Logistic solutions for dealing with the consequences of climate change for inland shipping

Knowledge for Climate

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1. Introduction

1.1 Background

Climate change can affect the transport of passengers and goods in various ways. Examples of consequences of climate change include severe rain showers that can lead to traffic congestion on roads, extreme low river tides which can hamper inland navigation and storms that could damage the train infrastructure (e.g. fallen trees on overhead wires). These disruptions of transportation have an impact on all modes of surface transport being deep sea shipping, short sea shipping, inland navigation, train transport and road transport. Climate change will have a different impact on each mode of transport. This can result in shifting the competitive positions of transport modalities.

To date not much research has been done in the field of climate change and transportation (VU, 2009). An exception is the Knowledge for Climate study executed by TNO. This study specifically focuses on the impact of climate change on the competitive position of inland waterway transport for the transport of goods (Van Meijeren and Groen, 2009). The geographic scope of this study concerned the river Rhine between the Port of Rotterdam and the German hinterland until Koblenz. In this study scenarios for the reference situation and the climate change situation are compared to determine the consequences of climate change. First the water levels on the sea and the main rivers were determined by using the W+ climate change scenario of the KNMI. This scenario has the highest impact on water levels and can be considered a worst case scenario within the current set of KNMI scenarios. Second the future volumes of freight flows and the number of vessels needed to transport these volumes was determined using the economic WLO scenario 'Global economy' of the CPB which includes the highest predicted economic growth. The time horizon for determining the impact was set to 2050.

It was found that climate change is expected to result in an increase of sea water level. The consequence for inland shipping results from an increased likeliness of more frequent occurrence and longer durations of closed storm surge barriers. When these barriers are closed, inland and sea vessels cannot enter or leave the seaport which disrupts transport flows. In addition, climate change affects the water levels of rivers. Although the consequences of closed storm surge barriers can be severe, the impact of more extreme river water levels on inland shipping is expected to be much larger. Particularly relatively long periods of low discharges (in the order of 10 tot 30 days) during and after summer time are expected to have a major impact on inland shipping. This can result in periods when shipping is only possible with strongly restricted shallow draught and can even result in periods when inland navigation is infeasible. These disturbances result in higher costs of inland navigation and reduced reliability when inland navigation becomes infeasible.

There is a range of solutions to respond to the consequences of climate change for inland navigation. Examples include information management, river management, fleet management and logistic management. Information management implies offering up-to-date on-line information about present and expected water depth along the route, local stream patterns and water velocities, real-time draught and trim of the vessel. River management includes dredging, installing movable weirs, adjustable groins, using reservoirs and retention basins. Fleet management concerns all measures related to operating inland waterway transport such as extra (temporary) buoyancy to decrease the vessels draught or using vessels of smaller draught. To compensate for the lower loading capacity of vessels with smaller draught, longer, broader and more light-weighted vessels or push barges can be used. The last category of measures is the logistics management measures. These measures can be taken by companies that operate logistic chains. Examples include holding extra stock or storage capacity, taking alternative routes, using other transport modalities, etc. Measures in the categories information management, river management and fleet management will be studied in other subprojects of Knowledge for Climate, Water and Transport. This report focuses on logistics management measures.

Each measure that can be taken in reaction to the consequences of climate change for inland shipping has advantages and disadvantages. It depends on the specific context which measure will best suit the needs of the stakeholder that is faced with these consequences. Important criteria for

assessing the measures are the technical feasibility, the costs and benefits, the implementation term and the impact on the environment.

1.2 Focus

The relation between logistic activities and climate change is illustrated in Figure 1. Transport causes CO2 emissions and therefore contributes to climate change. As these emissions in the whole transport sector still increase – contrary to the decreasing trend in other polluting sectors – (additional) measures might be needed to reduce the emissions and to mitigate the impact of climate change (Quak et. al., 2009). Such measures can be found in the logistic domain. Examples of changes in logistic activities that mitigate the effects of climate change are a lower trip frequency or a more efficient trip planning to save on transportation costs. A CO2 tax can be an extra incentive to stimulate this type of changes in logistic activities. Although these mitigation measures are relevant and can significantly change logistic choices of stakeholders, this report focuses on the other relation illustrated in Figure 1; the impact of climate change on logistic activities. More specific, this report focuses on climate adaptation measures which can be found in the logistics domain.

Climate change can have a variety of effects on logistics activities. The most direct effect is the emergency logistics needed in case of climate disasters (such as flooding or hurricanes). As incidents and disasters require a specific logistics strategy that deviates significantly from the ordinary logistic activities within supply chains, this will be outside the scope of this report. This report specifically focuses on the consequences of climate change on the competitive position of inland waterway transport and which measures companies can take to deal with these consequences. As the previous study of Van Meijeren and Groen (2010) concluded that the competitive position of inland shipping is predominantly affected by low water levels, the selection of measures will include different ways within the logistic domain to deal with more frequent and longer periods of low water levels in the future.

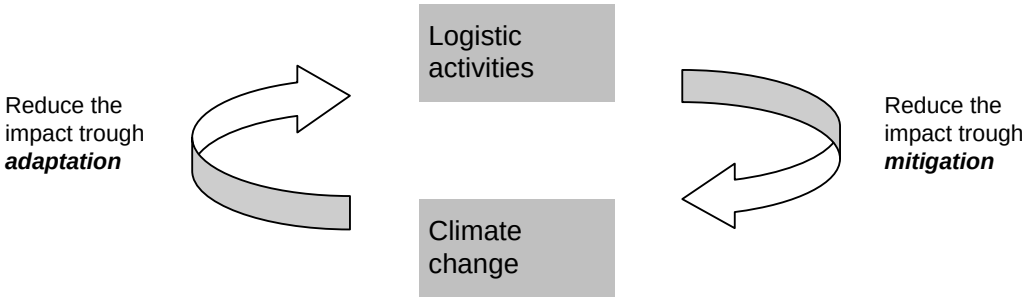


Figure 1: Climate change mitigation and adaptation (Quak et. al., 2009)

1.3 Content of report

The next chapter will elaborate on the expected frequency and duration of low water levels in the future. Furthermore, the direct consequences of disturbances due to low water levels on logistics processes will be discussed. In chapter 3 the strategies companies can choose to deal with risks affecting their logistics processes, such as disturbances due to low water levels, are discussed. In addition, adaptive policy-making, a strategy for governments to deal with uncertainties that affect policy-making, is discussed. Chapter 4 gives an overview of concrete logistic measures companies can take when confronted with disturbances due to low water levels. Chapter 5 puts these logistic management measures in perspective.

2. Disturbances due to low water levels

2.1 Feasibility of inland waterway navigation

This chapter gives a summary of the research results of the study on low water levels of Van Meijeren and Groen (2010). This study presents annual results and results for the worst case 10 day period in the year. The climate change scenario studied, leads very temporarily to problems over the year. Therefore, a specific moment in the year, the 10 day period, which demonstrates the highest impact of climate change (the lowest water levels), is included in addition to the overview of the impact of climate change for the whole year.

Figure 2 gives an overview of the annual results and the results for the worst case 10 day period. Climate change has on impact on the feasibility of inland waterway trips. Reduced feasibility of inland navigation means that inland navigation trips are still feasible but result in higher transport costs due to re-routing or reducing the load rate of the vessel. In some periods inland waterway navigation will become completely infeasible. This leads to reduced reliability of inland waterway navigation. When inland waterway transport has become completely infeasible, companies can choose to accept this or use alternative modes of transport. Both reactions are expected to lead to a cost increase compared to the situation in which inland waterway transport is not disturbed.

Although the scenarios included in this study consider the highest impact on water levels and the highest economic growth, it was found that the 86 percent of the yearly volumes transported with inland navigation is not affected by the impact of climate change. The analysis concerned the transported volumes with inland navigation within, to, from and through the Netherlands. The other 14 percent of the transport volumes are affected by climate change. For half of these affected transport volumes, transport is still feasible but it faces higher transport costs. The other seven percent becomes unfeasible to transport through inland waterway navigation because the goods cannot be delivered at the planned moment. In reaction to the increase in unreliability and reduction of level-of-service, companies choose for a modal-shift of 8 percent of the total annual volume. From the volumes transported by other modes, 88 percent is expected to shift to rail transport and 12% to shift to road transport.

In addition tot the annual results the effects of climate change for the worst case 10 day period in the year are analyzed. During worst case 10 day period, the share of transport volumes not affected by the impact climate change scenario is 55 percent. Compared to the annual results, the percentage of transported volumes that is confronted with the impact of climate change is much larger; 45 percent during the 10 day period compared to 14 percent of the annual transported volumes. In total 35 percent of the affected transport volumes becomes infeasible; these goods cannot be delivered at the planned moment. The other 10 percent of the affected transport volumes can still be shipped but higher transport costs. In reaction to the increase in unreliability and reduction of level-of-service during this 10 day period, companies choose for a modal-shift of 28 percent of the total volume in this period. From the volumes transported by other modes, 78 percent is expected to shift to rail transport and 22% to shift to road transport.

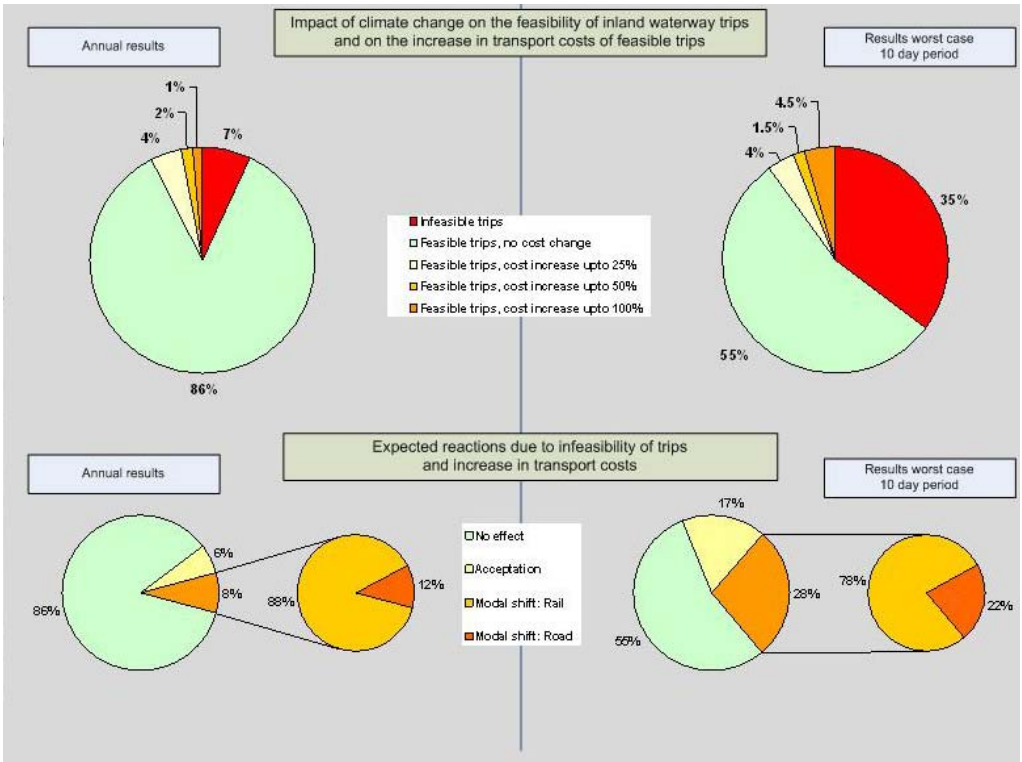


Figure 2: Impact of climate change on the trip feasibility and costs

Figure 3 projects the expected frequencies and durations of the periods of low water in 2050. Particularly in the second half of the year more and longer periods with low water levels are expected. The projected water levels in 2050 can be seen as the worst case situation.

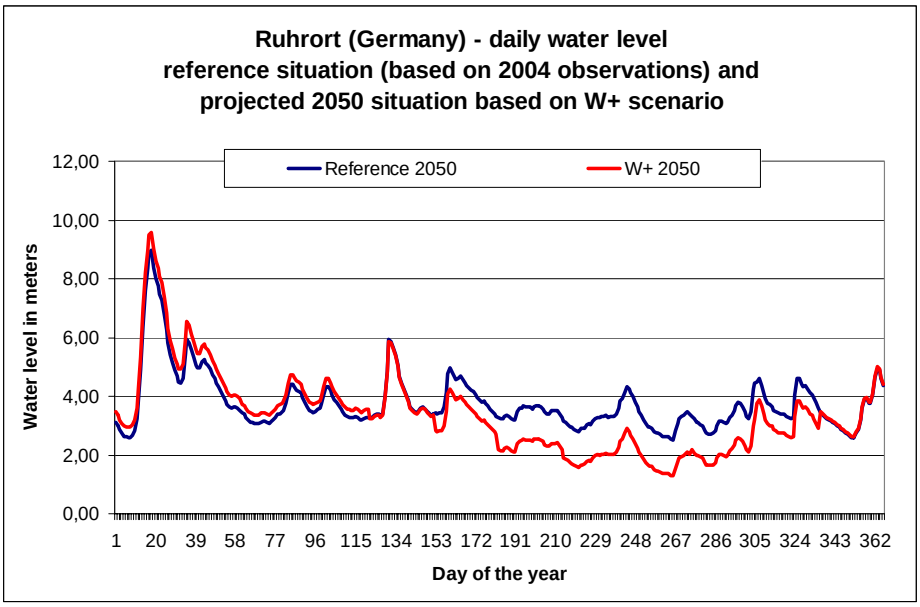


Figure 3: Overview daily water levels in the reference situation and the W+ scenario, location Ruhrort (Germany)

When determining the impact of climate change on companies it is also relevant to consider the current frequency and duration of periods with low water levels and how this will develop over time. Currently, disturbances due to low water levels are still incidental. As illustrated in Figure 4 this is expected to change from incidental disturbances in 2010 into more structural disturbances in 2050.

Consequently, the measures that companies consider in reaction to disturbances due to low water levels might change during the period between 2010 and 2050. On the short term the disturbances due to low water levels are likely to be treated as incidents because the frequency of occurrence will be low and the duration of the disturbances will be relatively short. On the long term, however, it is expected that the frequency of disturbances due to low water levels is higher and the duration of the disturbances also increases, making disturbances due to low water levels a more structural problem. It is uncertain when incidental disturbances transform into structural disturbances.

Companies can take a range of measures (see chapter 4) in reaction to disturbances (ranging from incidental to structural). Over time companies will become more experienced with disturbances due to low water levels and are more likely to consider the disturbances as structural problem. It must be noted that it depends on the specific company whether disturbances are considered incidental, semi-incidental or more structural. Similar, measures that one company considers suitable for incidental disturbances might be considered appropriate measures for structural disturbances by other companies. For example, companies that work in supply chains of goods with short lead times might be more focused on the short term. These types of companies – with short term strategies – might be more inclined to take measures that are already cost effective in case of several incidents and might be less inclined to take long term measures such as the decentralization of warehouses.

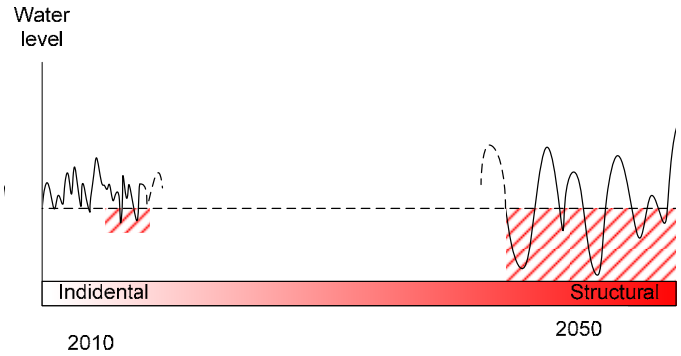


Figure 4: Incidental versus structural disturbances due to low water levels

2.2 Direct impact on logistics processes

Low water levels can have two direct consequences for logistic processes.

- Higher costs

The direct consequence of low water levels is that the draught of ships has to be lowered. This lowers the vessel capacity. Hence, more vessels are needed to ship the same volume of goods or measures need to be taken to create extra (temporary) buoyancy to decrease the vessels draught. If those measures are infeasible, other logistic measures can be taken or the consequences (such as claims of customers who do not receive their goods in time) disturbances due to low water levels can be taken. These consequences can be financial, leading to higher costs. Most measures are also likely to result in higher transport costs because they require extra effort and investments.

- Lower reliability

It is not possible to precisely predict when low water levels will emerge and how low the water level will be. This makes the magnitude of the disturbance unpredictable and affects the overall reliability of inland waterway navigation as transport modality. Depending on the water levels along the route the company prefers, inland waterway transport will still be possible when corrective measures are taken or will not be possible anymore. Even when inland waterway transport is possible despite low water levels, the reliability of the service can be affected. For example, it might be difficult to arrange sufficient additional vessels to transport the complete load. This may cause delays in the transport of the goods. Of course, reliability is most at stake when water levels do not allow for any inland waterway transport. Reduced reliability is also likely to result in higher costs.

The measures needed to still be able to execute the transport in case of low water levels can result in delays of shipments because it often takes time to implement measures. In addition, when more vessels of smaller capacity (e.g. due to decreased draught) are used it will take more time to transport

the same volumes of goods. The exception is when a company decides to shift from inland navigation to road transport. However, shorter delivery times usually involve higher costs. Periods with fewer or no shipments reduce the company's turnover. The magnitude of the decrease in turnover depends on the duration of the disturbance (number of days), the type of disturbance (reduced feasibility of inland waterway trips or infeasibility of inland waterway trips), whether measures are possible and if this is the case, what costs are involved in taken these measures. Indirect effects of higher costs and lower reliability can be a lower level of service towards customers (late or no deliveries which can result in production stops) and reducing the company's image. This in turn can result in losing customers and even endanger the continuity of the company. Similar to the effects these disturbances can have on the customers of a company, the company itself can also be faced with consequences of the disturbances their suppliers are confronted with. Furthermore, also other stakeholders such as the government and the end customers can affect the market when they respond to climate change.

3. Strategies to deal with logistic disturbance

In this chapter strategies to deal with uncertainties will be discussed. Low water levels can be seen as an unexpected uncertainty for companies in the logistics chain. Strategies to deal with unexpected uncertainties are identified from the field of risk management.

3.1 Risk management

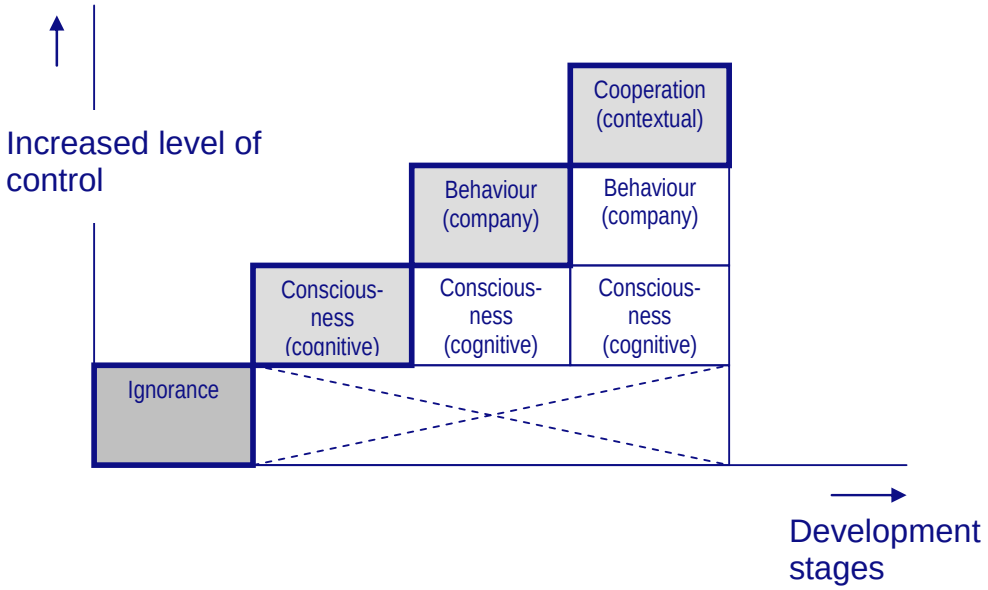
Risk management consists of mapping and quantifying the risks and choosing appropriate measures to influence these risks. The implementation of measures and continuously updating the required set of measures is also part of risk management (Lammers, 2010). The definition of risk management assumes that a company is already aware of the fact that it faces risks and is willing to take measures and continuously update the required measures when the risks change. In practice, there is a great variety in the levels of risk awareness of companies. For example, Janssen (2010) investigated how well prepared shippers and carriers are for disruptions. It was found that over 95% of the respondents considered their own level of preparation to a disruption sufficient. However, it was also found in this study that only 58% of the shippers actively pursuits risk management. The main reason companies mention for their lack of or limited effort into risk management is difficulty of monetizing the benefits of risk management (Janssen, 2010).

For some companies it will be much more obvious to pay attention to risk management than for other companies. This depends on the risk awareness of companies and the specific decision maker within the company. The risk awareness depends on a number of aspects such as:

- The visibility of the risks – is the risk obvious or only when the disturbance manifests
- The level of knowledge and experience – how much is known about the risks and with what certainty
- The moment a disturbance takes place - have there been many similar disturbances in the previous months or years
- The place – is the disturbance causing a bottleneck in the logistics chain of the stakeholder
- The risk attitude – how much risk is the stakeholder willing to take in choosing whether or not to take measures
- The position of the decision maker – how much freedom does the stakeholder have in choosing between the alternative measures?
- The possibilities to decide – do you have to do it, or do you want to do it?
- How does it emerge – a sudden disturbance or series of small accidents which little by little reveals the magnitude of the total disturbance

Companies with a high level of risk awareness will pay more attention to risk management. Figure 5 shows the four phases of risk management which can be used to classify companies based on their involvedness in risk management. With each development phase the level of control increases. Hence, when companies are ignorant about the risks they face, they are not in control of these risks. Companies can also be aware of the risk (cognitive) but without actively pursuing risk management activities. Next companies can take actions to deal with the risks they face. Last, companies can cooperate with other companies in the supply chain in order to not only be prepared to disruptions that directly affect their own company, but also for indirect disruptions in the entire supply chain.

Figure 5: Company positions towards risk management



3.2 Risk strategies

Depending on the type of risk companies can choose various strategies to deal with uncertainties. There are various classifications of risk strategies. In this section two classifications are discussed; the classification of Khemani (2007) and the risk matrix of Husdal (2008).

The first classification of Khemani (2007) distinguishes the following risk strategies:

- **Avoid** Proactive action that eliminates the possibility of an event.
- **Respond** Predetermined actions taken after an event occurs in order to reduce the impact.
- **Minimize** Proactive action that reduces the probability of an event occurring.
- **Accept** Decision to bear risk exposure without taking any additional actions ("do nothing")
- **Transfer** Proactive action (often financial or legal) that shifts risks to a third party.
- **Mitigate** Proactive action that reduces the impact if an event occurs.
- **Monitor** Continuous scanning of the environment that triggers alternative actions or the implementation of certain measures if predefined thresholds are exceeded.

Low water levels do not necessarily have to be problematic for a company. If a company for example did not plan to use inland navigation in the period of low water levels in the first place, there will be no need to take measures. Low water levels become a problem when it disturbs the regular operational processes of a company. Hence, the event is defined as disturbance due to low water levels. The occurrence of disturbances due to low water levels can hardly be influenced by companies. Only when inland navigation is completely avoided, the possibility of disturbances due to low water levels is eliminated. Khemani (2007) also includes monitoring as separate risk strategy. In this report we do not follow this distinction because monitoring is seen as inextricable part of risk management and a continuous effort.

It depends on the type of risk which strategy is most suitable. The second classification of Husdal (2007) couples the risk strategies to the type of risks. The magnitude of the risk consists of the probability that a disturbance occurs multiplied with the impact of that disturbance. Low water levels can have an increasingly higher probability and can have a severe impact (depending on the type of company). Companies do not have many options to take proactive actions that eliminate the possibility of disturbances due to low water levels (risk strategy: *avoid*). Important risk strategies are therefore *transfer* and *reduce*. With the classification of Khemani (2007) the latter category can be specified into minimize, mitigate (proactive) and respond (reactive).

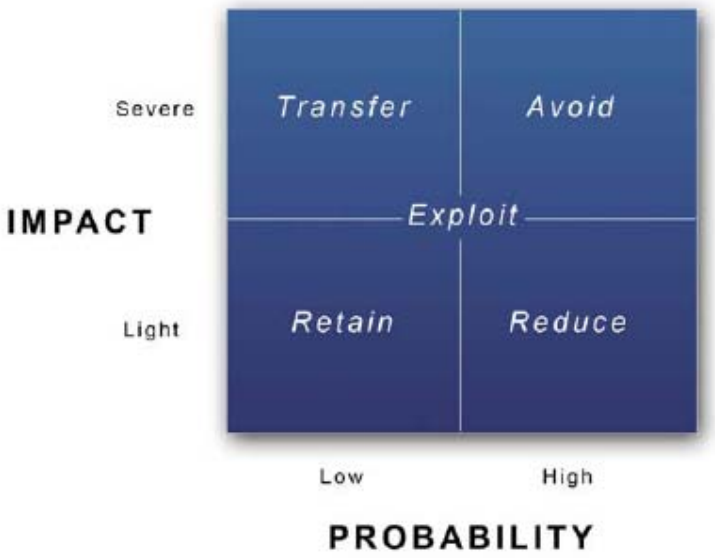


Figure 6: Five classic risk management strategies in a risk-matrix (adapted from: Husdal, 2008 in Janssen 2010)

Resilience

A key concept within risk management is resilience. Often the terms robustness and flexibility are also used in this context. Figure 7 illustrates the three concepts. A company is robust when it is confronted with disturbances but is still able to continue the basic processes. A flexible company decides to adapt the company strategy in reaction to disturbances. Resilience is the ability of companies or supply chains to reduce damage after major disruptions and to return quickly to the original (or desired) situation (Lammers et. al., 2009).

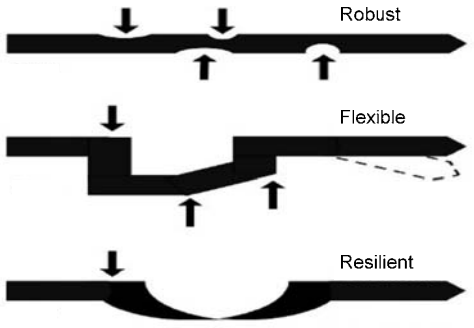


Figure 7: Robust, flexible and resilient (Husdal, 2008 in Lammers et. al., 2009: 13)

Risks in supply chains are increasing. Drivers for these increased risks include “market volatility, outsourcing, globalization and single point sourcing. Networks are becoming more vulnerable as supply chain become longer and leaner.” (Christopher and Rutherford (2004:24). There is an optimum in the relation between costs and leanness. When companies become to lean and mean they also become more vulnerable (see Figure 8). Therefore, measures to become resilient are increasingly important.

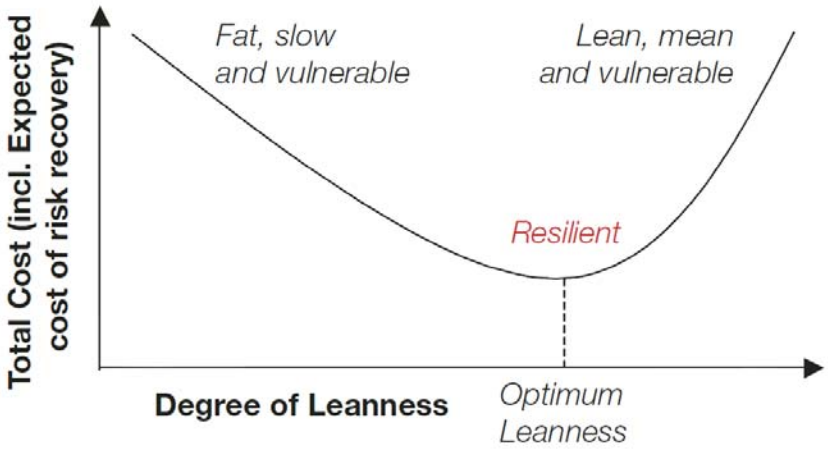


Figure 8: Cost and leanness (Cristopher and Rutherford, 2004: 28)

There are four classes of measures to become more resilient (Lammers, 2010):
- o Redundancy: holding more stock or obtain back-up capacity
- o Flexibility: creating the option to use alternatives
- o Transparency: obtaining more information on the (anticipated) disturbances
- o Collaboration: cooperating with other stakeholders in reaction to disturbances

In the next chapter logistics measures that can be taken in reaction to disturbances due to low water levels are listed. When applicable a reference is made to this classification (for example measure to mitigate the impact of disturbances that specifically increase the flexibility of logistics processes).

3.3 Dealing with uncertainties from a policy-making perspective

Not only companies are faced with the uncertain consequences of climate change. Also governments face these uncertainties and can formulate a strategy to deal with climate change and if necessary take measures. The large uncertainties involved in the political debate on climate change make formulating adequate policies very challenging. It is uncertain which measures need to be and will be implemented towards 2050. To proactively deal with these uncertainties governments can choose for adaptive policy-making (Walker et. al., 2001). Figure 9 gives an overview of the steps involved in the adaptive policy-making process.

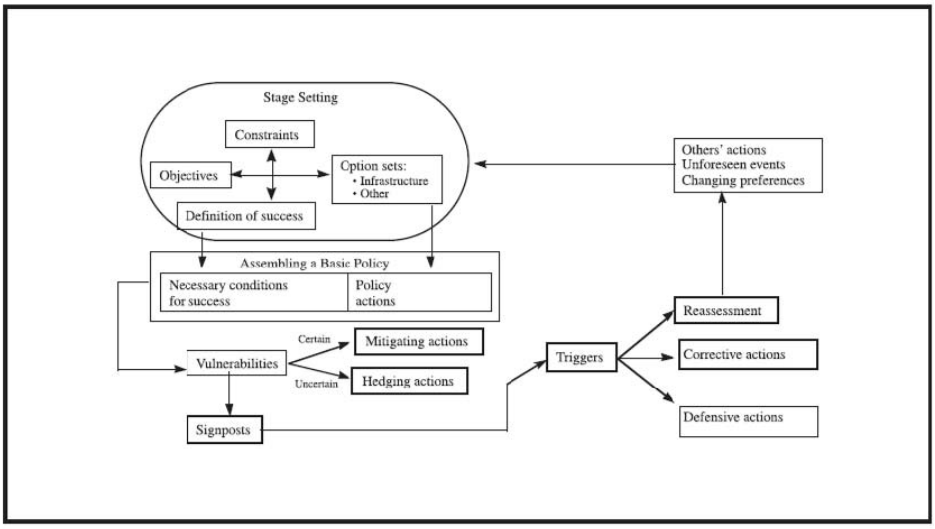


Figure 9: The adaptive policy-making process (Walker et. al., 2001:286)

An adaptive policy-making approach concerns the entire policy-making cycle from policy formulation to policy implementation and evaluation. The focus in this section is on policy formulation. It must be noted that policy formulation is not a one-time activity. New developments (such as changes in the political ambition) or information (such as more accurate predictions of the consequences of climate change in terms of low water levels) might require policy adaptations. Hence, the policy-making process is a continuous cycle.

Step 1 Setting the stage
Step 1 consists of discussing the various objectives, constraints, and policy options. Furthermore, the definition of success is set. The main objective of the Dutch government is to obtain waterways of sufficient quality and capacity to support the projected growth in transport volumes. The government aims for free passage on the primary corridors of the inland waterway network (Ministry of Transport, 2008). One of the constraints is the water level which is affected by climate change. The government acknowledges the necessity for the inland navigation industry to take the climate change into account. In view of the government more lightweight inland navigation vessels should be introduced. Furthermore, the government expects that climate change and high oil prices can enhance the development towards clean and efficient engines. This in turn might increase the demand for rail transport, transport by short sea shipping and inland navigation. The government will take the consequences of climate change into account when prioritizing solving bottle necks in the waterway network (Ministry of Transport, 2008).

Optional policy options governments have consist of modifications of the waterway infrastructure, measures aimed at making better use of waterway capacity, climate change awareness-raising measures and pricing measures. The success of a measure can be defined in terms of its contribution to the quality and capacity of the waterway network. Defining the quality levels is a political process; it is possible that the governments change their ambitions over time. For example, the extend to which governments leave responsibility to market parties or the level of ambition of the objectives on the transport share that should be accommodated by inland navigation can change over time.

Step 2 Assembling a basic policy
Assembling a basic policy consists of the specification of a promising policy instrument in terms of concrete policy actions and identifying the necessary conditions for the success of the policy. Monitoring these conditions can contribute to the early signalling of setbacks. It is not clear which concrete policy measures the government is willing and able to implement in the coming years. As low water levels is typically an international challenge, it is expected that one of the necessary conditions for success includes effective cooperation and agreement on the strategy to deal with the consequences of climate change between the neighbouring countries. For each condition the government can define various sets of possible zones of outcomes of the policy.

Step 3 Specifying the rest of the policy
The first aspect of the specification of the rest of the policy consists of identifying *vulnerabilities*. These vulnerabilities can have a large influence on the policy outcomes. Examples of vulnerabilities include changes in the scope of the government plans and problems with technology to create buoyancy to decrease the vessels draught. Vulnerabilities can be certain or uncertain. Similar to the principles of risk management are the type of measures dependent on the type of vulnerabilities. Mitigation actions can be taken in case of certain vulnerabilities and hedging action can be taken in case of uncertain vulnerabilities.

The second aspect is the monitoring of *sign posts,* which are indicators of the success of a policy. To this end triggers are formulated. These are boundary values which, if reached, are an indicator that additional measures might be needed. An important sign post is the development of the capacity of waterway. If the capacity is too often lowered due to low water levels, this might be the trigger for governments to take action. Depending on the specific problem, governments can re-assess the situation, take corrective measures or take defensive actions.

4. Logistic measures to deal with disturbance

4.1 Classification of measures

Companies that operate logistic chains can take various measures to deal with the higher costs or reduced reliability resulting from disturbances due to low water levels and due to the inability to use inland navigation. This section gives an overview of the measures. The list of measures is the result of a brainstorm with experts and a brief literature review. Furthermore, the study of Quak and van der Moolen (2009) is used to complement the list of measures. This study gives an overview of all kinds of logistic measures that companies can take in reaction to road pricing which is expected (when implemented) to have an impact on the costs and the performance of road transport (i.e. less congestion).

In addition the list of measures is classified into:

- *Structural measures*
  These measures change the basis logistic choices of a company. Generally these measures have a more long term focus.
- *Responsive measures*
  These measure are taken when the disturbance due to low water levels occur. These measures can be taken on the short term.
- *Transparency measures*
  These measures increase the transparency of the processes in the supply chain. More and more accurate information becomes available and is shared between the various stakeholders within the supply chain.
- *Cooperative measures*
  These 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*
  These measures all relate to financial or contractual arrangements between suppliers (this can be both carriers and shippers) and customers.

Table 1 gives a classification of measures companies can take in reaction to disturbances due to low water levels. Furthermore, each measure is characterized in terms of the type of reaction (see section 3.2), the 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). If a measure can be placed in a specific category without question (for example the measure is most likely to be taken by a shipper) this is indicated with a bold check mark. For some measures it is less clear that they belong to a specific category (for example when a shipper has not outsourced the transport, he can also take transport related measures), which is indicated with a grey check mark. Some measures cannot be placed in a specific category (for example using other vessel types is a measure that is only suitable in case of reduced feasibility of inland waterway navigation and not when inland waterway navigation has become completely infeasible) these cells are left blank intentionally.

In the classification of measures the spectrum from incidental disturbances to structural disturbance (see Table 1) is simplified in two categories to indicate whether the measure is more suitable for incidents or for structural disturbances. As explained in section 2.1, some companies might consider one or two incidents already a structural disturbance whereas other companies still consider this to be incidental. The impact of disturbances due to low water levels can differ very much between companies. Similar, companies can also hold very different opinions on how incidental or structural the disturbance is and what they consider a suitable measure for the type of disturbance. Hence, the classification is simply an indication of the relative position of the measure (more suitable for incidental disturbances or more suitable for structural disturbances).

Table 1: Classification of measures

Measure	Type of reaction	Initiator measure		Suitability of measure for type of disturbance		Suitability for disturbance impact	
		Shipper	Carrier	Reduced feasibility of inland waterway trips	In-feasibility of inland waterway trips	Incidental (one or several incidents in every five years)	Structural (several disturbances per year)
Structural logistics measures							
Diversification of customers	Mitigate: flexibility	x	**x**	x	x		**x**
Geographical spread of customers	Mitigate: flexibility	x	**x**	x	x		**x**
Decentralization/ re-location of own (production and warehouse) locations (instead of centralization)	Mitigate: flexibility	**x**		x	x		**x**
Flexible production processes (e.g. option to produce products simultaneously or sequential; product postponement)	Mitigate: flexibility	**x**		x	x		**x**
Back-up capacity in production processes and employees	Mitigate: redundancy	**x**	x	x	x	x	**x**
Dual or triple sourcing (back-up suppliers of goods and (logistic) services)	Mitigate: flexibility	**x**		x	x		**x**
Multiple suppliers	Mitigate: flexibility	**x**	x	x	x		**x**
Geographical spread of suppliers	Mitigate: flexibility	**x**	x	x	x		**x**
Extra stock of (bottleneck) products	Mitigate: redundancy	**x**		x	x	x	**x**
Extra storage capacity	Mitigate: redundancy	**x**		x	x		**x**
Higher delivery frequency (smaller loads)	Mitigate: flexibility	**x**		**x**	x		**x**
Longer delivery times (include more slack)	Mitigate: redundancy	x	**x**	**x**	x		**x**
Transport goods outside low water season	Minimize	**x**	x	x	x		**x**
Back-up inland navigation capacity (more similar vessels, extra smaller vessels or more lighter vessels)	Mitigate: redundancy	x	**x**	**x**		x	**x**
Replace inland navigation vessels by lighter, smaller or more flexible (e.g.push barges) inland navigation vessels	Minimize (flexibility)	x	**x**	**x**			**x**
Modal shift (stop using inland navigation)	Avoid	**x**	x	x	x		**x**
Hybrid transport networks	Mitigate: flexibility	x	**x**	x	x		**x**
Responsive measures							
Decrease load capacity vessels	Accept	x	**x**	**x**		x	x
Recovery plan (after the disturbance e.g. prioritize customer deliveries)	Respond	x	**x**	x	x	x	**x**
Postponement of transport	Respond	x	**x**	x	x	**x**	x
Lower delivery frequency (all customers temporarily receive fewer goods)	Respond	x	**x**	x	x	x	x
Use back-up inland navigation capacity	Respond	x	**x**	**x**		x	x
Take alternative routes	Respond	x	**x**	x	**x**	x	x
Use alternative ports	Respond	x	**x**	x	**x**	x	**x**
Use alternative transport modalities	Respond	x	**x**	x	x	x	x
Transparancy measures							
Using the same IT systems as customers / suppliers	Mitigate: transparency	x	**x**	x	x	**x**	**x**
Early warning of disturbance by low water levels	Mitigate: transparency	x	**x**	x	x	**x**	x
Contingency plans (during the disturbance)	Mitigate: transparency	x	**x**	x	x		**x**
Technologies (RFID, GPS, sensors etc.) to enable tracking and tracing (particulary relevant for combined shipments or storage)	Mitigate: transparency	x	**x**	x	**x**		**x**
Better load planning (internal / external)	Mitigate: transparency	**x**	**x**	x	x	x	x
Cooperative measures							
Bundling of goods flows with other companies	Respond	x	**x**	x	**x**	x	**x**
Selecting suppliers based on resilience	Mitigate: cooperation	**x**	x	x	x		**x**
Financial or contractual measures							
Shift risk to customers	Transfer	**x**	x	x	x	x	x
Purchase insurance to cover risks	Transfer	x	**x**	x	x	x	x
Pass on the costs of disturbance by low water to customers	Transfer	x	**x**	x	x	x	x
Outsourcing transport	Transfer	**x**	x	x	x		**x**
Avoide contractual arrangements which limit flexibility in delivery times or shipped volumes	Mitigate	x	**x**	**x**	x		**x**
Require contractual commitment for purchasing certain volumes (purchase obligation reduces the risk of customers switching suppliers)	Mitigate	**x**	x		**x**		**x**
Become a preferred customer through contractual arrangements (carrier gives your load priority in case of disturbances)	Mitigate: flexibility	**x**		x	x		**x**

Structural logistics measures

Structural logistic measures are measures that alter the basic logistics choices of a company. Some measures can be taken relatively easy such as the number of (back-up) suppliers. Other measures, such a centralization or decentralization of production facilities, might even require a completely different logistic strategy. Structural logistics measures concern three types of proactive reactions to disturbances:

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

Both shippers and carriers can take structural logistics measures in reaction to disturbances due to low water. The measures related to production, storage, location choices, frequency and volumes of shipments, and modal shift are most likely to be taken by shippers. Measures related to the delivery times and the choice of transport modalities are most likely to be taken by carriers. In case a shipper takes the responsibility for the delivery of goods to his customers or has not outsourced the transport, these measures are also relevant for shippers. The diversification of customers and the geographical spread of customers make a company less vulnerable for a disturbance in a specific supply chain. When a carrier transports a variety of different goods (using various modes of transport) only part of his shipments, being (part of the) the inland navigation shipments, can be affected by disturbances due to low water levels. The same holds for a geographical spread of customers. If a disturbances occur on a specific corridor only part of the customers is likely to be affected. Carriers can also choose to invest in additional and different vessel types or to use hybrid transport networks. Shippers can reduce their vulnerability in a similar way as carriers through the use of multiple suppliers and the geographical spread of suppliers.

Most structural logistics measures are suitable for both types of disturbances – reduced feasibility of inland waterway trips and infeasible inland waterway trips – because these measures mitigate the impact of disturbances on inland navigation in general. There are a few measures, however, that are only applicable in case of reduced feasibility of inland waterway trips. These measures concern a higher delivery frequency, longer delivery times, back-up inland navigation capacity and replacing inland navigation vessels with vessels that can cope more easily with low water levels. When the duration of the disturbance is short, companies with a high delivery frequency only risk missing a relatively small shipment compared to companies with a low delivery frequency for which missing one shipment can have much larger consequences. Longer delivery times can create sufficient slack for a carrier to recover from a short term disturbance, so that his customer will not even notice. The last two measures, related to the vessel type, are only applicable when the water levels are still high enough to execute inland waterway transport.

Given the nature of structural logistic measures, these measures are more applicable for structural disturbances than for incidents. Especially when the assessment of taking a measure solely includes disturbances due to low water levels, these measures are not likely to be cost efficient in case of incidental disturbances due to low water levels. In some cases back-up measures (vessel capacity, employees) and additional stock might already be suitable when the disturbances still have a more incidental character. In section 4.2 also other reasons for taking measures are discussed.

Responsive logistic measures

Responsive measures are measures that do not require preparations by the company. When a disturbance due to low water levels occurs, a company can choose two types of reactive reactions to disturbances:

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

As responsive logistic measures most directly relate to the execution of transport, the carrier is likely to be the initiator of this measure. When the shipper has not outsourced the transport, these measures can also be taken by shippers. Two measures can only be taken in case of reduced feasibility of inland waterway trips: decrease the load capacity of the vessel and use back-up capacity. Use alternative routes and port can be suitable for both types of disturbances. However, these measures are particularly relevant when inland waterway transport on the regular corridor has become infeasible. Most responsive measures are suitable for more incidental and more structural disturbances. As making a recovery plan and using alternative ports require preparations, these measures are slightly more suitable for structural disturbances. Simply postponing the transport might be acceptable for customers in case of incidents but is expected to become a less suitable option in case of structural disturbances.

Transparency, Cooperative, Financial or contractual measures

Transparency, Cooperative, Financial or contractual measures concern three types of proactive reactions to disturbances:

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

Transparency measures are most likely to be taken by carriers, except for better load planning. This specific measure can only be taken in close cooperation with the shipper and combining loads is not always favored by shippers because sharing required information can conflict with competitive interests. Combining good flows in reaction to disturbances only requires temporary cooperation and information sharing which can be initiated by the carrier. Financial or contractual measures can be taken by both shippers and carriers. Measures typically taken by shippers include shifting risks to customers, outsourcing transport, require purchase obligations and becoming a preferred customer. Measures typically taken by carriers are purchasing insurance, passing on the costs to customers and avoiding contractual arrangements which limit the flexibility in delivery times or shipped volumes.

Most structural logistics measures are suitable for both types of disturbances – reduced feasibility of inland waterway trips and infeasible inland waterway trips – because these measures mitigate the impact of disturbances on inland navigation in general or they transfer the risk or consequences. However, three measures are considered more suitable in case inland waterway trips have become completely infeasible:

- the use of technologies for tracking and tracing
- the bundling of good flows with other companies
- requiring purchase obligations.

Technologies for tracking and tracing are particularly useful when there is a risk of losing track of goods which is more likely to occur when inland waterway trips are infeasible for a certain period. That could result in packed warehouses and goods being temporarily stored at different locations. Bundling of good flows after the disturbance occurred requires substantive preparation (especially when more structural cooperation between companies is lacking). This is probably only worthwhile when the disturbance is very severe and inland waterway navigation has become impossible. Requiring purchase obligations (solely in reaction to the risk of disturbance due to low water levels) is considered to be a rather severe measure. The risk of losing customers is most likely apparent when inland waterway navigation has become infeasible and when it concerns a structural problem.

Similar to structural logistics measures, transparency, cooperative and financial or contractual measures are more applicable for structural disturbances than for incidents. Most measures require (substantive) preparation, cooperation or negotiation with other stakeholders. Companies will only be willing to make these investments if the measures contribute sufficiently to reducing the costs or improving the reliability in case of disturbances due to low water levels. This is more likely in case of structural disturbances because the investments are spread over a larger number of events.

4.2 Assessment of measures

Evaluation criteria

Taking a measure involves costs and benefits. Although not all companies will have completely optimized their logistics choices, the majority of companies have good reasons for the logistics choices they have made in the past. Hence, when companies are forced to deviate from their normal logistics operations it is very unlikely that it will result in a more efficient logistic process. Therefore, the benefits of a measure are defined in terms of their contribution to improving the reliability of the service which has been jeopardized by the disturbance due to low water levels and in terms of their contribution to reducing the costs resulting from the disturbance.

In Table 2 all measures are scored on cost and benefit criteria, being:

Costs

- Cost of the measure
  The most expensive measures are rated with three minus signs. Measures that (hardly) cost any money are rated with a 0.
- Implementation term
  If the measure needs to be prepared long in advance of the event, the measure gets a negative score on implementation term. Measures that (hardly) cost any preparation time are rated with a 0.
- Dependence on stakeholders
  If the implementation of a measure cannot succeed without the support of other stakeholders the measure is rated negative on the criterion dependence on other stakeholders because implementing the measure is more complex than when a company can solely implement the measure. If a company does not depend on other stakeholders the process is very simple and taking the measure will not require additional effort. Therefore measures that can be taken without dependence on other stakeholders are rated with a 0.

Benefits

- Contribution to reliability
  The extent to which measures reduce the negative effect on reliability, determines how well (up to three plus signs) the measure scores. Measures that do not have an effect on reliability are rated with a 0.
- Contribution to cost
  The extent to which measures reduce the cost of the disturbance determines how well (up to three plus signs) the measure scores. Measures that do not have an effect reduce the costs are rated with a 0.
- Synergy effects
  Many measures are taken for a variety of reasons and disturbances due to low water levels can be just one of these reasons. If a measure can also contribute to various objectives (e.g. improving environmental quality, reduce the impact of congestion, become more resilient) it is rated positively on the criterion synergy effects.

Summarizing, when a company needs to decide on taking measures in reaction to disturbances due to low water levels, the following aspects are taken into account:

1) The impact of the disturbance due to low water levels in terms of costs and reduced reliability, taking into account the company's specific situation (type of product, logistics strategy and supply chain).
   - o A single disturbance:
     - frequency and duration of low water levels
     - less or completely infeasible inland waterway transport
   - o Multiple disturbances:
     - frequency and duration of low water levels
     - less or completely infeasible inland waterway transport
     - incidental or more structural character or the disturbances
2) Optional measures (for an individual carrier or shipper)
   - o Proactive
   - o Reactive
3) Selection of reaction (accept or not accept) based on cost and benefits of measures
   - o Costs
   - o Implementation term
   - o Dependence on stakeholders
   - o Contribution to reliability
   - o Contribution to costs
   - o Synergy effects

Table 2 Assessment of measures

	Costs			Benefits		
Measure	Cost of the measure	Implementation term	Dependence on stakeholders	Contribution to reliability	Contribution to cost	Synergy effects
	--- / -- / - / 0	--- / -- / - / 0	--- / -- / - / 0	0 / + / ++ / +++	0 / + / ++ / +++	0 / + / ++ / +++
Structural logistics measures						
Diversification of customers	--	---	---	+	+	+
Geographical spread of customers	---	---	---	+	+	?
Decentralization/ re-location of own (production and warehouse) locations (instead of centralization)	---	---	-/0	++	0/+	+
Flexible production processes (e.g. option to produce products simultaneously or sequential; product postponement)	--	---	0	+	++	+
Back-up capacity in production processes and employees	--	--	0	+	++	+
Dual or triple sourcing (back-up suppliers of goods and (logistic) services)	-	-	-	+	++	+
Multiple suppliers	-	-	-	+	++	+
Geographical spread of suppliers	-	-	--	+	++	?
Extra stock of (bottleneck) products	-	0	0	++	+	+
Extra storage capacity	-	-	0	+	+	+
Higher delivery frequency (smaller loads)	-	-	-	+	+	+
Longer delivery times (include more slack)	-	0	--	++	+	+
Transport goods outside low water season	--	-	--	+++	0	0/+
Back-up inland navigation capacity (more similar vessels, extra smaller vessels or more lighter vessels)	---	--	-/0	+++	+	+
Replace inland navigation vessels by lighter, smaller or more flexible (e.g.push barges) inland navigation vessels	---	--	-	+++	+	0/+
Modal shift (stop using inland navigation)	--	0	-	+++		0
Hybrid transport networks	-	-	-	++	++	+
Responsive measures						
Decrease load capacity vessels	-	0	0	0/+	0/+	0
Recovery plan (after the disturbance e.g. prioritize customer deliveries)	0	-/0	0	0	+	+
Postponement of transport	0	0	0	0	0	0
Lower delivery frequency (all customers temporarily receive fewer goods)	-/0	0	0	+	0	0
Use back-up inland navigation capacity	-/0	0	0	+	0/+	0
Take alternative routes	-	0	0	+	0/+	0
Use alternative ports	--	0	0	+	0/+	0
Use alternative transport modalities	-	-/0	0	+	0/+	0
Transparancy measures						
Using the same IT systems as customers / suppliers	0	--	---	0/+	0	+
Early warning of disturbance by low water levels	0	--	--	0/+	0/+	0
Contingency plans (during the disturbance)	0	-/0	0	0	0/+	+
Technologies (RFID, GPS, sensors etc.) to enable tracking and tracing (particulary relevant for combined shipments or storage)	-	-	--	+	0	+
Better load planning (internal / external)	-/0	-/0	--	0	+	+
Cooperative measures						
Bundling of goods flows with other companies	-/0	-/0	--	0	+	+
Selecting suppliers based on resilience	0	-/0	-	+	0	+
Financial or contractual measures						
Shift risk to customers	-/0	-/0	---	0	0	0
Purchase insurance to cover risks	-	-/0	-	0	++	0
Pass on the costs of disturbance by low water to customers	0	0	---	0	+	0
Outsourcing transport	-/0	-	-	0/+	0	0/+
Avoide contractual arrangements which limit flexibility in delivery times or shipped volumes	0	0	--	+	+	0
Require contractual commitment for purchasing certain volumes (purchase obligation reduces the risk of customers switching suppliers)	-/0	-/0	---	0	+	0/+
Become a preferred customer through contractual arrangements (carrier gives your load priority in case of disturbances)	-/0	-/0	---	+	0	0/+

5. Summary

Background
The most important consequence of climate change for inland navigation is periods of low water levels of rivers. This report builds on an earlier Knowledge for Climate study executed by TNO into the impact of climate change on the competitive position of inland waterway transport for the transport of goods (Van Meijeren and Groen, 2009). In this earlier study, insight has been given in the extent of the impact of climate change on inland waterways transport. The focus of this report is on the logistic solutions companies can take for dealing with the consequences of climate change for inland shipping. These consequences concern disturbances due to periods when shipping is only possible with strongly restricted shallow draught and periods when inland navigation is completely infeasible. These disturbances result in higher costs of inland navigation and reduced reliability when inland navigation becomes infeasible. This can even result in shifting the competitive positions of transport modalities.

Risk strategies
In this report we discuss risk management which consists of mapping and quantifying the risks and choosing appropriate measures to influence these risks. This assessment of whether certain measures are necessary is seen as continuous process. Almost every company faces the risk of supply chain disruptions. Several risk strategies also contribute to making a company more resilient. Through redundancy, flexibility, transparency and collaboration companies or supply chains will become better able to reduce damage after major disruptions and to return quickly to the original (or desired) situation. Also governments can choose a strategy to deal with uncertainties; the adaptive policy-making approach. In this approach the policy-making process is a continuous cycle in which new developments or information are continuously monitored and can lead to policy adaptations.

Logistic measures to deal with the impact of climate change
This report identified thirty-nine logistic measures logistics companies can take in reaction to disturbances due to low water levels (see table 1). This list resulted from a brainstorm with experts and a brief literature review. The measures are classified into five categories and for each measure the most appropriate types of reactions - Accept, Avoid, Minimize, Mitigate (cooperation, flexibility, redundancy, transparency), Respond and Transfer - were indicated.

- *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).

Relevant aspects for decisions to take measures
When a company needs to decide on taking measures in reaction to disturbances due to low water levels, the following aspects are taken into account:

1) The impact of the disturbance due to low water levels in terms of costs and reduced reliability, taking into account the company's specific situation (type of product, logistics strategy and supply chain). The impact of the disturbance also depends on how often the disturbance occurs:
    - A single disturbance:
        - frequency and duration of low water levels
        - less or completely infeasible inland waterway transport
    - Multiple disturbances:
        - frequency and duration of low water levels
        - less or completely infeasible inland waterway transport
        - incidental or more structural character of the disturbances
2) Optional measures (for an individual carrier or shipper)
    - Proactive measures
    - Reactive measures
3) Selection of reaction (accept or not accept) based on cost and benefits of measures. Criteria to include in this assessment are (see table 2 for rates for criteria):
    - Costs
    - Implementation term
    - Dependence on stakeholders
    - Contribution to reliability
    - Contribution to costs
    - Synergy effects

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