IMPACT OF CLIMATE CHANGE ON THE COMPETITIVE POSITION OF INLAND WATERWAYS TRANSPORT AND LOGISTIC SOLUTIONS

Jaco van Meijeren
Tsjitske Groen
Diana Vonk Noordegraaf
TNO – Sustainable Transport and Logistics
Delft, Netherlands

1. INTRODUCTION

In several analyses of transport demand (for instance Port of Rotterdam, 2011), in scenarios with high economic growth it is expected that the volume of freight flows will increase severely. In the Port of Rotterdam area, it is expected that these large volumes of freight flows will lead to reduced accessibility (congestion on the road) of the port area and environmental problems. Therefore, a strong shift of freight flows from road to rail and inland waterways transport is necessary. From the perspective of sustainability, the European Commission also sets targets in the recent White Paper (EC, 2011) for modal shift of road to rail and inland waterways transport for transport distances above 300 kilometres.

In worst case climate change scenarios, a severe impact is expected on the sea water level (increase) and the water level on the main rivers (mainly decrease in second half of the year) on the long run (time horizon 2050). As a consequence, storm surge barriers have to close more often and inland shipping is only feasible by reducing loading rates or in worst case situations inland shipping is not feasible at all. This leads to increased transport costs and decreased reliability of inland waterways transport.

If the two developments described above are combined, the following picture results. On the one hand it is needed that inland waterways transport is able to handle very large volumes of freight transport (with a higher market share in a growing transport market) to avoid accessibility problems, environmental problems and to reduce CO2 emissions, on the other hand in worst case climate scenarios there is a chance that the capacity of inland waterways transport is reduced substantially (reduced loading rates or even infeasibility of trips) and the reliability of inland waterways reduces dramatically (less attractive as a robust transport alternative). Concluding, developments in climate change scenarios are a potential risk for the modal-split targets set by amongst others the Port of Rotterdam and the European Commission.

In this paper, first it is investigated what impact can be expected from climate change on the competitive position of inland waterways transport. In a second step, measures are analyzed that can be taken to reduce the negative impact of climate change on inland waterways transport. An inventory is made of possible measures and logistic measures that can be taken to make inland waterways transport and supply chains more resilient against incidental and structural disturbances in the inland waterways network are analysed in more detail.

The study has been carried out within the National Research Programme Knowledge for Climate in the Netherlands. For this project TNO – Mobility and Logistics worked in a consortium together with the Dutch Ministry of Infrastructure and Environment, the Port of Rotterdam, Delft University of Technology, Deltares, VU University of Amsterdam and Arcadis.

2. GENERAL APPROACH IMPACT OF CHANGING WATER LEVELS

Within this study, 2004 is taken as the base year, as for 2004 both transport data as well as water level data are available. The transport data from the Basisbestand Goederenvervoer 2004 study (NEA/TNO, 2007) are used in combination with the water levels of 2004, which was an average dry year. Since it is expected that most of the impact of climate change will take place on a very long term, the selected time horizon is 2050. To determine the volume of freight flows and the corresponding number of vessels for the year 2050, an economic scenario is used. Because it is intended to determine an upper bound for the impact of climate change, the WLO Global Economy scenario (CPB/MNP/RPB, 2006), is selected. This scenario has – by far – the highest growth and the highest volume of freight flows. A climate change scenario is needed to determine the future water levels on the sea and on the main rivers. In 2006 the KNMI has developed four new climate scenarios for the Netherlands (KNMI, 2006), of which the W+ scenario is the scenario with the highest impact on water levels. Therefore, the W+ scenario has been used as the worst case climate change scenario.

To determine the impact of climate change, based on the economic and climate scenario's mentioned above, two situations are constructed: the reference situation and the climate change situation. The reference situation is represented by the volume of freight flows and corresponding number of vessels in 2050 without climate change, that is, with the 2004 water levels. The climate change situation is represented by the combination of the transport data for 2050 and the W+ 2050 water levels.

For the impact of high sea water levels an analysis of the closing frequency of the Maeslantkering and the Hartelkering and the costs corresponding to these closings is made. Concerning the impact of low inland water levels, both the reference and the climate change situation are input for the transport model for inland navigation "BIVAS" (Binnenvaartanalyse Systeem). BIVAS assigns the freight flows to the inland waterway network with fluctuating water levels. These results are used to determine the direct impact on inland waterway transport: level-of-service, reliability and the use of alternatives. The level-of-service, or the performance, of the inland waterway transport is affected by the change in transport costs and times, while delays and obstructions caused by lower water levels will affect the reliability of the inland waterway transport. The BIVAS results are then input for the TRANS-TOOLS model to determine the incentive for a modal shift: if the impact is high, alternatives can be found in using other transport modes or moving to another port, for instance the port of Hamburg in stead of the port of Rotterdam.

3. IMPACT HIGH SEA WATER LEVELS

In the Rotterdam area two storm surge barriers prevent the regions below sea water level from flooding: the Maeslantkering on the Nieuwe Waterweg and the Hartelkering on the Hartelkanaal. In case of a storm with high sea water levels the storm surge barriers are closed to stop the seawater entering the rivers and canals. Consequently, the rivers and canals are also obstructed for inland waterway and sea vessels. Currently, it is expected that these storm surge barriers have to close once every 10 years.

In the climate change scenario it is expected that up to 2050 the sea water level will increase with 0.35 meter. This increase would cause the storm surge barriers to close once every 5 years. It seems obvious to conclude that this increase is not severe, but although the year 2100 is outside the scope of this study, it is interesting to see that in the worst case climate scenarios, where an increase of the sea water level up to 1.30 meter is expected, the closing frequency of the Maeslantkering and Hartelkering will rapidly increase to about 30 times a year.

When the storm surge barriers close, the obstruction lasts 24 hours. For the current situation, figures from the MER Maasvlakte 2 (Projectorganisatie Maasvlakte 2, 2006) have been used because in this source the split has been made between the number of vessels on the Nieuwe Waterweg and on the Hartelkanaal. Then the growth figures from the Global Economy scenario have been used. As the report 'Evaluatie sluitingsregime Maeslantkering, consequentie document' (Witteveen+Bos, 2009) shows, some vessels will just wait and continue their journey afterwards without changing anything. Some vessels will also wait, but after the storm surge barriers open again, they will catch up the time losses by sailing at higher speeds in order to meet the agreed arrival times in the scheduled services. From this report, the figures about the shares of vessels that do, or do not, catch up, and the figures about waiting costs and catching up costs are used. For the inland waterway transport it can be concluded that the costs of the closures increase from more than 232 thousand Euro in 2010 to more than 651 thousand Euro per year in 2050.

The question is whether these impacts will influence the competitive position of inland waterway transport. Since the storm surge barriers close not very often in 2050 (24 hours every 5 years), the number of hindered ships is still rather limited and the costs do not increase extremely. Therefore, it is expected that the competitive position of inland waterway transport is not affected by this increase in closing frequency.

4. IMPACT LOW INLAND WATER LEVELS

For both the reference and the climate change situation, Deltares has translated the scenarios into daily water levels on the main rivers in, to and from the Netherlands. Figure 1 shows for both situations the daily water levels at the Rhine near Ruhrort in Germany. In the climate change situation slightly higher water levels are expected in the first half of the year. Nevertheless, in the second half of the year, the water levels are expected to be substantially lower than in the reference situation, with a number of peak periods with water levels below 2.0 meter. Figure 2 shows the bottlenecks related to low water levels. The most severe problems will arise along the IJssel, the Rhine and the Waal near Arnhem and Nijmegen and especially the Rhine in Germany.

Although the reference and the climate change situation have different water levels, the pattern over the year is the same, because Deltares applied the expected change of the water levels up to 2050 on the observed water levels for the year 2004. Therefore, the water levels in the climate change scenario are strongly linked to the observed water levels in 2004. It should be kept in mind that especially the pattern over the year could be different in 2050.

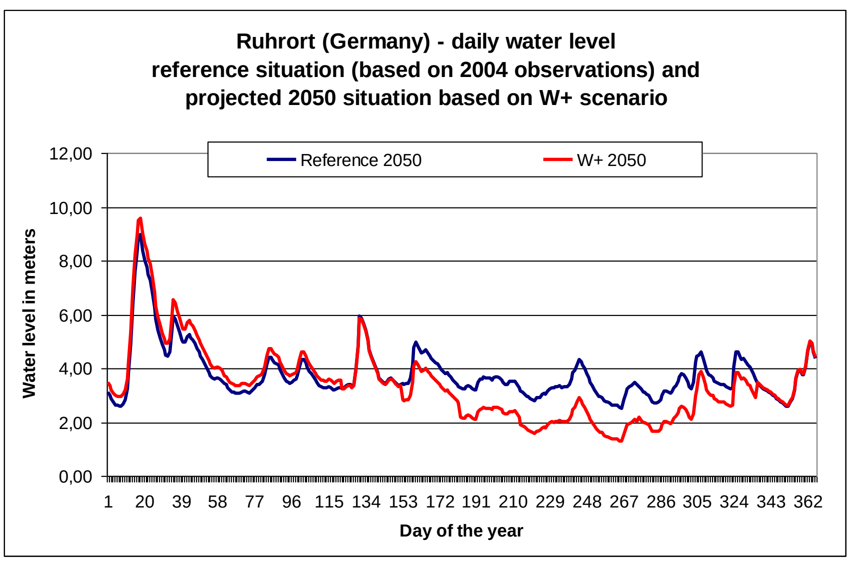

Figure 1: Daily water levels

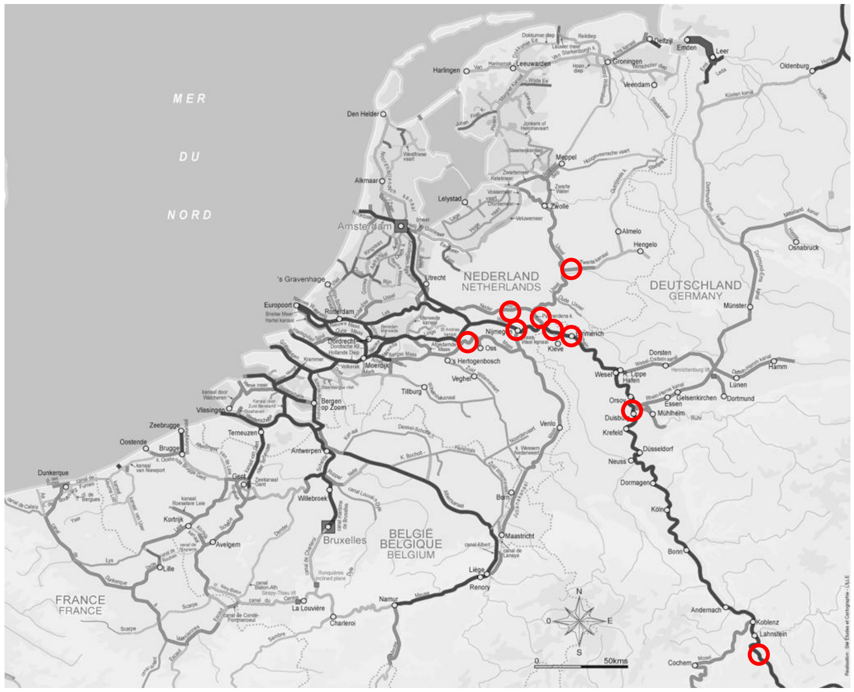

Figure 2: Overview low water related bottlenecks

BIVAS model

The BIVAS model has been developed by Rijkswaterstaat (RWS) mainly to analyse the traffic on the inland waterway network, the impact of obstructions in the network and the impacts of long term developments on inland waterway transport. The model assigns each vessel from the input origin/destination travel matrix to the inland waterway network taking into account the dimensions of the vessels including their draught. Assignments can be made based on a constant water level per year, or on fluctuating water levels per season or per 10 day period.

The assignment works with the following steps. First for every trip in the O/D travel matrix, the model tries to select the route on the network with the lowest travel cost. In case no feasible routes can be found, due to water levels too low to navigate, the load rate of the vessel will be decreased, restricted to the maximum of - 50% offload. Again the model tries to select the route with the lowest travel cost. If there is still no feasible route available, the inland waterway trip becomes infeasible.

To be able to make an assignment per 10 day period, RWS has aggregated the daily water level results of Deltares to an average water level per 10 day period. After the assignment, the results of all 10 day periods are aggregated to annual results. Both the annual results and the results of each 10 day period have been transferred to TNO for in-depth analysis.

BIVAS results

In this analysis a comparison between the reference and the climate change situation is made. In the annual results the share of volume of the infeasible trips due to low water level problems is 7%. The share of the volume on which climate change does not have an impact is 86%. The other 7% of the volume faces increased transport costs, due to either having to travel another longer route, or having to decrease the load rate and therefore to increase the number of trips to transport the volume.

These annual results might lead to the impression that the impact of the climate change scenario is rather limited. The climate change scenario leads to very temporarily problems over the year, averaging out in the annual results. Therefore it is necessary to have also a look at the impacts in the 10 day period with the lowest water levels. What will happen the moment these severe temporarily problems occur?

In this climate change scenario, the worst case 10 day period occurs in the autumn. At that moment the share of volume of the infeasible trips is 35%, 55% of the volume is not affected and the other 10% shows increased transport costs. Both the annual and the worst case 10 day period results are shown in figure 3. In both cases, the share of infeasible transport, as well as the share of transport facing increasing transport costs, is by far the highest for the transport markets between the Netherlands and Germany. These BIVAS results are used as input for the TRANS-TOOLS model.

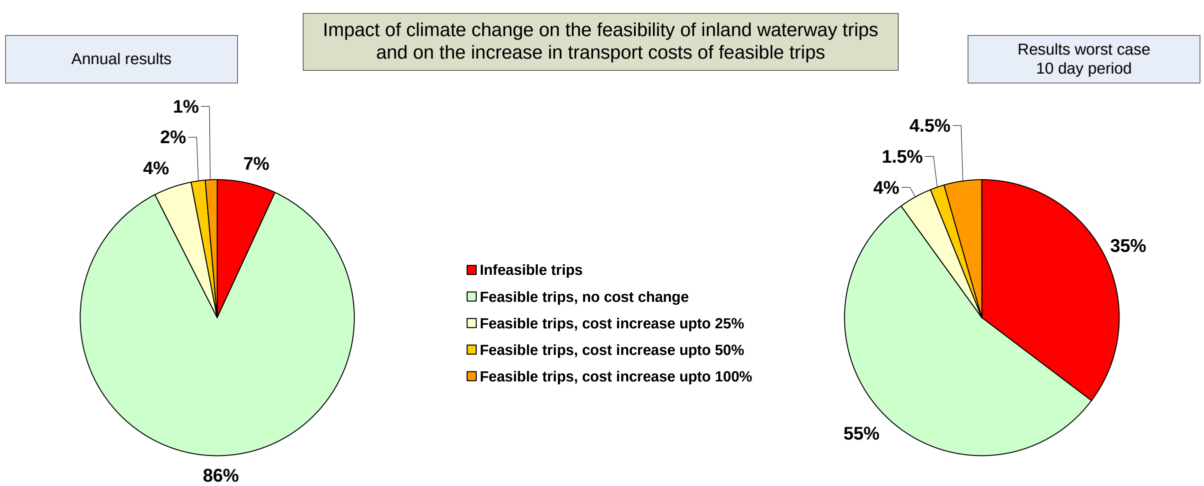

Figure 3: Expected impact of low water levels on feasibility and transport costs

TRANS-TOOLS model
TRANS-TOOLS is a European transport network model developed for and owned by the European Commission. The development of the first version of the model was coordinated by TNO. The TRANS-TOOLS model is an aggregate transport model, that is, the freight transport is modeled at the aggregated level, covering current and future regional transport in terms of transport volume (tonnes) and performance (transport units and distances). This regional transport is covered by more than 300 regions in Europe for the 4 transport modes road, rail, inland waterways and sea, and the 99 commodity groups according to the 2-digit NSTR classification.

The BIVAS results are input for the modal-split module in the TRANS-TOOLS model. This modal-split module determines changes in the modal-split based on the generalized transport costs and the shares in volumes of the transport modes road, rail and inland waterways per commodity group. However, the model does not restrict the transport capacities per mode. Therefore, the modal shift is labeled as an incentive to modal shift. Afterwards the feasibility of the shift results has to be evaluated.

The modal shift module works as follows. The inland waterway transport that is still feasible faces higher generalized transport costs leading to a decrease of the competitive position of inland waterway transport. As a consequence the modal-split module shifts part of the inland waterway transport to road and rail. The other part accepts the increased costs. For the inland waterway transport that becomes infeasible (unreliable), it is assumed that the actors in the transport market will wait until the inland waterway transport becomes feasible again. The generalized cost of the delayed inland waterway transport is calculated by including additional costs for the delay time consisting of the value-of-time and the value-of-reliability of the goods. Then based on these generalized transport costs part of the inland waterway transport will shift to the other transport modes, the other part will accept the delay and wait until the inland waterway transport becomes feasible again.

TRANS-TOOLS results
As the annual BIVAS results already showed, 86% of the total volume of inland waterway transport within, to, from and through the Netherlands is not affected by the impact of the climate change scenario. The TRANS-TOOLS results show that for 6% of the volume the delays or increased costs are accepted and that for the other 8% of the volume an incentive for a modal shift exists. This 8% of the volume can be divided into 88% that has an incentive to shift towards rail and 12% towards road transport.

For the worst case 10 day period, 55% of the total transport volume within, to, from and through the Netherlands is not influenced by the impact of the climate change scenario at all. From the 45% that is affected, 17% is expected to accept the impact and for 28% of the total volume the increase in transport costs is high enough to consider using an alternative transport mode (road or rail). For that part of the transport where an alternative mode is considered, rail transport is by far most attractive (78%) followed by road transport (22%). Both the annual and the worst case 10 day period results are shown in figure 4.

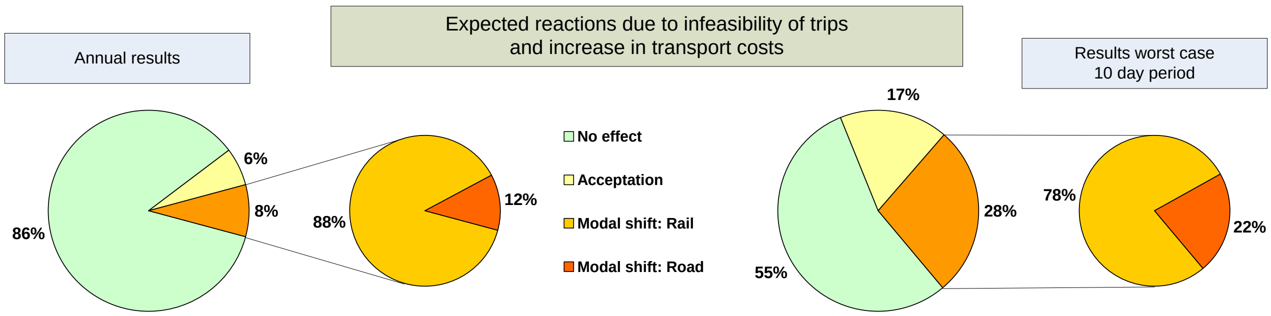

Figure 4: Expected impact of increased transport costs and infeasibility on the modal split

Interpretation of the results

At the moment the climate change problems are incidental problems. These expected problems will stay incidental the next years, but up to 2050 the frequency will increase. If the W+ climate scenario will persist, the mentioned problems will be structural in 2050. First, actors in the transport market will try to find flexible solutions for the incidental problems, but later on as the problems become structural they will try to find structural solutions. This is especially relevant to consider in relation to the feasibility of the modal shift to road and rail transport. In case of incidental problems, the question is whether it is possible to organize a strong shift to road and rail transport. In case of structural problems as they are considered in this study, the problems are no surprise and the shift to road and rail can be organized on a structural basis.

If the inland waterway transport to and from Rotterdam is obstructed, a first reaction could be to try to transport the goods to and from another seaport. However, the low water problems on the inland waterway network will obstruct inland waterway transport to and from other surrounding seaports such as Antwerp, Vlissingen, Terneuzen, Moerdijk and Amsterdam as well. Another possibility could be to shift the goods to Hamburg and Bremen and transport the goods with inland waterway transport to the hinterland regions in Germany. However, the share of inland waterway transport in these German seaports is not that high. The accessibility via inland waterways to and from these ports is of lower quality, compared to the Dutch and Flemish seaports.

If a shift takes place to the transport alternatives road and rail, it is possible that – depending on the transport costs and available capacity – a shift takes place to other seaports, especially to the German seaports Hamburg and Bremen that have good railway services and good rail connections to the German hinterland. If this happens, up to around 4% of the total inland waterway transport could shift to these German ports.

5. CONCLUSIONS IMPACT OF CLIMATE CHANGE

Based on the scenarios, assumptions, and models used as well as the interpretations of the results, the following main conclusions can be drawn:

High sea water level
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.

Low inland water level
For the whole year, 86% of the total volume of inland waterway transport within, to, from and through the Netherlands is not affected by the impact of the climate change scenario. The 14% of the inland waterway transport that is confronted with the impact of the climate change, consists of 7% that becomes infeasible (unreliable) and 7% that is still feasible, but against increased generalized transport costs. The increase in unreliability and level-of-service leads to an incentive for modal-shift of 8% of the total annual volume, of which 88% would like to shift to rail transport and 12% to road transport.

In the 10 day period with the lowest water levels, the transported volume not affected by the impact of the climate change scenario is 55%. The 45% of the volume that is confronted with the impact of climate change, consists of 35% that becomes infeasible (unreliable) and 10% that is still feasible, but against increased generalized transport costs. The increase in unreliability and level-of-service leads to an incentive for modal-shift of 28% of the total volume in this 10 day period, of which 78% has an incentive to shift to rail transport and 22% to shift to road transport.

The moment the volume with an incentive for modal-shift really shifts towards road or rail transport, up to around 4% of the total inland waterway transport could shift to German ports.

Coming back to the question whether there is a problem concerning the competitive position of inland waterway transport and the extent of this problem (the starting point of the study), it can be concluded that on specific transport markets between the Netherlands and Germany, the competitive position of inland waterway transport is threatened.

6. POSSIBLE SOLUTIONS

First, an inventory has been made of possible measures to reduce the impact of climate change on the competitive position of inland waterways transport. In the 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 summarized in this chapter. The consortium and experts selected the following categories of solutions:

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

A more detailed explanation of these measures is included in the final report of the Knowledge for Climate project (Knowledge for Climate, 2011).

In the next chapter, the logistic measures are described in more detail.

7. LOGISTIC MEASURES

Risk management

Before identifying measures, it was investigated how companies can deal with risks. By applying risk management, companies can map and quantify the risks and choose appropriate measures to influence these risks. The 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.

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, a TNO study (TNO, 2009b) 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, 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. 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).

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**

Table 1: Classification of measures

8. CONCLUSIONS SOLUTIONS AND LOGISTIC MEASURES

In the study thirty-nine logistic measures were identified that 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.

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).

Besides, it is indicated whether measures are structural or responsive. Based on the type of incidents companies deal with of foresee, and the risk they are (not) willing to take, each company should develop an action plan (with a selection of measures from table 1) with structural or incidental (responsive) measures to deal in the best possible way with disruptions in the transport system and the supply chain.

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