2.3 Step 3: Analysis of solutions

This step focused on low discharge rates for which possible measures were evaluated and assessed. A basic quick-scan was performed for high water discharges. Each partner of the consortium investigated one or two of the solutions.

2.3 Time schedule

The project was started on 12 December 2008 when the approval was given by the Zegveld Commission and was completed in April 2011.

Step 1 was carried out between December 2008 and January 2010.

Step 2 was carried out between February 2010 and October 2010.

Step 3 was carried out between November 2010 and April 2011.

2.4 Project organisation

This research project was carried out by a consortium of private companies, universities, knowledge institutes and public (governmental) parties. Researchers and directly involved parties worked on a daily basis on the project. Other (inter)national organisations were involved for exchanging knowledge and quality management. Therefore, the consortium consisted of four different levels of involvement.

1. Research
2. Project management and support
3. Soundboard, quality and information suppliers
4. To be informed

The research was carried out by Deltares, VU University Amsterdam, Delft University of Technology and TNO. The project management of this research study is carried out by ARCADIS, Port of Rotterdam and the Ministry of Infrastructure and the Environment.

Table 1: Project consortium

Organisations	Project team members	Role	Level
Deltares	Erik Mosselman Christiaan Erdbrink Sanjay Giri Jaap Kwadijk Henk Verheij	Team leader Researcher Researcher Expert Expert	1
VU University of Amsterdam	Olaf Jonkeren Piet Rietveld	Team leader Expert	1
Delft University of Technology	Ad van der Toorn	Researcher	1
TNO	Jaco van Meijeren Tsjitske Groen	Team leader Researcher	1
ARCADIS	Alice Krekt Thijs van der Laan	Project manager Project secretary	2
Port of Rotterdam	Rinske van der Meer Bert Luijendijk	Project manager Expert inland shipping	2
Ministry of Infrastructure and the Environment	Bas Turpijn (Rijkswaterstaat, Center for Transport and Navigation) Ernst Bolt (Rijkswaterstaat, Centre for Transport and Navigation) Harold van Waveren (Rijkswaterstaat, Centre for Water management, involved up to 2009) Rens Vermeulen (2008-2009), Marijke Dirkson (2009-2010) (Directorate-General for Aviation and Maritime Affairs)	Project manager Modelling expert Climate change expert Policy maker for maritime affairs	2
Central Commission for the Navigation of the Rhine (CCR)	Hans van der Werff	International affairs	3
Central Bureau for the Rhine and Inland Shipping (CBRB)	Robert Tieman	Safety and Environment	3

The 4th level is a large group of stakeholders including shippers and carriers such as barge operators. A number of these stakeholders were interviewed for the project.

2.5 Communication

2.5.1 Meetings

The consortium members of level 1 and 2 held meetings on a quarterly basis. These meetings were organised and facilitated by ARCADIS. However, the Port of Rotterdam and the Ministry of Infrastructure and the Environment were included in setting the agenda.

Table 2: Consortium-meetings

Date	Subject
09-03-2009	Project start-up: working method (Arcadis and Port of Rotterdam), scope and boundary conditions (Deltares and TU Delft)
28-05-2009	Presentations of first research results (Deltares, TU Delft, VU and TNO)
14-10-2009	Discussion of first draft reports (VU, TU Delft)
03-02-2010	Determination reports step 1 and discussion draft final reports
18-05-2010	Detailing step 2 and defining possible solutions (step 3)
04-10-2010	Presentation of investigation of possible solutions (step 3)
14-12-2010	Review possible solutions and final report

In September 2009 and June 2010 progress meetings were organised by ARCADIS, Port of Rotterdam and the Ministry of Infrastructure. These meetings were held with each research partner separately. Topics on the agenda included the following:

1. Short evaluation last period
2. Process and collaboration
3. Current workload
4. Review of the products
5. Future workload and activities

2.5.2 Workshop

On 7 April 2010 a workshop for a large group of stakeholders was held in the LEF Centre, Utrecht, the Netherlands, which was facilitated by the consortium.

1. Introduction by Rinske van der Meer (Port of Rotterdam) and Bas Turpijn (Ministry of Infrastructure and the Environment).

2. Information carrousel: Transport costs and shipper and carrier behaviour (VU), Impact on water level, routing, costs of transport and modal split (TNO), River morphology (Deltares).

3. Promising solutions: types of ships (TU Delft), Smart Solutions (Port of Rotterdam), Logistics and transport (VU), Technical innovative solutions (Deltares).

4. Research for solutions in 2010.

The Dutch participants included Vliegasunie, KSV Schuttevaer, DuBarCo, EVO (association logistics of inland shipping), EICB (expertise and innovation centre inland shipping) and region Rijnmond-Drechtsteden.

The international participants included European Federation of Inland Ports (EFIP) and Bundesanstalt für Gewasserkunde (Bafg).

The results of the workshop have been elaborated in a workshop report (Appendix 6).

The results were also posted on Schuttevaer's website: http://www.schuttevaer.nl/nieuws/havens-en-vaarwegen/nid13666-klimaatverandering-kost-periodiek-lading.html.

2.5.3 Conferences

Some consortium members attended the CCR conference in Bonn, Germany (24, 25 June 2009). The conference was titled "climate and inland shipping, challenge and opportunity" and had three separate themes: infrastructure, fleet and markets and logistic chains. The conference was attended by Rens Vermeulen (DGLM), Ernst Bolt (Ministry of Infrastructure and Environment) and Rinske van der Meer (Port of Rotterdam).

A large group of the consortium attended the conference 'Deltas in times of climate change', in Rotterdam, The Netherlands (29 September to 2 October 2010). Alice Krekt presented a poster for one of the theme sessions.

2.6 Financing

The total budget for the project was €320.000,--. The project was financed by:

- Knowledge for Climate programme (50%).
- Own contributions from ARCADIS, Deltares, VU, TU Delft and TNO (20-30%).
- Ministry of Infrastructure and the Environment and the Port of Rotterdam (20-30%).

The budget included costs for research, reporting, accountants, printing of reports and travel costs. Each partner billed their share through the financial system of Knowledge for Climate.

3 Assumptions and scope

3.1 Introduction

The start of a study requires a clear description of the project system. For this study the following items were defined: inland waterway transport, geographical limits of study area, system description, the forecasting time span, and the scenarios for economy climate and change. The National Policy and the policy of the Port of Rotterdam is described as a starting point for this study.

3.2 Inland waterway sector

The inland waterway sector represents all private companies and public organisations related to inland shipping, such as shippers of freight, carriers (e.g. ship, barge and operators), port operators, freight handling terminals and clients receiving freight.

The main focus is on inland water way transport. Other modes of transport and alternative shipping routes have been considered for prolonged periods of low water levels in the Rhine. For each of the three aspects (high water, low water and sea level rise) a specific topic was investigated, such as bulk transportation during low river discharge rate and container transportation during high river discharge rate.

3.3 Geographical area

This project focuses on inland navigation to the hinterland of Dutch Ports, focussing on the Port of Rotterdam. The geographical area that is taken into account is the physical river system of the Rhine (including the Waal and the IJssel) between the Port of Rotterdam and the German hinterland.

This physical system includes the Rhine, and the main branch of the 'Waal', from the Port of Rotterdam to the German hinterland up until Koblenz (see Figure 2). For freight transport the most important part of the shipping route is between Rotterdam and the Ruhr area, with a length of approximately 200 km. However, the navigation routing program used for this research (BIVAS) covered all shipping activities within, and to and from to the Netherlands, as well as smaller contributions from other ports.

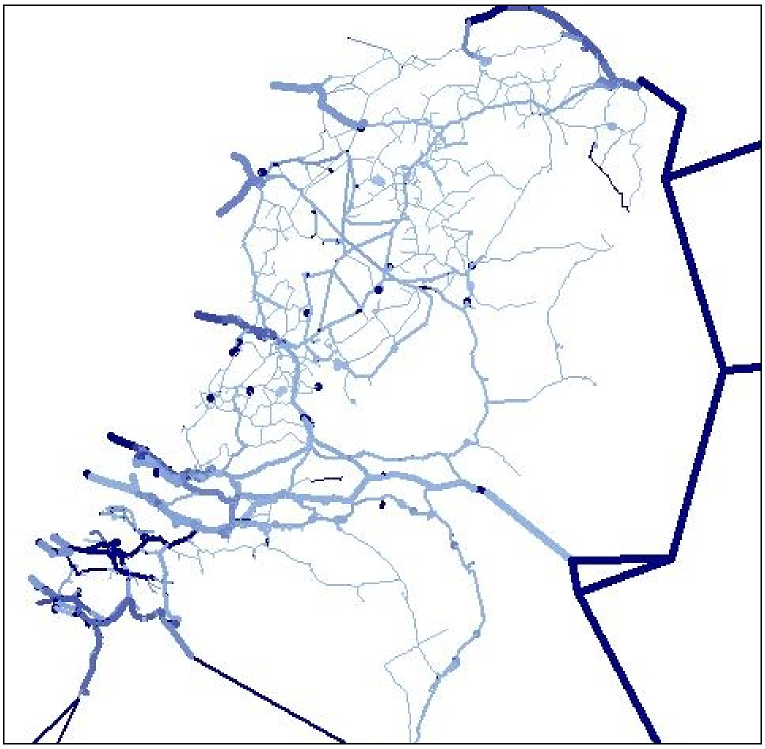


Figure 2: Geographical system boundaries as used in BIVAS

3.4 System description

The relationship between the waterway sector and the river system is that the goods are transported by inland navigation, where the Rhine is being used as main fairway. Because of the value of this important logistic chain and the size of the inland vessels, the actual transport capacity is strongly related to the discharge of the Rhine, or more precisely to the water depth and width of the shipping channel. Therefore, the maximum capacity of inland vessels actually determines the wet cross section of the river. However, the dimensions and thus the capacity of vessels are restricted by the water depth, which is related to the river discharge.

Human measures may have a positive influence on the logistic process as well as on the physical system. For this research it was therefore important to find out which measures were a positive or even optimal contribution in terms of capacity, reliability and costs. In addition to that damage is also defined in terms of impact on image and reputation.

The main dynamic transformation in this system is the effect of climate change scenarios on river discharge, the water depth along the shipping route, and finally the consequences for freight transport along this main shipping route in accordance with economic scenarios.

3.5 Economic scenario

Depending on two key uncertainties: international cooperation and institutional reforms, which are more or less triggered by political decisions, the world economy will develop according to four scenarios: A strong Europe, Global Economy, Regional Communities or Transatlantic Market [CPB Document 38; Quantifying four scenarios for Europe]. The scenario of Global Economy predicts the highest world export rates (of 5.6 %, which is in the same order as the last 20 years) and therefore the highest volume transported by inland navigation. This scenario was chosen for the study in order to clearly illustrate the consequences of climate change.

3.6 Climate scenarios

Worldwide climate scenarios have two main uncertainties which are large scale circulation patterns (changed / unchanged) and global warming (moderate / large). Based on these worldwide scenarios, the Royal Dutch Meteorological Institute KNMI has presented 4 climate scenarios for the Netherlands, which are the G, G+, W and W+ scenarios. For these scenarios the main climate parameters, such as mean temperature, mean precipitation, number of rainy days are different and therefore predict a different discharge rate during the year.

The W+ scenario was chosen for this study as this is the worst scenario in terms of precipitation during dry periods and therefore will give the largest change in periods with a low or even very low discharge. 2004 was chosen as base year because this was an average year with respect to river discharge (whereas 2003 was a very dry year and thus an extraordinary one for inland navigation). A practical argument was the availability of data for this year. For the W+ scenario the hydrological model showed an increase in discharge rate for winter and more importantly a decrease in discharge rate for the Rhine in 2050.

3.7 Time horizon

This research considered noticeable effects of climate change, and was thus a time frame of 50 to 100 years was selected. However, global economic scenarios are of a shorter time span, in the order of 25 years. For this reason the scenario to 2050 was chosen, while taking into account that worldwide economic scenarios are forecasted to 2040 would also be valid for 2050 (considering the effects of the recent economic recessions).

3.8 National Government and Port of Rotterdam policy

An important starting point for this study was the Policy of National government on Waterway transport and the Policy of the Port of Rotterdam. The Dutch cabinet has decided, as set in the coalition agreement, to stimulate freight transport by water and innovation of inland waterway transport. The Dutch cabinet's policy nota 'Varen voor een vitale economie' ('sailing to a vital economy') describes five points for which a key focus is required. Inland waterway transport is a strong and independent sector with a long history in the Netherlands and accounts for a major part of freight transport to seaports. The waterways can accommodate at least double the amount of current water traffic load whereas there is an increase of traffic congestions on the roads and limited rail capacity. The ambition of the Dutch cabinet is thus to promote water based transport and ensure that the Dutch inland waterway transport sector will be able to utilise current market opportunities in order to innovate and grow independently.

The ambition of the Dutch cabinet is set out in the following five key focus points

- To strengthen the competitive position of inland waterway transport.
- To ensure a network of waterways and ports for the future by adopting a network and supply chain approach.
- To ensure that inland waterway transport will be the cleanest mode of transport.
- To permanently improve safety of inland waterway transport.
- To stimulate innovation in the inland waterway transport sector.

For the Port of Rotterdam, rail and inland shipping are the main hinterland modalities for the future. With ongoing increase of container transport, rail and inland shipping are ideal transport modes for ensuring that in addition to the important Dutch market, the European market remains optimally accessible as well. Barge and rail transport fit in perfectly with Rotterdam's sustainability strategy. The Rhine and Meuse rivers provide an excellent infrastructure for efficiently transporting containers to and from Belgium, Germany, France, and the Netherlands. Of course, all these advantages do not automatically guarantee a successful future. The expected growth poses major challenges.

Currently 6.8 million TEU is transported across the European continent - mainly by road - to and from Rotterdam, whereas expectations are that this will increase to 20 million TEU by 2035. By that time, the Port of Rotterdam Authority will bind customers to move 45 % of their hinterland transport from the Maasvlakte by inland shipping and 20 % by rail. In the current modal split container transport is 39 % by water and 13.5% by rail. Absolute numbers say even more about the impact of the growth ambitions: inland shipping will grow from 2.8 million TEU right now to 9 million TEU in 2035 (an increase of 6.5 % per year), rail from 600,000 TEU to 3.7 million TEU (6 % growth per year).

4 Problem analysis

4.1 Introduction

First step in this study focuses on the question: 'Is there a problem concerning the competitive position of inland waterway transport, and if so, how can this be attributed to changes in water levels in the W+ climate scenario?'

In order to address this, water levels on the rivers and number of closures of the Maeslant storm surge barrier were investigated and predicted for the future.

4.2 Current situation

4.2.1 Hydrology of the Rhine

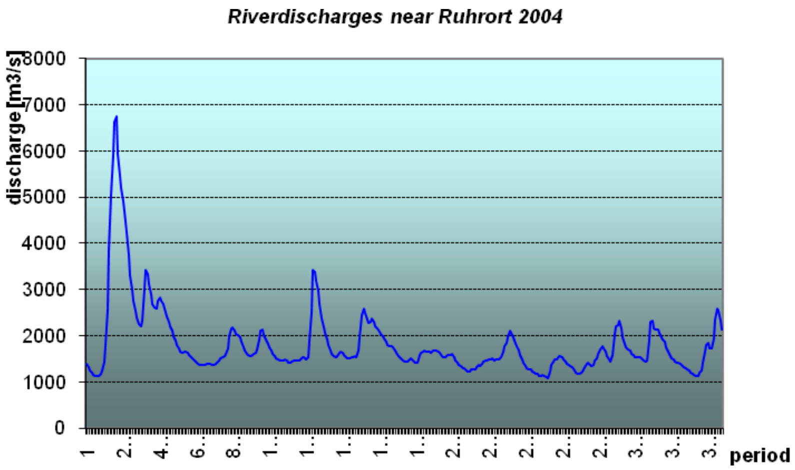
Important hydrological factors of the river are the discharge rates and water levels. Table 3 shows the average discharge rates of the Rhine in summer- and in winter between 1968 and 1998. The Rhine is a mixed snow melt and rainfall river.

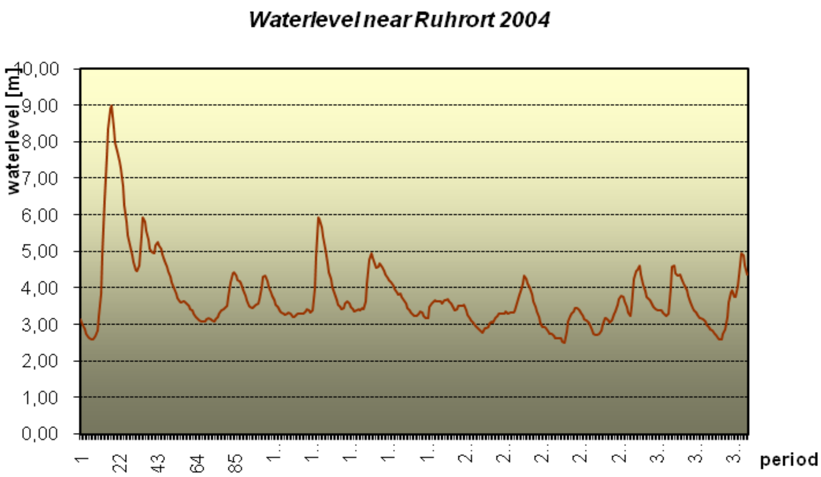
Table 3: River discharge rates for the Rhine (Source: Verheij, 2010)

Year	1968 – 1998
Average discharge in summer (m^3/s)	1700
Average discharge in winter (m^3/s)	2750

Figure 3 shows the discharge rates and water levels for 2004 near Ruhrort, Germany. This data was used to describe the current hydrological situation of the Rhine river system.

Figure 3: Discharge rates (above) and water levels (below) near Ruhrort for 2004 (source: Deltares)



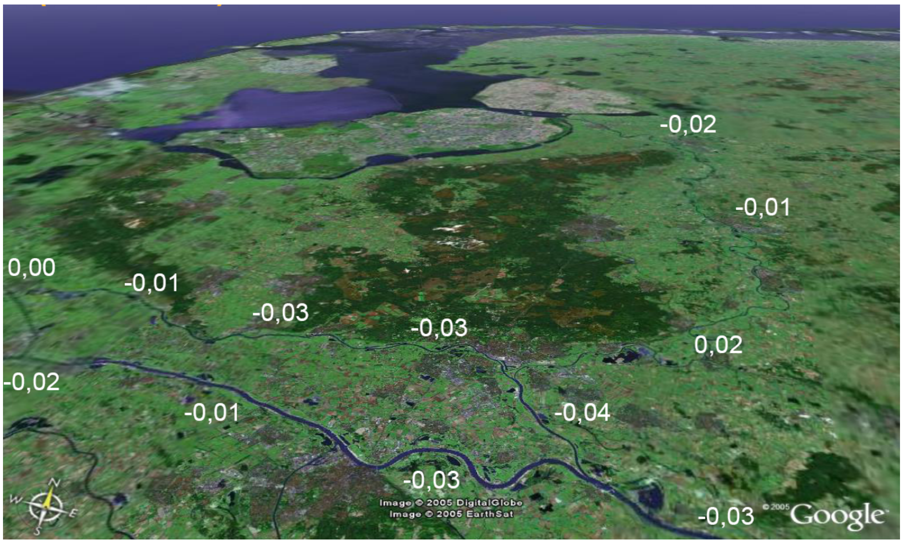


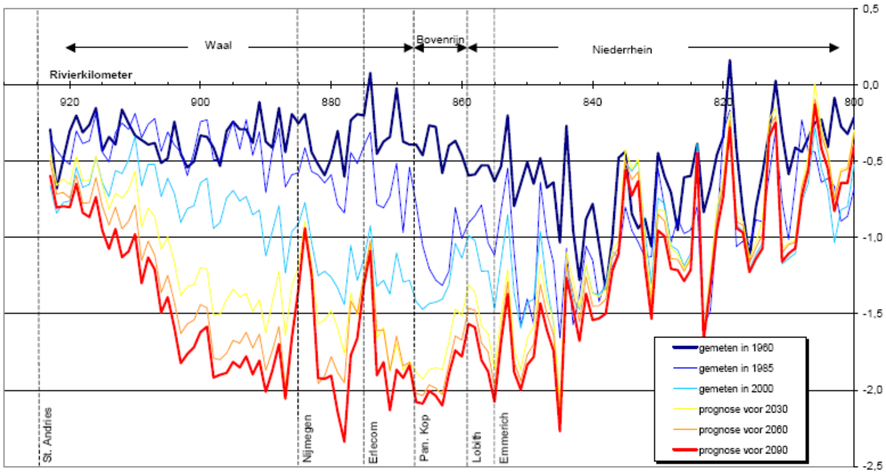
4.2.2 Riverbed of the Rhine

In the Netherlands there is a continuous process of land subsidence, which is shown in Figure 4. The rivers are subjected to the morphological processes of accretion and erosion which change the topography of the riverbed. However, at some locations there is a fixed bed layer. These fixed layers are stable and are not subjected to erosion but have caused local bed elevations, as shown in Figure 4 on the right side of the river. These elevations can be hazardous for navigation or even cause congestion. Section 4.3 addresses this item in more detail.

Figure 4: Land subsidence in the Netherlands (above).

Cross-section of the Waal river show land subsidence between 1960 (measured, blue) and 2090 (predicted, red) (below)





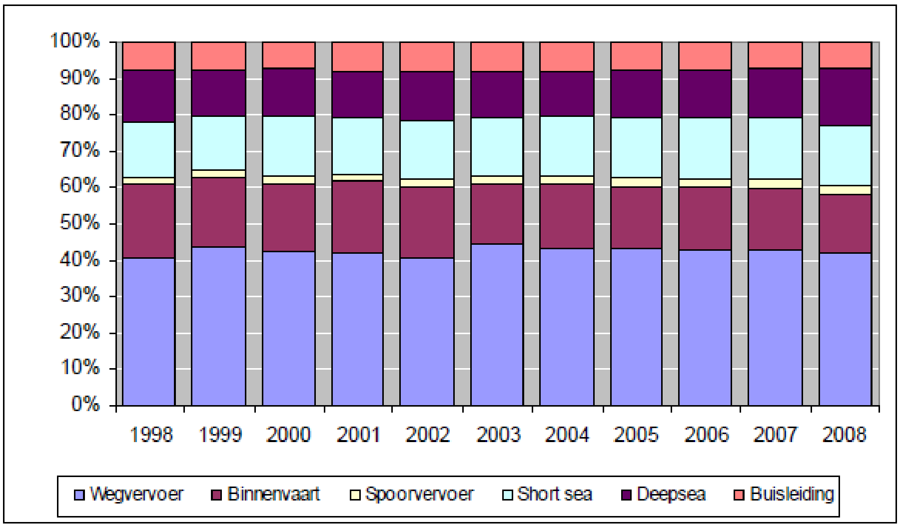
4.2.3 Inland Navigation in the Netherlands

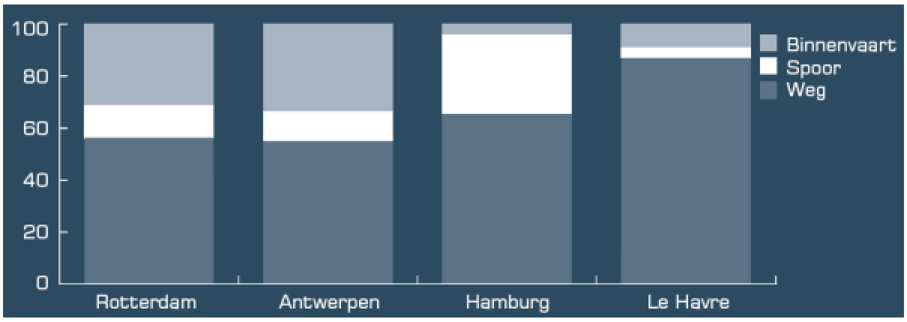
Over the last year over 300 million tons of freight has been transported on the Dutch waterways. The share of inland waterway transport accounts for approximately 20% of the total freight transport in the Netherlands (see Figure 5, 'binnenvaart', which means inland waterway transport). Inland waterway transport is very important for the port of Rotterdam.

Figure 5: Modal split of freight transport in the Netherlands (above) (source: Rijkswaterstaat)[1]

Modal split of freight transport between the largest ports in North-western Europe (below)

Inland waterway transport = "binnenvaart"
Roads = "weg"
Rail = "spoor"

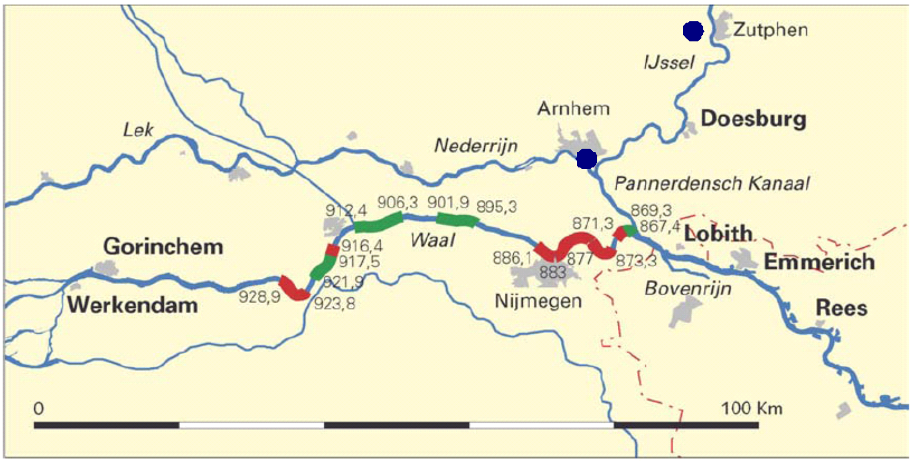




In the Netherlands there is an extended network of waterways. The national waterway network covers approximately 7,600 km of navigable inland waterways along rivers, canals and lakes. The so called 'Rijntakken', comprising of the Rhine river, the Waal river and the IJssel river have been classified as the Main Transport Axis and accommodate approximately 75% of inland waterway freight transport. Maintaining navigability of the 'Rijntakken' is vital in order to serve the Dutch transport networks (see Figure 6).

Figure 6: The branches of the Rhine are shown in blue

Rijkswaterstaat (the Dutch Ministry of Infrastructure and Environment) aims to maintain the navigability of the Rhine branches. Rijkswaterstaat strives to maintain a minimum water depth in the waterways under the so called 'agreed low water level' (OLR). The water depth for the Waal (the main route on the Rijntakken) is 2.80 m at OLR. Navigation is prohibited for water levels below OLR. At this moment, several bottlenecks for navigation in the Rijntakken have already been signalized (figure 7, red: problems with fixed bed layers, green: problem during high water, blue: width problem). Rijkswaterstaat is conducting projects to solve these bottlenecks.



Vaste knelpunten		Hoogwaterknelpunten	
Hulhuizen	(km 869,3 - 871,3)	Pannerdensche Kop	(km 867,4 - 869,3)
Erlecom	(km 873,3 - 877,0)	Winssen-Deest	(km 895,3 - 901,9)
Haalderen	(km 877,1 - 883,0)	Ochten-BenedenLeeuwen	(km 906,3 - 912,4)
Nijmegen	(km 883,0 - 886,1)	Zennewijnen-Ophemert	(km 917,5 - 921,9)
Passewaaij	(km 916,4 - 917,5)		
St, Andries	(km 923,8 - 928,9)		

Figure 7: Current navigation bottlenecks in the Rijntakken (source: Rijkswaterstaat, MIT-verkenningennota Duurzame Vaardiepte Rijndelta, 2007)

4.3 Future situation

4.3.1 Autonomous development

The water depths for navigation change in the autonomous development. These autonomous changes, however, do not result from changes in amounts of water but from changes in the topography of the river bed. River morphology is the science of describing, modelling and forecasting changes in river bed topography as a result of processes of erosion and sedimentation. This represents a separate, distinct source of navigation bottlenecks, in addition to extended periods of low flows and the limited space under bridges during river floods or storm surges. The Rhine branches experience two ongoing morphological autonomous developments.

River bed degradation

First, they exhibit a trend of overall river bed degradation as a result of a deficit in the sediment supply from upstream, excessive dredging in the past, a retarded adaptation to river training works and an inland shift of the erosion base (river mouth). The relative contribution of each of these factors is still unknown. River training along the river Waal increased the sediment transport capacity with values up to 60% in the 19th century. The resulting erosion produced substantial bed degradation, which appears still active because recent lowering of the Boven Merwede river bed cannot be explained from sand mining alone. HKV (2006, 2007) predicts further degradation till 2066 to amount to 0.75 m in the rivers Bovenrijn and Waal and 1.0 m in the Pannerdensch Kanaal. Continued bed degradation poses a problem, because the fixed layers in the outer-bend pools at Nijmegen and Sint Andries do not follow the degradation and hence become obstacles for navigation (see also figure 7). Furthermore, continued bed degradation threatens the protection cover of cables and pipelines, the stability of banks protected by riprap, the stability of 510 groynes on the Bovenrijn and the Waal and the stability of 68 groynes on the Pannerdensch Kanaal. Havinga (2009) points at the growing discrepancy between the degrading bed in the Netherlands and the stabilised bed in Germany, because this is expected to create a nautical bottleneck between Lobith and Emmerich within 5 to 10 years. More details on problems due to overall bed degradation are given in Appendix 4.

Room for the river programme

The second autonomous development in river morphology is the implementation of the Room for the River programme. Most measures of the programme involve in increasing the space in the floodplains. Discharges of frequently occurring floods will hence increase on the floodplains and decrease in the main channel. The resulting decrease of annual sediment transport capacity in the main channel induces sedimentation. Uniformly distributed sedimentation along the river is not the largest problem and might even be beneficial for navigation as it might reduce or arrest the ongoing problematic overall bed degradation of the Rhine branches. The major problem for navigation is that most measures, except for the lowering of groynes, have a limited spatial extent and hence cause accentuated local shoals during floods. Those shoals remain obstacles in the main channel for some time during low-flow periods if they are not dredged.

Consultancy firms have assessed local short-term morphological effects for individual measures within the programme, but an overall long-term morphological impact assessment remains to be carried out. One of the drivers of overall morphological change will be the resulting modification of discharge hydrographs in individual Rhine branches, caused by increased flows into the Waal at moderate floods due to the lowering of groynes under the programme. Shoals due to implementation of the Room for the River programme can be seen as an indirect result from climate change, as the programme is partly motivated from an expected future increase of the design flood discharge at Lobith to 18,000 m^3/s. The implementation is to be completed by 2015.

4.3.2 Morphological effects and climate change

The climate change scenarios lead to changes in river discharges, i.e. the amounts of water in the river, as well as to changes in river bed topography. Both types of changes affect navigation depth. The detailed analyses in the present study, however, are based on changes in river discharge only, under the assumption that the river bed remains unchanged. Navigation depths have thus been inferred from water levels at specific gauge stations.

Changes in river bed topography due to erosion and sedimentation have been neglected in the detailed analyses of the present study. Such changes will be induced by climate change, but they will also occur in the autonomous development of continued overall river bed degradation and implementation of the Room for the River program. The morphological changes due to climate change result from modification of annual discharge hydrographs and from developments in the supply and extraction of sediment.

Appendix 3 shows that the annual discharge hydrographs of the G and W scenarios increase the annual sediment transport capacity on the Rhine by 3% to 12%. This is an order of magnitude less than the 60% increase due to training of the river Waal in the 19th century. The G+ and W+ scenarios have an opposite effect, as they produce a 3-5% decrease in sediment transport capacity. This decrease would help in arresting the trend of overall bed degradation, making climate change a blessing in disguise rather than a threat. It is worth noting that varying discharges affect river morphology and navigability not only through their frequencies of occurrence, but also through their rates of change. Shoals formed during a flood may be eroded away by the river itself if the flood recedes slowly, whereas they may remain obstacles for navigation if the flood falls rapidly. A more refined picture of the morphological changes due to varying discharges requires computations using calibrated numerical models.

Developments in the supply and extraction of sediment depend on dredging, sediment nourishment and river-basin sediment yield. Changes in these developments depend on future societal demands and financial constraints and are essentially unknown.

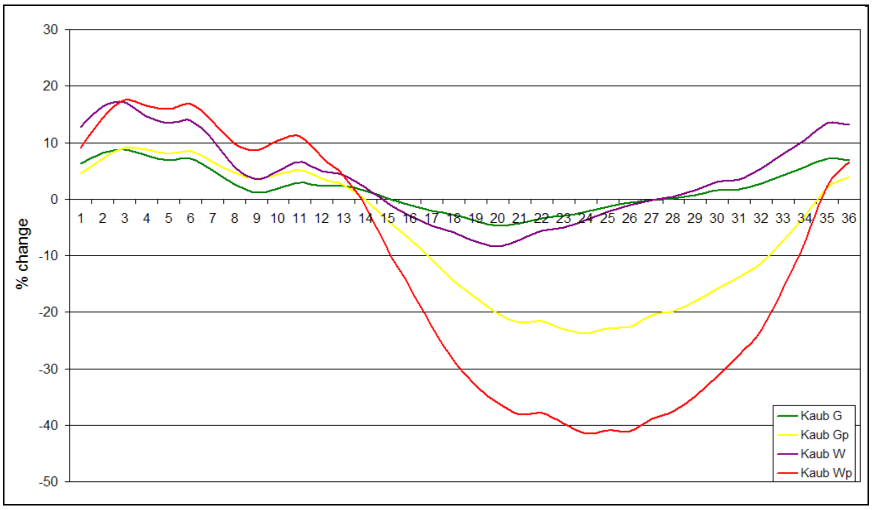
The morphological effects of climate change and autonomous developments interact in a complex manner. Climate change affects discharge hydrographs and sediment yield in ways that either aggravate or mitigate the formation of navigation obstacles. It also incites further extension of Room for the River measures in order to provide safety at higher design discharges. The increased occurrence of shoals due to these measures may necessitate more river training and sediment management. Replacing the current sector approach to river interventions by an integral approach would create optimum conditions for doing justice to these complex interactions, allowing synergy rather than accumulating adverse effects.

4.3.3 Changes in water levels

As a result of climate change, inland waterway transport may experience problems related to higher volatilities in water levels.
The river Rhine is a combined rain-snow river. As a result of climate change, it is expected that the Rhine will be more rain-fed in the future. More specifically, it is expected that, in winter, precipitation will increase, and higher temperatures will cause a smaller proportion of precipitation to be stored in the form of snow in the Alps. As a result, in winter more precipitation will directly enter rivers, average and peak water levels will be higher, and the number of days with low water levels will decrease. In summer, besides a reduction in melt water contribution, there will be less precipitation and more evaporation due to higher temperatures. As a consequence, inland waterway vessels on the Rhine will experience lower water levels, as well as an increase in the number of days with low water levels in summer and autumn (Middelkoop et al., 2001; Verheij, 2010). Low water levels imply restrictions on the load factor of inland ships. This suggests that the capacity of the inland waterway transport fleet is (severely) reduced in periods with low water levels, which has (economic) consequences.

As low water levels hardly occur during winter, the reduction of days with low water levels in winter will be small. However, an increase of days with high water levels in winter implies an increase in the number of days on which inland waterway transport is blocked for safety reasons.[5]

Figure 8: Change in discharge (in m^3/sec) of the Rhine during a year under the KNMI'06 climate scenarios at Kaub (source: te Linde, 2007)



[5] River dikes are heavily put to the test in periods of high water levels, and they may break as a result of the extra pressure inland waterway vessels impose on these dikes during periods with high water levels.

Figure 8 illustrates what the effect of climate change on discharge of the river Rhine at the location Kaub (a small town which is located on the East bank of the Rhine in middle Germany) is expected to be under the four climate scenarios that were described in chapter 3.7.[6] On the horizontal axis, the time period of one year is divided into 36 periods of ten days. The vertical axis shows the expected percentage change in discharge compared with the average discharge between 1961 and 1995.

In the summer months June, July and August, there are only minor changes in the mean discharge in the G and W scenarios. However, the G+ and W+ scenarios (each with a strong change of atmospheric circulation), show a decrease in mean discharge of 22 – 42 per cent (te Linde, 2007). A reduction in discharge may cause several problems. For example, inland ships may have to reduce their load factor resulting in higher unit transport prices. Jonkeren et al. (2009) compare the average annual number of days with water levels at Kaub that cause load factor restrictions for an inland ship of average size in the period 1987 – 1995 with the year 2050 under the four KNMI'06 climate scenarios (see Table 4).

Table 4: Effect of climate scenarios on the length of the low water period (Source: Jonkeren et al., 2009)

Climate scenario	**Base period (1987 – 1995)**	**G (2050)**	**G+ (2050)**	**W (2050)**	**W+ (2050)**
Average annual number of days with load factor restrictions	103	99	140	95	182

In Table 4, we observe that only in the G+ and W+ scenarios, the number of days with load factor restrictions increase considerably compared to a year under current climate conditions (base period). In addition to load factor restrictions, the reliability of inland waterway transport may be negatively affected as a result of low water levels. Lower load factors imply more traffic movements leading to longer loading, unloading and waiting times in front of locks for carriers.

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[6] Discharges in rivers (measured in m^3/sec.) can be converted to water levels (measured in centimeters) by means of the so called discharge rating curve. Formulas exist for this conversion for several locations at the Rhine. These formulas have to be updated now and then because of changes in the structure of the riverbed over time. Discharges and water levels at the location Kaub are especially important as it is here that water level restrictions are most limiting: they determine the load factor of virtually all inland ships that pass Kaub.

Focusing on high water levels, the mean rise in discharge in the winter months December, January and February varies from 8 per cent for the G scenario to 16 per cent for the W+ scenario (te Linde, 2007).

Interesting for the inland waterway transport sector however, is the frequency and length of high water level periods that lead to a blockage of inland waterway traffic under future climate change. Unfortunately, no data is available on this. As an alternative we present the history of inland waterway transport blockages on the Rhine since the year 2000 in Table 5. Except from the year 2002, blockages occurred not at all, or once a year. The length of a blockage is between one and four days. Clearly, a blockage on inland waterways negatively affects reliability and consequently may increase transport costs for shippers.

Table 5: Blockages of inland waterway transport in the Rhine as a result of high water levels[1]

Date	Location	Length (in days)
23-03-2002	Bingen	3
04-11-2002	Maxau	4
14-01-2004	Maxau	2
16-01-2004	Koblenz	1
17-01-2004	Andernach	1
23-08-2005	Maxau	3
24-08-2005	Mainz	n.a.
10-03-2006	Maxau	3
09-08-2007	Maxau	3
23-04-2008	Maxau	1

In the next section, we will discuss the effects on climate change on transport costs, reliability and modal share.

4.4 Effects

4.4.1 Effects on inland navigation and modal split

Figure 9 shows an overview of the inland waterways network with several well-known “low water related bottlenecks” along the Rhine in Germany (Ruhrort and Kaub), along the Rhine and the Waal near Arnhem and Nijmegen and on the IJssel and the Meuse.

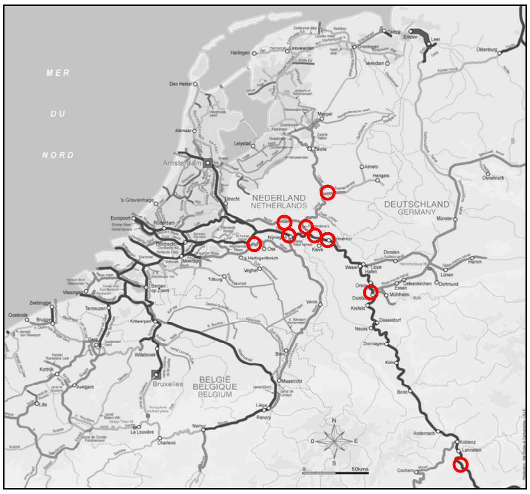

Figure 9: Overview low water related bottle-necks

The expected water levels in the W+ scenario lead to problems concerning feasibility of inland waterways transport, the reliability of inland waterways transport and increased transport costs.

With the inland navigation model “BIVAS” has been estimated the amount of navigation trips that will become infeasible (no inland waterways transport possible) due to low and high water levels in the river system of the Rhine. BIVAS also estimated the increase in transportation costs for the remaining navigation trips, facing draught problems (vessels can only be partly loaded or have to take an alternative – longer - route). These results have been used in the TRANS-TOOLS model to determine the impact of periods with low water levels on the competitive position of inland waterway transport (modal-split and port competition).

Summarized, we can expect an increase in transportation costs between 9% and 23% (see Appendix 1), due to more high and low water levels if the W+ climate scenario will persist. The impact on the modal shift has been analyzed for each 10-day period in the year 2050. In this section, we present the results for the whole year and for the 10-day period with the lowest water levels.

Annual results (see figure 10):

- For the whole year, from the total inland waterway transport within, to, from and through the Netherlands 86% of the total volumes is not affected by the impact of the W+ climate change scenario;
- From the 14% of the inland waterway transport that is confronted with the impact of the climate change, 7% becomes infeasible (unreliable because the goods cannot be delivered at the planned moment) and 7% is still feasible, but against increased generalized transport costs;

- The increase in unreliability and level-of-service leads to a modal-shift of 8% of the total annual volume. From this volume 88% has an incentive to shift to rail transport and 12% to shift to road transport;

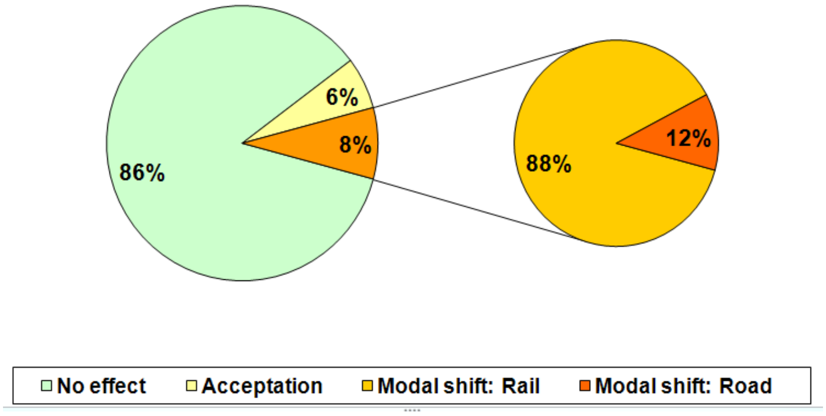

Figure 10: Annual results of the impact of periods with low water levels on the competitive position of inland waterway transport

Results 10-day worst case period (see figure 11):

- For the worst case 10-day period, the volume not affected by the impact of the W+ climate change scenario is 55%.

- From the 45% of the volume that is confronted with the impact of climate change, 35% becomes infeasible (unreliable because the goods cannot be delivered at the planned moment) and 10% is still feasible, but against increased generalized transport costs;

- The increase in unreliability and level-of-service leads to a modal-shift of 28% of the total volume in this 10-day period. From this volume 78% has an incentive to shift to rail transport and 22% to shift to road transport.

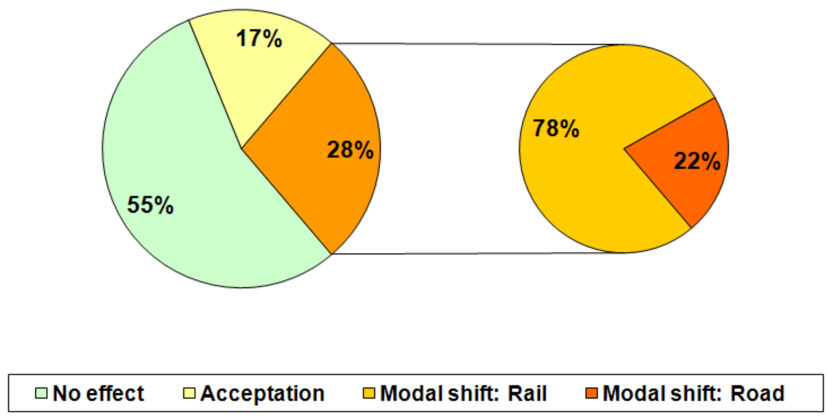

Figure 11: 10-day worst case period results of the impact of periods with low water levels on the competitive position of inland waterway transport

4.4.2 Effects on transport prices and reliability

Costs and reliability determine, among other factors, the competitive position of inland waterway transport. The previous sections have shown that low and high water levels result in restrictions on the load factor of inland ships and possibly blockages on inland waterways, implying higher transport costs and a deterioration of transport reliability. Climate change in G+ and W+ scenarios is likely to affect these determinants of mode choice negatively, possibly resulting in a loss of freight by inland waterways to competing modes. Shippers may decide to use another transport mode, which means a loss of demand for inland waterway transport. Consequently, the competitive position of sea-ports that rely on inland waterway transport (the Port of Rotterdam for example - see also figure 5) may worsen. The effect of climate change on costs and reliability of inland waterway transport is assessed by means of interviews with inland waterway transport dependent shippers. Parallel, a model study has been conducted to estimate the effects on costs and infeasibility in a quantitative manner (see Appendix 5).

Because knowledge on the frequency and duration of future high water level situations - leading to a blockage of inland waterway transport - is lacking, we confronted the shippers with hypothetical W and W+ high water levels situations based on high water level situations from the recent past. Between 2002 and 2008 those situations happened infrequently and lasted for a relatively (compared to the duration of low water situations) short period of time (2 – 4 days). According to the respondents, the reliability of inland waterway transport will then decrease; however, because high water level situations can be forecasted quite precisely, carriers are able to arrange alternative forms of transport. So, consequences for shippers are probably limited.

In case of low water levels, in both climate scenarios, W and W+, all interviewed shippers expect that transport costs will increase. Depending on the route, cargo type and size of the barges used[7] this increase varies between 10% and 500% and more. Reliability is not affected in case of climate scenario W but in the W+ scenario interruptions and even a standstill of production processes are expected due to low water levels.

The short and long term actions that are undertaken by shippers and carriers (only last two bullets) to reduce the impact of high and low water levels on transport costs and reliability are:

[7] Jos Helmer, senior business manager Containers, Breakbulk & Logistics at the Port of Rotterdam, emphasized that especially the increase in ship size in recent years has contributed to the increase in load factor restrictions of barges.

- Using alternative transport modes (for the whole inland waterway transport route)[8]
- Examining new logistical chains (partly inland waterways, partly rail e.g.)
- Postponement of inland waterway transport (in case of a short high/ low water level period)
- Hiring extra capacity on the inland waterway transport spot market
- Investing in stock facility capacity/ higher stocks
- Increase of the own fleet of inland ships
- An increase of navigation speed
- Transformation from barge-operator to container operator

For the Port of Rotterdam it is interesting to determine whether the above mentioned actions may have an impact on the functioning of the port.[9] As shippers mention that using alternative transport modes is a solution and a carrier is planning to convert its organization from barge-operator to container operator, a more frequent occurrence of periods with (more intense) low and high water levels (climate scenario W+) may increase the frequency and intensity of demand for alternative transport modes. As the railway system is relatively inflexible, those situations are likely to lead to a lack of rail transport capacity.[10] As a result, less cargo will be transported from and to the port in periods with low and high water levels. In addition, more transport by truck is contrary to the policy of the Port of Rotterdam to encourage the shift towards intermodal transport.

Postponement of inland waterway transport may lead to peaks in demand for barge handling capacity as it is likely that just before and after a (short term) high or low water level period these demand peaks will arise. Container handling and transport capacity will be able to cope with these demand peaks, but for the bulk cargo segment the danger of congestion is present here.

The existence of peaks in demand for barge handling capacity implies that there will also be peaks in demand for storage capacity. After all, if there are low and high water level periods in which barge transport is postponed or limited, the containers and bulk cargo which is supplied by sea vessels must be temporarily stored. Again, a problem is likely to arise here for bulk cargo. Container storage capacity is sufficiently available, certainly in the near future when the second Maasvlakte is constructed.

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[8] In recent years, a few large shippers in the Ruhr area invested in a railway (un)loading site at their industrial area in order to secure transport.

[9] Although not all the examined routes have Rotterdam as an origin or destination point, the behaviour of the shippers concerned is relevant as there may exist non-interviewed shippers which do make use of the Port of Rotterdam and show similar behaviour.

[10] Jos Helmer mentions the passenger – freight conflict and the number of available locomotives.

4.4.3 Effect on competitive position of Port of Rotterdam

Coming to the question whether there is a problem concerning the competitive position of inland waterway transport and the extent of this problem, it can be concluded that on the specific market between the Netherlands and Germany, the competitive position of inland waterway transport is threatened, especially during and after summer time. Navigation with large barges then will face troubles on the "Rijntakken" (see figure 6): for some trips, navigation will become infeasible. Others have to unload partially to navigate during summertime and will face higher costs.

Concerning the increase of the closing frequency of the storm surge barriers in the Rotterdam area, it is concluded that the increase of the closing frequency of once every 10 years now to once every 5 years in 2050 will not have a substantial impact on the competitive position of inland waterway transport neither on the competitive position of the port of Rotterdam.

The modelling exercise with BIVAS and TRANS-TOOLS shows that the climate change can have a substantial impact on the competitive position of inland waterways transport on specific markets (both competition with other transport modes and with other ports). A loss of 8% annually or 28% in the worst case 10-day period in transport demand for all inland navigation within, to, from and through the Netherlands might occur (on specific corridors such as Rotterdam - Germany, these percentages are substantially higher).

The majority will tend shifting to rail transportation. The German ports are well connected with the German Rhine Area by railways. As figure 4 shows us, the German seaports are relatively less depended on inland waterway transportation compared to Rotterdam. A decrease in navigability by inland waterways, combined with well railways connections of Hamburg and Bremen, might also cause a shift from Rotterdam to German ports. If this happens, up to around 4% of the total inland waterways transport could shift to these German ports.

The interviewed stakeholders expect that high and low water levels under the W and W+ scenarios are unlikely to have severe negative impacts on the competitive position of the Port of Rotterdam (via costs and reliability of inland waterway transport). Based on interviews with stakeholders, the identified potential impacts for the Port of Rotterdam are:

- less incoming and outgoing cargo to/ from the port in periods with low/ high water levels,
- temporal more train and truck movements and (un)loading operations,
- congestion in bulk handling because of high demand for handling capacity just before/ after period with low/ high water levels,
- a shortage of storage capacity for bulk cargo in the port.

The different results from the interviews compared to the modelling results concerning the competitive position of the Port of Rotterdam can be explained by the time horizon that is taken into account. Stakeholders such as shippers, carriers and operators in general have a relative short time horizon (up to maximum 5 years). These stakeholders do not experience climate change problems at the moment and they don't expect them for the next couple of years. In the modelling exercise, the time horizon is 2050 and it is assumed that the W+ climate change scenario becomes reality.

A more detailed overview of the impact on the modal-split and the competitive position of the Port of Rotterdam is included in Appendix 5.

4.5 Matching problem analyses, with policy and stakeholder considerations

The policy of the Ministry of Infrastructure and Environment and the Port of Rotterdam is to enlarge the share of inland waterway transport. In order to reach that goal, stakeholders like shippers and barge operators demand reliability and cost effectiveness. Climate change will negatively involve those goals and demands. In summary there appear we to be three problems for the future of inland water transport:

1. Periods of low water levels will be the largest problem
2. With ongoing sea level rise the Maeslant storm surge barrier will have to be closed more often and for a longer periods of time
3. High water periods will occur occasionally

The challenge is to decrease the negative effect of climate change on reliability during low water periods and at certain times of high water periods. Uncertainty is the effect of morphology on this problem.

A major issue is the sense of urgency among companies as the "keepers of solutions". Although reliability of the inland waterway connection is top priority for the business sector, the sense of urgency about climate change is not high enough to start developing large scale adaptation solutions at this moment.

The problem seems a future challenge to companies, on which action can be taken later. The timescale and uncertainties of impact is subject of discussion amongst shippers and carriers. In future these problem situations will occur more often. Is there time to adapt at that moment? Do we need to act now, to be ready for climate changes? This will be topic for the next chapter.

5 Analysis of solutions

5.1 Introduction

In this study four main types of solutions have been identified. For each type the most promising solutions were selected by the partners of the consortium in an expert meeting. Each partner of the consortium investigated one or two solutions from their perspective and expertise. This allowed a first selection of solutions, which are summarised in this chapter. The consortium and experts selected the following categories of solutions:

1. River management: dredging, and construction of structures such as movable weirs, adjustable groynes, reservoirs and retention basins.

2. Management of logistics: Increasing the resilience and flexibility of the sector by modifying the supply chain. This can be accomplished by providing larger stock or storage capacity, alternative routes, other transport modalities, extra cargo handling facilities in ports and terminals.

3. Information management: Providing up-to-date on line information on current and expected water depths in the shipping route, local patterns of currents and water velocities, as well as real-time draught and trim of the vessel.

4. Fleet management: Using vessels with a shallower draught. Thus, vessels which are wider and longer, constructed of light weight materials and, or extra (temporary) buoyancy.

5.2 River management

5.2.1 Waterway improvement

Navigability can be improved by implementing technical measures in the main channel such as dredging, and construction of structures such as groynes, fixed bed layers, bottom vanes, bendway weirs and longitudinal dams, and modification of existing groynes. In Appendix 7 a summary is provided of the DVR studies on the effectiveness of these measures that may increase navigation depth by 0.1 to 0.5 m.

The navigation depth of a river section is determined by the smallest depth sounded within that section, while the location of shoals is not taking into account. For some locations the lack of sufficient depth could be resolved by construction of a groyne, whereas for other locations adaptation of river training works over a considerable length may be required. Once the most problematic shoal has been taken away, another shoal will determine the navigation depth for that section, possibly with different characteristics that pose other requirements for corrective measures. This means that there is no straightforward relationship between cost of intervention and increase in navigation depth.

In the Waal River there are approximately five groynes per km. The costs for construction of a groyne are approximately €0.3 million, and costs for modification of an existing groyne are approximately €0.1 million. Therefore, the costs for modifying or constructing groynes in the Waal would be approximately €0.5 to 1.5 million per km. These prices vary even more, however, because they depend on the number of groynes involved and the possibilities of re-using construction materials. Costs for longitudinal dams range from €1 to 3.5 million per km., again depending on the possibilities of re-using construction materials.

Dredging is by far the cheapest technical solution to improve navigability. The dredging costs are approximately €2 to €40 per m^3, depending on ground conditions and dredging volume. However, more expensive permanent measures are preferred because dredging can cause disturbance for river traffic, or an increase of the risk of accidents. A review of a cost-benefit analysis of dredging by Van der Most et al (2005) confirms that there is no simple relationship between costs of dredging and increase in navigation depth.

The costs for increasing the navigation depth by 0.1 to 0.5 m in the main channel are estimated at approximately €0.1 to 10 million.

5.2.2 Canalisation of the Rhine

The second adaptation measure studied in this report is canalisation of the section of the Rhine (Waal and Lek, see figure 12) between Rotterdam and the Ruhr area. Analysing costs and benefits of this measure is interesting because it is a highly complex and controversial measure. Canalisation of the mentioned section could be applied by the construction of about 4 weir-lock-complexes. In times of low water discharges the weirs are in closed position and so give enough water depth. These locks make it possible to overcome the created differences in heads, here estimated as about 5 meter per weir. Though with some delay, navigation with normal draught is still possible by using the navigation locks.

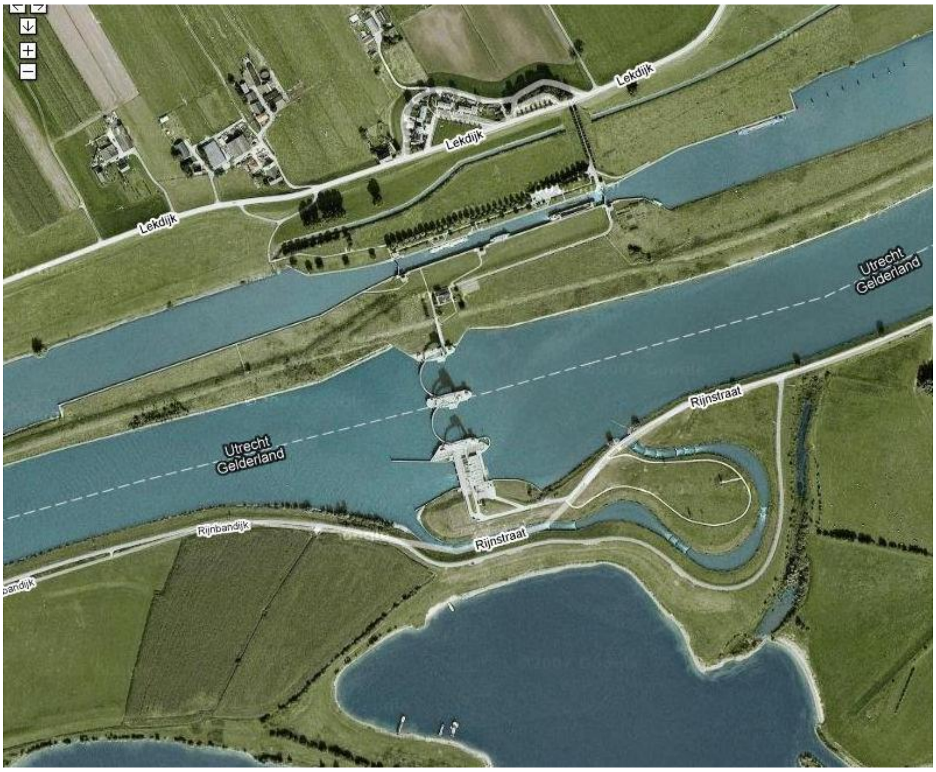


Figure 12:
River Lek: In order to give passage to the navigation of nearly closed weirs, these weirs are mostly combined with one or two navigation locks.

Annual benefits of this measure are calculated and defined as the reduction of transport costs (see Appendix 10). So, benefits are expressed as ‘avoided transport costs’ for shippers. Higher transport costs as a result of waiting in front of locks are subtracted from the benefits (Verheij, 2008). Other (indirect) benefits are ignored. The implicit assumption that is made is that as a result of canalization, under future climate conditions (W+ KNMI’06 scenario), inland ships will be able to navigate without load factor restrictions during the whole year. This results in an average decrease of inland waterway transport costs in the low water level period of 26.2% for the Rotterdam - Ruhr area route compared to a situation with future climate conditions (W+) without canalization. This cost reduction is equal to €317 million annually.

Costs occur both initially, at the start of the project (construction costs of weirs and locks), and annually (maintenance and operation of the weirs and locks). Other than those cost types are ignored. Environmental costs may be substantial however.

Using a discount rate of 5% and infinite time scale, the present value of future annual costs is equal to €3820 million. The net present value of the annual benefits is equal to €6340 million (see Appendix 10). The annual extra amount of cargo transported by inland waterways on the Rhine (Waal and Lek) as a result of canalisation is expected to be approximately 10 million tonnes.

5.3 Logistic management

Almost every company faces the risk of supply chain disruptions. Several risk strategies can contribute to making a company more resilient. These strategies include redundancy, flexibility, transparency, and collaboration. Companies and, or supply chains will be more resilient, and able to reduce damage after major disruptions. Thirty-nine logistic measures of logistics companies have been identified in reaction to disturbances due to low water levels. This list resulted from a brainstorm with experts and a literature review. The measures are classified into five categories. For each measure the most appropriate types of reaction was provided, which was one of the following: Accept, Avoid, Minimize, Mitigate (cooperation, flexibility, redundancy, transparency), Respond and Transfer.

- *Structural measures*

These measures change the basis logistic choices of a company. Generally these measures have a more long term focus and aim to:

- avoid the chance of the disturbance (i.e. a modal shift to avoid disturbances in inland navigation)
- reduce the chance of the disturbance (minimize; measures to reduce the probability of disturbance due to low water levels)
- reduce the consequences of the disturbance (mitigate; to reduce the impact of disturbance due to low water levels).

- *Responsive measures*

Responsive measures are measures that do not require preparations by the company and can be subdivided into:

- accept the disturbance due to low water levels and, in when inland navigation is still feasible, only decrease the load capacity of the vessel.
- respond to the disturbance by trying to execute the transport in the most suitable way.

- *Transparency, cooperative and financial measures*

Transparency measures increase the transparency of the processes in the supply chain through information. Cooperative measures aim to improve the cooperation between stakeholders in the supply chain. In case of disturbances, stakeholders jointly take measures and work together to reduce the impact of the disturbance. Financial or contractual measures relate to financial or contractual arrangements between suppliers (this can be both carriers and shippers) and customers. Types of reactions in this category are:

- respond to the disturbance by cooperating with other stakeholders to execute the transport
- mitigate the effects of disturbances due to low water levels by reducing the consequences through
    - increased transparency in the supply chain
    - increased cooperation between stakeholders in the supply chain
    - increased flexibility in the logistic processes
- transfer the risks of disturbances due to low water levels or the consequences of these disturbances.

Furthermore, each measure was characterized in terms of the most likely initiator of the measure (shipper of carrier), the suitability of the measure for the type of disturbance (reduced feasibility of inland waterway trips or infeasibility of inland waterway trips) and the suitability of the measure for the disturbance impact (ranging from incidental to structural). A more detailed overview of the logistic measures in included in Appendix 9.

Two measures were mentioned by companies that were interviewed. They seem to be the most feasible and obvious in the current situation. Those measures are higher number of operational hours, and investing in additional storage capacity. Other measures demand a more structural change of the logistic process.

5.3.1 Higher number of operational hours

Navigating more hours per day by inland ships is a way to increase fleet capacity in periods with low water levels. Analysing costs and benefits of this measure is interesting because, contrary to canalization, it is relatively easy to apply.

Inland carriers can operate on a 14, 18 or 24 hours basis, dependent of the ship crew. At the moment only 25% of the companies operate around the clock, so in times of low water depth the other 75% have room to increase the number of operational hours per day and so generating extra transport capacity in periods with low water levels.

The benefits are determined by estimating the extent to which the load factor of inland ships is restricted in the low water periods in a KNMI, W+ climate scenario (Jonkeren, 2009). The loss of revenue that is caused by restricted load factors can then be regarded as the potential benefits that can be achieved by navigating more hours per day.

The costs are caused by navigating extra hours per day by inland ships that do not already navigate 24 hours a day. Costs for fuel, maintenance and labour will increase whereby it must be noted that labour costs do not only increase because of a higher number of navigable hours but also because, according to safety regulations, the ship crew must be increased.

Given several assumptions, the explorative welfare analysis of the measure *'higher number of operational hours'* demonstrates that the benefits outweigh the costs by €7.44 million per year. For a detailed calculation of the costs and benefits we refer to Appendix 10.

5.3.2 Investing in additional storage capacity

An adaptation measure which can be taken by shippers is increasing the storage capacity so that they can survive longer periods without being supplied by inland ships. For this adaptation measure, an on-line survey was carried out to analyse this adaptation measure. This method seems more suitable than carrying out cost-benefit analyses for one or two specific carriers. Now, more general results are drawn. Although no statistical significant conclusions can be drawn from the information obtained with the on-line survey, some interesting findings can be reported.

Eight of the twelve respondents were confronted with low water level problems in 2003 and three respondents indicated that they are planning to invest in extra storage capacity in the future. Strikingly, only two of those three shippers belong to the group of four shippers that did *not* experience low water level problems in 2003.

Several characteristics of the shippers are likely to have an impact on the decision whether to invest in extra storage capacity before 2050: the shippers' critical Rhine kilometre, the vessel size hired and the dependency on inland waterway transport. The shippers' 'critical Rhine kilometre' is defined as the most upstream located place (the production facility, the customer or supplier) that is visited by a barge which performs transport for the shipper. The three respondents that are planning to invest in extra storage capacity indicate that the more upstream the critical Rhine kilometre is located and the larger a shippers' dependency on inland waterway transport, the more likely the shipper is to invest in extra storage capacity.

The size of the vessels that are hired by the three respondents who are planning to invest in extra storage capacity in the future is relatively small, which is counter-intuitive.

5.4 Information management

5.4.1 ICT systems for inland shipping

The increase in multimodal transport has led to an increasing need for exchanging traffic and cargo information between the several parties involved in the logistics chain. Consequently ICT is increasingly used to improve the efficiency of the logistics chain and the lead time of the transportation of cargo.

Besides, ICT is used for safe and efficient navigation on the waterways by providing the skipper traffic information amongst others about: waiting times at locks or bridges, waterway conditions and the most efficient route of navigation, in order to save fuel and thus to navigate more environmental friendly.

Both public and private parties are heavily investing in the development of ICT systems for exchanging traffic and cargo information that has so far resulted in a number of operational systems. It is not clear which system will be the future standard. Yet the success of these systems is largely determined by the number and variety of stakeholders (Government, Port Authorities, barge operators, shippers) that use the system. Therefore the use of these systems asks for strong promotion. Support is needed for the extension of functions and the integration of these systems. A bottleneck to enlarge usage and usability is the lack of budget and/or cooperation among (market) parties.

Various ICT systems

A major challenge is to link the relevant information and systems, to provide all the parties concerned the necessary information that needs to be shared. Therefore it is important to either create generally accepted ICT-systems or to make existing systems compatible. This cooperation can be at governmental level, like the development of RIS, but also by the cooperation of private organisations. For the Portbase system a merger of the port community systems of the Ports of Rotterdam and Amsterdam, providing the service Barge Planning is required. MIS-Cobiva was established by a cooperation of several container operators.

River Information Services (RIS)

RIS are modern traffic management systems that provide swift electronic data transfer public and private parties participating in inland waterborne transport:

entrepreneurs, captains, waterway authorities and other public institutes. The information is shared on the basis of information and communication standards. The general objectives of RIS are:

- Enhancement of inland navigation safety in ports and rivers
- Optimise the resource management of the waterborne transport chain by enabling information exchange between vessels, lock and bridges, terminals and ports
- Better use of the inland waterways by providing information on the status of fairways
- Environmental protection by providing traffic and transport information for an efficient calamity abatement process.

As regards the status of fairways, the Fairway Information Service portal (FIS, being part of RIS) will be launched in spring 2011 (see also annex 1). FIS is a single window for all infrastructure information and supports the exchange of waterway conditions: are there circumstances that influence navigation (floods, draughts, obstructions etc.)?

Portbase – Barge Planning

Portbase is the neutral hub for all logistics information in the ports of Rotterdam and Amsterdam. Via Portbase's port-transcending Port Community System, companies can benefit from a multitude of intelligent services for simple and efficient information exchange, both between companies and between the public and private sector.

The main purpose of their service 'Barge planning' is to provide an optimal method of communication between all container barge operators and inland terminals on one side and sea terminals and empty depots with quay access on the other, in order to optimise the handling of container barges. The service allows for:

- Good coordination of arrival and departure times for barges
- Pre-notification of sea terminals about containers by means of the electronic submission of loading lists and discharge lists and the exchange of status information on these containers
- Operational report by means of which the sea terminals and empty depots provide the barge operators/inland terminals with an electronic loading/discharge confirmation.

Barge planning is presently used by many container barge and terminal operators. The aim is to extend this service to the bulk sector and to extend the functionalities i.e. to link it with MIS-Cobiva (see below) for which clear agreements are being made. A next step could be the integration with traffic management information as described above, which is among the ambitions of Portbase.

Management information system for inland container shipping (MIS-Cobiva)

MIS-Cobiva has been developed by five container barge operators, Alcotrans, Bulcontrans, Contargo, Danser Containerline and Rhinecontainer, yet can be used by other parties as well. The system works with real time information being based on tracking and tracing of barges by GPS. The owner / commissioner of the ship can see in his application a.o. the location of the ship, its direction and at what speed it travels. This information is linked to other data on the MIS-Cobiva server, like engagements and travel information. MIS Cobiva can predict at what time the ship will be at its destination, just like navigational equipment for road transport. It takes into account bridges, locks and the rate of flow in rivers. By using these predictions and the reliability of the real-time information the logistical chain can be planned more accurately. It also creates the possibility to better anticipate on possible interruptions (somewhere else) in the chain. Unnecessary waiting times on and by connecting modalities can be prevented.

At present over sixty vessels are equipped with MIS-Cobiva and the participation is expected to be enlarged. Next to a possible integration with Barge Planning, another future application could be real-time information at container and even cargo level, next to vessel level i.e. MIS-Cobiva can be used to optimise the integrated logistic chain for each container of even each freight package. Obviously, in order to provide a reliable logistic service, accurate real-time information about the condition of the fairway is crucial. Both Barge Planning and MIS-Cobiva are able to distribute and communicate fairway information quickly, on the condition of course that as many as parties possible use these systems.

5.4.2 Use of ICT in the waterway (Smart Waterways)

One of the ways to improve navigability is to provide ship captains with more recent and spatial information about the water depths to be encountered during a trip. The water depth information will allow them to increase the cargo load and the corresponding draught of the ships. The effectiveness of this type of information is known from several experiences. Firstly, some ships are loaded up to 30 cm more than the available water depth in the river IJssel, because their captains know the locations of the critical shoals and manage to sail around them. It is to be noted, however, that the current implementation of the Room for the River program is expected to change these locations, so that ship captains will no longer be able to rely on experience alone. This underscores the importance of good up-to-date information. Secondly, the shipping sector has shown its willingness to participate in the removal of shoals by modification of their sailing tracks or by targeted utilization of the propeller race. The latter, known as “agitation dredging”, was common practice until it was banned in 1995, partly for environmental reasons. Yet new, environmentally more acceptable techniques are currently investigated, such as suppression sailing (Dutch “platvaren”) and dune shaving using ploughs. Experts at Deltares agree that 10 to 30 cm extra navigation depth can be gained if better information in the form of water depth maps is available. In addition, better information about water depth and flow velocities enable captains to optimize their travel schedule and, hence, to save fuel and to reduce CO_2 emissions.

These considerations, along with the latest technological developments, have led to the idea of Smart Waterways (Dutch: Slimme Vaarweg). This advanced navigability monitoring and forecasting system will be based on the echo sounders that are normally mounted on ships plying the river, a data acquisition and processing system, a hydrological low-water forecast model, a morphological bed-topography forecast model and data-assimilation techniques to use measured data for updating real-time navigability forecasts.

In a first assessment of the effects of climate change on inland water transport on the Dutch Rhine, Bosschieter (2005) concludes information management to be the most feasible measure on a short term. This measure would aim at collecting, recording, visualizing and sharing information on water depths. She expects gains in efficient sailing in times of low water levels from the reporting of up-to-the-minute water depths, water depth forecasts for the coming days and shipments of goods. Bosschieter recommends to avail the opportunities to explore information management by means of River Information Services (RIS), and to bring about a co-operation between the Netherlands and Germany for water depth forecasts a few days ahead.

It is against this background that a definition study for an advanced navigability monitoring and forecasting system has been included in the present project under the Knowledge for Climate programme. The results are reported in Appendix 11. A preliminary version of this appendix has already resulted in follow-up actions. Rijkswaterstaat, ThyssenKrupp Veerhaven, Havenbedrijf Rotterdam, MARIN, Deltares and Delft University of Technology are preparing a €1.2 million project to develop the system, including a route planner, starting in 2011. As this project may still leave a few loose ends before the system is fully operational, the total costs of the development are estimated to amount to €2 million. In terms of a cost-benefit analysis, the ICT solution is hence expected to increase the navigability by about 20 cm at an investment of €2 million.

5.5 Fleet management

5.5.1 Ship types

Because of the economy of scale, there is a long-term upward tendency for European inland navigation. The average size of vessels is still becoming larger and larger, from an average deadweight of 2,000 ton in the year 2000, via 3,000 ton in 2006, to a predicted 4,000 ton around approximately 2012.

The only reason why this upward trend will ever slow down, stop or even will be bowed in a downward direction is when certain limits will be reached in future or narrowed limits will be crossed. Such limits may come from the width, length or depth of navigation locks, the 'free' opening of weirs, the 'free' height of bridges (also in times of high discharges!), the varying natural or artificial depth and width of rivers or canals (also in times of low discharges!), maximum water depths in front of quays, the reach of cranes, legislation with respect to the minimum size of the crew in relation with the size of the vessel, the strength of vessels with extreme proportions, environmental reasons, etc.

The general economic tendency is that ship dimensions, so their 'optimal' transport capacity, will grow until they reaches one or even more of the above mentioned 'hard' boundaries, which are of course not really hard but time dependent and differs for different shipping routes.

And so there are good economical, historical, geographical, technical, infrastructural, environmental and/or social reasons for a nowadays optimal capacity and related dimensions for groups of specific vessels like a Neokemp, a Donau-vessel, a Rhine-vessel (see pictures below).



But of course when one of these restrictions is the 'hard' limiting factor, for the growth of inland navigation on a specific shipping route, there will be pressure on that specific factor and related factors to be widened or even to be completely removed.

For example in ship design one tries to find more transport capacity for a 'given' maximum draught, by widening the other dimensions like the width and/or the length of vessels, until other limits from strength, navigability or efficiency are reached. But then another way of increasing the transport capacity (without growth of the dimensions) is still possible by applying new (e.g. stronger and/or lighter) building materials.

The Delft University of Technology has developed design programs to calculate strength, capacity, fuel consumption and sailing costs of these new vessels with other dimensions and/or new materials in a rather detailed way and in a relative short time span. One of the alternatives for periods with low discharge and related small water depth is a kind of Donau-vessel used as a Rhine-vessel. This means a length of 110 meter, a width of 11.45 meter, but with a maximum draught of 2 meter instead of 3.5 meter. Of course this new designed vessel with a maximum cargo capacity of 1,656 ton is not that efficient as a 'normal' Rhine-vessel sailing in 'normal' conditions, which then has a maximum cargo capacity of 3,218 ton. But the more (longer and severe) low water periods, the better the transport efficiency of the 'adapted' Rhine-vessel will be (what they will lose during 'normal' conditions, they will gain back in periods of low discharges!).

In Table 6 a 'normal' Rhine-vessel with a maximum draught of 3.5 meter is compared with the efficiency of an 'adapted' Rhine-vessel-type with maximum draught of 2 meter for three water depths.

Table 6: Optimalisation of draught compared to vessel type

Scenario	Water depth 1.5 m	Water depth 2.0 m	Water depth 2.5 m	Water depth 3.5 m	Unit costs Normal Rhine vessel	Unit costs Adapted Rhine vessel
0	0 week	0 week	0 week	52 week	3.5 €/1000tkm	6.0 €/1000tkm
1	10 week	5 week	5 week	32 week	4.8 €/1000tkm	6.7 €/1000tkm
2	20 week	10 week	10 week	12 week	7.3 €/1000tkm	7.4 €/1000tkm

A preliminary conclusion, purely based on transport costs, may be that a kind of break-even point will only be reached if dry periods cover about 80 % of the time.

But from economical studies the expectation is that during long dry periods the transport prices will raise, so net costs will be lower. If for instance in dry periods net costs will be lowered by 50%, the break-even point will be reached earlier (if 60% of the time will be dry).

Though the extreme adapted Rhine vessel will only be feasible in extreme dry conditions, the overall conclusion still might be that investments in vessels with less draught could be the right direction for the expected, but hard to predict 'dry' years to come.

5.5.2 Extra buoyancy

Another direction to overcome dry periods with less water depth, so less draught and transport capacity for 'normal' vessels, is the use of extra buoyancy only during these 'dry' periods, particularly to overcome critical 'dry' sections of the Rhine.

This extra buoyancy can be added aside of the vessels (if there is room enough in the shipping lanes!).

This solution has already been practiced in the 17th century, when they lift sailing vessels across the sandbanks (called Pampus) near Amsterdam by so called 'ship camels'. These camels were a kind of u-shaped wooden docks, which could be fastened around a VOC-vessel.

In present time extra buoyancy by big tubes or side airbags has been used already to safely lounge new vessels from a Chinese shipyard in the case of less water depth.



Though technically possible, the feasibility of this type of solution depends highly on the working out in more technical, logistical and nautical details: How does a universal lifting system looks like, how long does the process of (un)fastening takes by how many people (costs!) and is there room enough in (at that time rather narrow!) shipping lanes?

These questions are not answered within the scope of this report.

5.6 Implementation of solutions

Criteria to compare the solutions were determined by two groups of stakeholders: companies as users of waterways and Dutch government as provider of infrastructure. For both groups it is important to remember that effects of climate change will increase slowly during the years. This provides time to respond and do further research, but it also influences the willingness to respond now. Timeframe for implementation is an important criteria for all actors involved.

- Companies: Changing their logistic chain will always be checked on costs, implementation term, dependence on stakeholders, contribution to reliability (and flexibility), synergy effects. The sense of urgency to take action to respond to the effects of climate change for companies using the inland waterways not very high. Some companies already work on cost efficient solutions , while others do not sense the problem. Companies are main actors to invest Logistic management and Fleet management solutions.

- Government: Costs and benefits for community and environment are balanced by government as they decide to invest in infrastructure. To develop River management and Information management government has the lead, although close involvement of companies is an important condition for success.

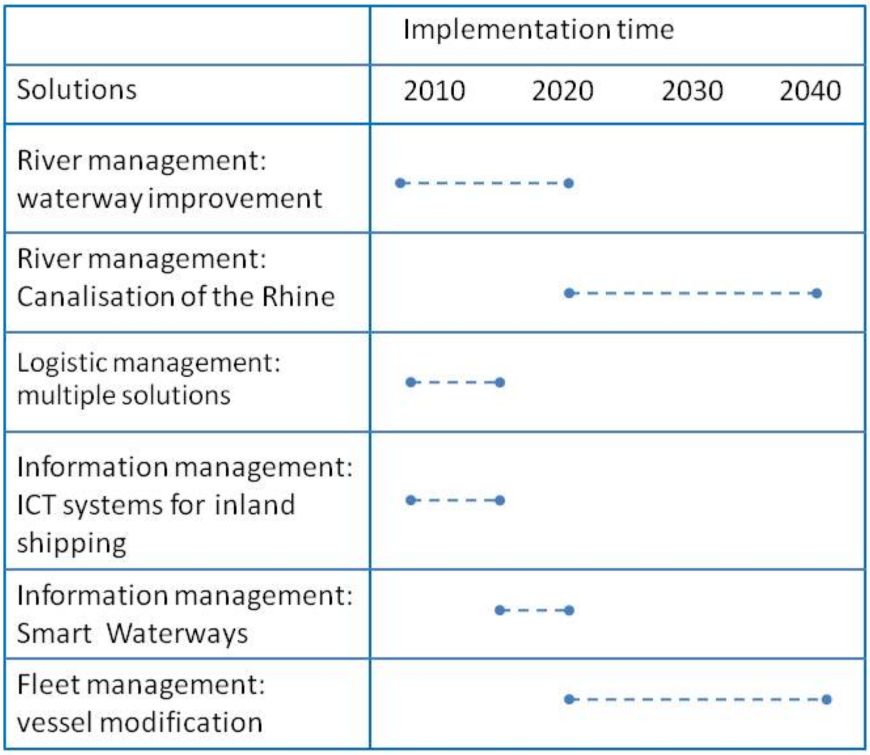
In table 7 the solutions are summarised for each criteria.

Table 7: Solutions and criteria

Solution	Costs (million €)	Effects (cm extra water depth)	Reliability	Time to start realisation (years)	Stakeholder
River management: waterway improvement	0.1-10	10-50	+	2-10	Government
River management: canalisation of the Rhine	2500 (net benefit)	200	++	20-30	Government
Logistic management: multiple solutions	Not case specific	-	+/++	0-5	Shippers/ carriers
Information management: ICT systems for inland shipping	Not determined	-	+	0-5	Government/ shippers/ carriers/ Port of Rotterdam
Information management: Smart Waterways	1-10	20	0/+	5-10	Government/ shippers/ carriers/ Port of Rotterdam
Fleet management: vessel modification	+/- 1000	50	+	20	Carriers/ government

The implementation timeframe of the solutions is shown in figure 13.

Figure 13: Implementation timeframe



The implementation time for waterway improvement is expected to be 2 until 10 years for maintenance. However these improvements can be implemented after 10 years, but will then be a more structural and extreme measure.

The specific logistic solutions for “higher number of operational hours” and “additional storage capacity” can be implemented at this moment, because they do not lead to large social, political or environmental consequences. This is opposite to the “Canalisation of the Rhine”. This measure can be elaborated further on costs and benefits. The conclusion can be different when other discount rates, other climate scenarios and/or less or more sluices are taken into account.

For the long term all stakeholders need to work together to find the right solutions. For this moment it is effective to invest in solutions that are beneficial for the short term as well. Information management is likely to be the most promising and effective solution in that regard. It provides information on water depth and cargo flows, which will be useful on the short term for private and public sector. For the long term this information is vital for strong inland waterway system. For the mid long term (5 to 10 years) logistic management and river management require decisions. In particular logistic management will make the sector more resilient, not only to climate change effect, but also to other disruptions.

6 Conclusions and recommendations

6.1 Conclusions

6.1.1 Effects of climate change on inland waterway transport

Climate change will have an impact on inland navigation on the Rhine River in 2050 and thus on the competitive position of ports along the river. This is especially the case for the main flow of goods transported between the Port of Rotterdam and the Ruhr area, where water depths are sometimes critical. Some actors of inland shipping will face increased transportation costs and decrease in transport reliability. The estimated increase in transportation costs of between 9% and 23% is due to more periods of high and low water levels according to the W+ climate scenario. It is estimated that approximately 7% of the total volume of goods cannot be transported via the Rhine river due to prolonged periods of low water.

In the worst case scenario, the decrease in annual transport capacity would vary from 8% to 28% in all inland navigation within, to and from the Netherlands. These percentages could be substantially higher on specific corridors such as Rotterdam – Germany. In this case, approximately 4% of the total inland waterways transport could shift to these German ports.

Increased transportation costs and reduced reliability in waterway transport would lead to a modal shift of 8% of the total annual volume. From this volume, 88% is likely to shift to rail transport and 12% to road transport. However the shippers and transport companies expect the impact of climate change on inland waterway shipping will be low.

The effects of high water levels in the future are limited, as these are expected to occur for relatively short periods of time (2 – 4 days). This will effect the reliability of inland waterway transport. However, high water levels can be accurately forecasted, which will enable carriers to arrange alternative forms of transport. Therefore, consequences for shippers are probably limited.

6.1.2 Selection of solutions

Currently, direct users of the main shipping route to and from Germany (shippers, companies, ship-owners) are little aware of a potential increase in transportation costs and reduced reliability of waterway transport in the long term because they operate on a shorter time horizon.

It is to be expected that players will respond to initial events as if these events were incidental. They are thus likely to seek ad hoc solutions, for instance, by using more partly loaded inland waterway vessels and/or by making more intensified use of the contracted fleet.

Greater frequency of events will force the parties involved to consider more structural solutions, with each party looking for solutions within their section of the logistic chain.

For the long term it is important that all involved keep an open mind for possible solutions and ways to cooperate. Especially when solutions will serve an extra goal beside adapting to climate change, it can be rewarding to investigate possibilities and start a change today.

- Information management

Information management is the most promising solution for the short and middle term. With this solution companies and government can adapt to sudden changes in water depth. Both public and private parties are heavily investing in the development of ICT systems for exchanging traffic and cargo information that has so far resulted in a number of operational systems.

- Logistic management

Almost every shipper and transport operator faces the risk of supply chain disruptions. Management of logistics is necessary to identify and quantify these risks and to select appropriate measures to mitigate the effects or to solve supply chain disruptions. Risk strategies can help protect companies to the effects of climate change, as well as contribute to making companies more resilient. Provision of extra storage capacity and longer working hours are measures which have recently been adopted in the logistic process.

Shippers and transport operators expect the impact of climate change on inland shipping to be rather low. Companies will be more resilient, and better equipped to reduce damage after major disruptions and to return quickly to the original (or desired) situation, by taking measures such as redundancy, flexibility, transparency and collaboration. If stakeholders wish to prepare themselves for the effects of climate change and other disruptions, a joint effort is required to accomplish this. However, if companies are hesitant to initiate this change, government or port authorities can stimulate this process.

- River management

A large impact could be achieved if central governments agree to simultaneously canalise crucial sections of the Rhine River (Appendix 8). This structural solution would guarantee about 0.5 m increase of water depth, but is very costly (about €3 to 5 billion). Furthermore, these major works need to be well designed in order to prevent major environmental impact.

- Fleet management

Changing the ship types demands time for research and structural changes in the logistic process of companies. Break even point will only occur as 60-80% of days are dry and demand a complete different type of ship. This solution seems only promising if the adjustment of ship types is done step by step.

6.2 Recommendations

6.2.1 Further research

This study was carried out using a mean reference year (base year 2004) which was translated to climate scenario W+ to 2050. In the analysis of the water levels, the base year 2004 had a strong impact on the results. The data on vessels are also based on 2004 and translated to 2050. The 2004 water levels (year with lower than average water levels) have been increased to the 2050 level which shows similar peaks in 2050 as in 2004. Although the translation with the base year 2004 gives a good first impression, sensitivity analysis with another base year need to be applied.

In the analysis, only the impact of climate change on water levels in the main rivers has been taken into account. However, the impact of climate change on smaller rivers and canals may also be relevant. It is therefore recommended to include a sensitivity analysis with climate change impact on small rivers and canals.

In this study, the problems identified in the W+ climate change scenario have been considered as structural problems because several periods of low water levels are expected to occur annually by 2050.

As actors of the inland shipping sector may react differently, the solutions are likely to differ depending on whether the problems are incidental or structural. A distinction needs to be made between incidental problems in the mid to long term, and long-term structural problems up to 2050.

The river bed is subjected to morphological processes, such as sedimentation and erosion and can lead to bottlenecks in navigation. This study did not consider the relationship between climate change and morphology. These relationships should be addressed to further research projects.

6.2.2 Further research for solutions

The main valorisation of the project lies in the integral approach to river management policies and inland waterway transport policies, combining solutions in the realms of ICT, engineering and economics. This combination is innovative and potentially useful for similar fluvial waterways elsewhere, such as the Danube, the Yangtze and the Mississippi. Moreover, individual components of the project, such as the navigability forecasting system, are receiving follow-up in projects to develop them into new products.

For the recommended four types of solutions, we recommend the following further research. Not all solutions have been quantified to the same level of accuracy.

- Logistic management

If shippers and transport operators do not want to accept the impact of the risks of climate change, they should prepare themselves by taking measures. Some measures can be taken right away, since they are not only relevant for problems due to low water levels, but they lead to more flexibility in the transport and supply chain offering clients a higher level of service. The next step in creating resilience should be taken together. Companies need to find partners to adapt. If those measures need more implementation time, effort from government is needed, since companies do not sense urgency to start with major changes now.

- Information management

It is not clear yet which system will be the future standard. Yet the success of these systems is largely determined by the number and variety of stakeholders (Government, Port Authorities, barge operators, shippers) that use the system. Therefore the use of these systems asks for strong promotion. Support is needed for the extension of functions and the integration of these systems. A bottleneck to enlarge usage and usability is the lack of budget and/or cooperation among (market) parties. Smart Waterways system is one of the promising ICT systems, that is worked out in a consortium as follow up on this project.

- River management

Some solutions involve major physical interventions in the rivers. Flood prevention and compliance with the Water Framework Directive also require major interventions. The current practice of designing interventions through sectoral approaches leads to suboptimal results. An integral approach to river improvement is recommended.

- Fleet management

The solution of extra buoyancy was only described briefly. Experts hesitate to state this as a promising solution, but more research on costs and benefit can provide more information.

List of appendices

The following reports are gathered in a separate appendices report:

1. Impacts of low and high water levels on inland waterway transport – Literature review for "Knowledge for Climate" (October 2009; O. Jonkeren, P. Rietveld, VU).

2. Climate change reliability and costs in inland waterway transport – An interview based report (December 2009; O. Jonkeren, P. Rietveld, VU).

3. Generation of river flow scenarios (October 2009, J. Kwadijk, Deltares)

4. River morphology (February 2010, E. Mosselman, Deltares)

5. Impact of climate change on the competitive position of inland waterway transport (July 2010; J.C. van Meijeren, T. Groen, TNO)

6. Workshop report (7 April 2010, LEF future centre, Utrecht)

7. River Engineering measures to improve navigability (January 2011; S. Giri, Deltares)

8. Cost estimate of weirs in the Rhine (November 2010; A. van der Toorn, TUD)

9. Logistic solutions for dealing with the consequences of climate change for inland shipping (December 2010; J.C. van Meijeren, D. Vonk Noordegraaf, TNO)

10. Economic analysis of adaptation measures to climate change for inland waterway transport (December 2010; O. Jonkeren, VU; P. Rietveld, VU; A. van der Toorn, TUD).

11. Definition study of Smart Waterways (October 2010, C. Erdbrink, Deltares)

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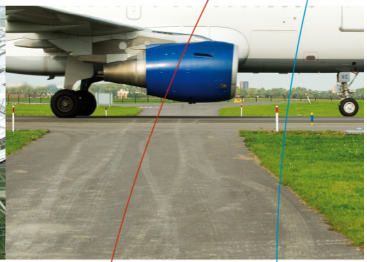

To develop the scientific and applied knowledge required for Climate-proofing the Netherlands and to create a sustainable Knowledge infrastructure for managing climate change

Contact information

Knowledge for Climate Programme Office

Secretariat:
c/o Utrecht University
P.O. Box 80115
3508 TC Utrecht
The Netherlands
T +31 88 335 7881
E office@kennisvoorklimaat.nl

Public Relations:
c/oAlterra (Wageningen UR)
P.O. Box 47
6700 AA Wageningen
The Netherlands
T +31 317 48 6540
E info@kennisvoorklimaat.nl

www.knowledgeforclimate.org