DELIVERABLE 2.2.2
ASSESSMENT OF ADAPTATION STRATEGIES

Final version

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1. Introduction

Climate change may affect water levels and thereby also Inland Waterway Transport (IWT), e.g. in terms of decreasing load factors and increasing costs. Accordingly, one of the objectives of ECCONET is to identify the impacts on IWT e.g. in terms of possible additional costs and to identify and recommend measures to reduce the impacts. These measures – the ECCONET adaptation measures – are the topic of study in workpackage 2.

In task 2.1 ECCONET has identified 13 different adaptation measures. These measures have been described in detail in the various deliverables of this subtask. It appeared that the measures are very different in nature, and have different impacts and costs. The first part of task 2.2 has assessed the feasibility of these various measures after a validation workshop with stakeholders and analysing the deliverables of task 2.1. This has resulted in an overview of more and less feasible measures (we refer to D2.2.1 for detailed results).

In subtask 2.2.2 an assessment strategy has been developed, which provides the project with a well-defined approach to assess all adaptation measures equally. This approach has been defined early in the project to structure the data collection on the adaptation measures. Given the diversity in measures a common approach is needed to facilitate a comparison between costs and effects for the various measures. This theoretical evaluation framework is described in this deliverable and was supposed to be applied as the standard assessment tool to rank measures. However, in deliverable 2.2.1 we concluded that the information on costs and effects is very fragmented and that we needed information from other sources to identify the most promising adaptation measures. ECCONET has searched for additional literature on cost-benefit assessments of adaptation measures. The Dutch programme Kennis voor Klimaat (Knowledge for Climate) has also assessed costs and benefits from adaptation measures (Knowledge for Climate, 2011) of which results have been included in this work. In addition, we have consulted stakeholders in a workshop about the feasibility of measures. The information about the feasibility of measures collected in this stage will be very relevant for future stages in the project , where NODUS runs are carried out and added to the final assessment work (the intention is to conduct cost-effectiveness analyses).

This deliverable is organised as follows. Chapter 2 defines the scope for the assessment and explains the focus on water level compensation. Chapter 3 explains the assessment framework developed within ECCONET to guide data collection and support future evaluation of the identified adaptation measures. Chapter 4 summarises findings from deliverable 2.2.1, brings in results on the assessment of adaptation measures from literature and the workshop, and identifies promising adaptation measures. Chapter 5 concludes and defines the adaptation measures which will be modelled with NODUS.

2. Scope for the assessment approach: water level compensation

2.1 Water level problems

Climate change may have an impact on future water levels. Water levels may be higher or lower, and the periods of high and low water may be longer. Low water periods causing a reduced payload and even a block of traffic, while high water events cause problems for ships that need airdraft (such as container vessels) and may lead to ban on inland shipping (in the extreme event of floods). ECCONET has decided to focus on the low water level problems, and hence also on ways to adapt to these situations. Low water periods are considered to have a much more dramatic impact on the competitive position of IWT than (extreme) high water periods.

More frequent occasions of low water periods and more extreme low water levels are considered to be the main threat for inland waterway transport due to climate change. In order to illustrate at what water levels vessels can't navigate at full capacity, it is needed to provide details on the vessel dimensions. The following table presents these details (in metres) based on the standards used by the Dutch waterway operator "Rijkswaterstaat". It is clear that much depends on ship types: larger vessels need more water.

CEMT	Type	Width	Length	Draft (loaded)	Draft (empty)	Tonnage
I	Spits	5.05	38.5	2.5	1.2	365
II	Kempenaar	6.6	50-55	2.6	1.4	550-615
III	Dortmund-Eems	8.2	67-85	2.7	1.5	910-1250
IV	Rijn-Herne	9.5	80-105	3.0	1.6	1370-2040
Va	Large Rhineship	11.4	110	3.5	1.8	2750

Table 2.1: Vessel type dimensions and loading capacities[1]

Water levels are crucial to our analysis and the feasibility of adaptation measures. When is a certain water level becoming a bottleneck for inland navigation? We illustrate this for water levels in two years (2003 and 2005) at Kaub, a well known bottleneck at the river Rhine. Figure 2.1 indicates that 2005 can be considered as a rather "normal" year. It has about 100 days with low water surcharges which seems comparable to the 1961 – 1990 period.

[1] All vessel classifications give an indication of characteristics and will vary from case to case. Empty draft figures include keel clearance and squat.

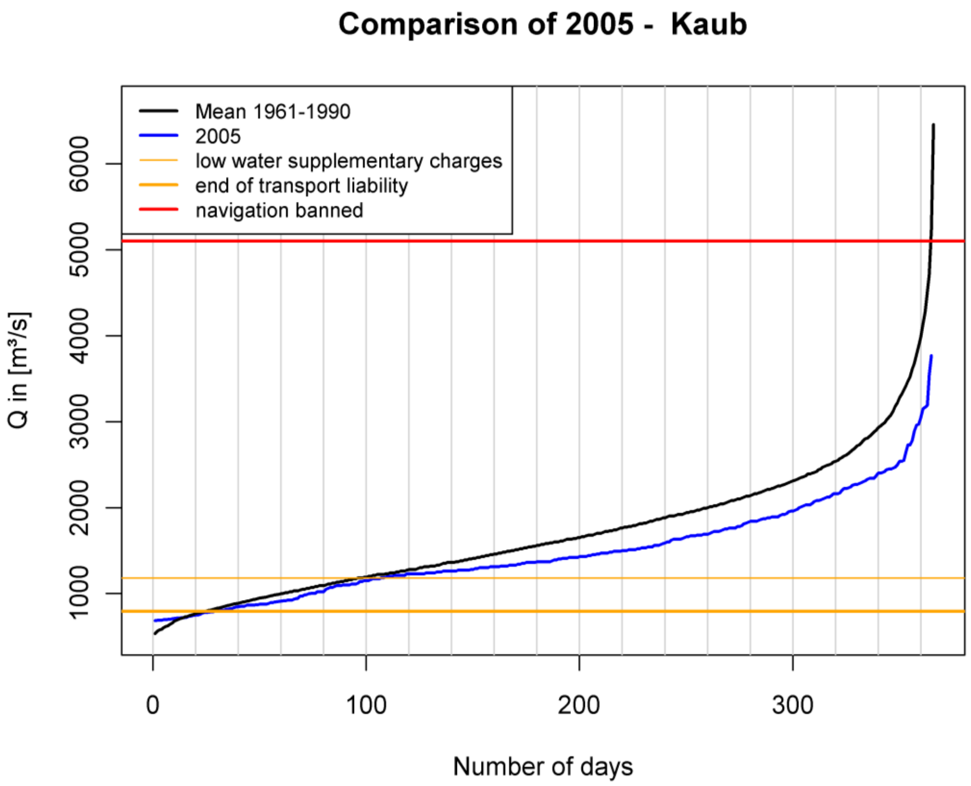

Figure 2.1: Discharge levels at Kaub for 2005

In contrast, 2003 was rather extreme and very dry. The 2003 water level situation has been considered as an example for future summers in the coming decades in climate impact and policy studies (Beniston, 2004). The following figure (2.2) presents the lowest water level per day for the Kaub section (stretch of 26 kilometres in the Rhine) for 2003 and 2005. These levels will be used by decision makers to determine loading capacities.

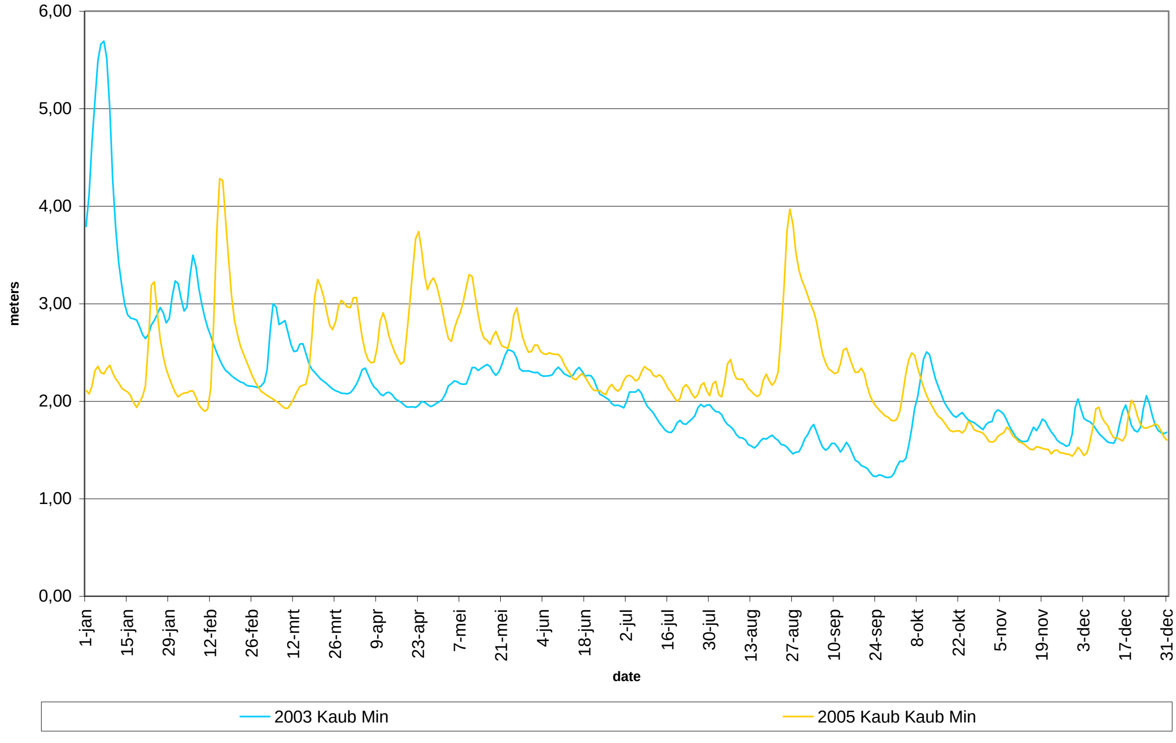

Figure 2.2: Water levels in Kaub (data from BfG, edited by NEA)

Figure 2.2 indicates that differences between years can be considerable. It also indicates that the lowest water level for this section has been below 3 metres for almost every day in 2003. This implies that the largest vessels could not be loaded to their maximum capacity. Moreover, it can also be seen that in the month September the water level was extremely low causing a complete block for most vessel types.

Water level (metres)	**2003**		**2005**	
	Number of days	%	Number of days	%
Over 4m	9	2%	2	1%
Below 4m	356	98%	363	99%
Below 3.5m	354	97%	354	97%
Below 3m	344	94%	324	89%
Below 2.5m	305	84%	263	72%
Below 2m	185	51%	103	28%
Below 1.5m	25	7%	12	3%

Table 2.2: Water levels for 2003 and 2005

Table 2.2 shows that there were much more days in 2003 when the water level was below 2 meters (185 days in 2003 and 103 days in 2005). The share of 51% for 2003 is much higher than 28% for 2005. As a consequence, 2003 had much more days with a low water surcharge which increased transport freight prices. On average in the year 2003 the minimum water level at Kaub was 17 centimetres lower than the year 2005. The question is now what the consequences of a dry year - such as 2003 - are for inland shipping, and what the target should be for adaptation. This information is needed to assess costs and effects.

2.2 Setting the target for adaptation at KAUB

The example situations of 2005 and 2003 are very useful when analysing impacts of adaptation measures to compensate for climate change. Climate change may lead to situations where we have more days with lower water, such as in the year 2003. When taking this 2003 level as a future scenario (just as an example), and compare this with 2005 (considering this as a 'normal' situation) we have the difference in water levels. This difference needs then to be compensated by the impact of the adaptation measures. Note that variation over a year is large, and that adaptation focuses on the days with low water levels.

We could ask the question how much increase of water level would be needed to offset the climate change effects with respect to the increase of transport costs for the cargo passing at Kaub on a yearly basis. This question is not easy to answer. The transport cost function or market price is not linear in relation to the water depth. In particular in cases where larger vessels can not operate anymore (e.g. during August and September 2003 at Kaub), there will be a shortage of vessels resulting in extremely high market prices.

It then comes down to preventing these cases and increase water levels or increase payloads of ships at similar or decreasing water levels. In both cases one can express effects in terms of water levels compensated. When we apply this to the 2003 and 2005 situation, the water level of 2003 needs to be increased with 25 cm to get the same amount of days below 2 metres (103).

If 25 cm of additional draft could be realised, the distribution would then be as in Table 2.3.

	Year 2003	Year 2005	Adapted Year 2003* (+0.25m)
Over 4m	2%	1%	3%
Below 4m	98%	99%	97%
Below 3.5m	97%	97%	96%
Below 3m	94%	89%	88%
Below 2.5m	84%	72%	68%
Below 2m	51%	28%	28%
Below 1.5m	7%	3%	2%

Table 2.3: Adding 25 cm to the water levels in 2003

In this example the 25 cm would be the required impact of an adaption measure in order to offset the impact of climate change. This is an average to compensate also days with very low water levels. Obviously, not all measures can compensate water levels with 25 cm's, or these will become very expansive. But it is a good criterion to be used to compare the effects of adaptation measures. We will elaborate on this below.

3. Approach for evaluation of adaptation measures

Governments and industry may respond and adapt behaviour to mitigate the effects of climate change. For example shippers can increase volume of stock in order to avoid transportation during periods with extreme water levels. Transport service providers can change the fleet (e.g. light weight or more smaller vessels) in order to reduce the draft of the average vessel. Moreover, waterway managers can change infrastructure in order to increase the water levels. Finally water level prediction methods could be improved resulting in more precise loading of the vessel (higher payload, e.g. reducing the safety margins).

It is clear that all measures will be different in nature and have different costs and effects, now and in the future. In order to identify the more efficient measures effects and costs should be evaluated which gives the need for an appropriate evaluation framework. The information on costs and effects of the adaptation measures is likely to be qualitative and quantitative. Therefore ECCONET has developed a multi-criteria type of assessment framework that will be explained below.

Each adaptation measure involves costs and effects. As explained before the primary effect to adapt to climate change aims at compensation in water levels. It was therefore considered crucial to start with a focus of the assessment on costs and water level effects. For each of the adaptation measures we would like to answer the following question:

What is financially needed to compensate (low water or high water) water levels at critical locations in Rhine and Danube with intervals of (for instance) 5 cm?

The difference in cost levels for the compensation of cm's of water levels shows relative efficiency impacts of the various measures. For instance, river engineering measures will involve considerable costs. But the effects in terms of water level compensation (5 or 10 cm?) may also be considerable making the investment relatively effective. This approach easily shows relative efficiency levels of the adaptation measures and may reveal interesting combinations of packages of individual measures. The intention is to collect as much information as possible on the effects (also other effects can occur, such as environmental effects) to allow a cost-effectiveness assessment.

ECCONET has defined some assumptions to structure data collection and analysis. This is needed because of the diversity of measures and the complexity of the analysis.

- The focus is on the effects of adaptation measures on low water levels at critical locations (Kaub and Ruhrort for Rhine, and Pfelling and Wildungsmauer for Danube). However, effective solutions for these locations may be transferable to other river sections;
- Costs data; the comparative analysis needs cost information. Estimations of investment and maintenance costs are needed;
- The feasibility of measures may depend on ownership and responsibility for the investment: is this a private stakeholder or a public institution (government);

- If possible, data needs to be collected for other effects too: transport speed, employment, environment (emissions, water pollution, etc.); this information is relevant for the cost effectiveness assessment when the NODUS model information is available.
- Any other information relevant for the assessment (e.g. legal issues, public acceptance) should also be addressed. This may affect implementation and feasibility of the measures.

For some measures it may be difficult to link adaptation to water level effects. Storekeeping and prediction methods are such measures. In those cases information about impacts and feasibility will be distilled from a literature review and a questionnaire amongst shippers (for the storekeeping measure). In addition, a stakeholder workshop has been organised where the effectiveness of these measures has been discussed to understand the impacts and importance relatively to the other adaptation measures.

4. Assessment results

4.1 Data availability for adaptation measures

Most of the information we present here comes from D2.2.1. That deliverable gives an overview of the identified adaptation measures. It presents the results from a review to identify costs and impacts of the measures according to the framework as outlined in chapter 3. We give a short review of most relevant outcomes.

ECCONET has identified 13 different adaptation measures based on literature review. These measures have been discussed in the workshop with stakeholders, where completeness of the list has been confirmed. Table 4.1 shows that information about cost and effects is only available for a limited number of measures. NODUS requires input on the cost functions to find any effect. This can be a change in water levels (affecting the payload), or changes in other parameters such as vessel weight or draught. The table below suggests that a meaningful analysis with NODUS is only possible for technical measures and infrastructural/maintenance measures.

Category	**Adaptation measure**	**Cost information**	**Impact on water levels**	**Other effects**
Technical and operational changes	Lightweight structures	Yes	Yes	Not available
Technical and operational changes	Adjustable tunnel	Yes	Yes	Not available
Technical and operational changes	Side blisters	Yes	Yes	Not available
Technical and operational changes	Flat hulls	Not available	Not available	Not available
Technical and operational changes	Small instead of large vessels	Not available	Not available	Not available
Technical and operational changes	Continuous operation	Not available	Not available	Not available
Technical and operational changes	Coupled convoys	Not available	Not available	Not available
Technical and operational changes	Strategic alliances between IWT and other modes	Not available	Not available	Not available
Infrastructure investment/maintenance	Maintenance measures	Yes	Indication available (20-30 cm)	Not available
Infrastructure investment/maintenance	River engineering	No	Indication available	Not available
Prediction methods	Prediction methods	Not available	Not available	Not available
Storekeeping/relocation	Storekeeping	Not available	Not available	Not available
Storekeeping/relocation	Relocation of production process	Not available	Not available	Not available

Table 4.1: Overview of adaptation measures and available data (source: D2.2.1)

4.2 Adaptation: a search for promising solutions

We have seen that information about costs and effects is only available for a few measures. This was not sufficient to obtain a proper insight into the feasibility of the measures. Therefore, ECCONET has reviewed additional literature which addresses the assessment of adaptation measures and consulted stakeholders in a workshop to support in our work to identify the more promising and feasible measures. This has been very helpful. The results from this exercise are reported per category of measures.

Technical and operational changes

There is a long-term tendency of economies of scale within inland navigation. This means that the average size of vessels is growing over time. This can be done until certain limits will be reached, which may come from the size of locks, water depths and width of canals. Within the existing limits, technology will focus on ways to increase transport capacities at reasonable costs to make investments feasible (see also Knowledge for Climate, 2011).

Deliverable 2.1.1 and 2.2.1 have identified a list of detailed innovations which can make the fleet and the use of the fleet more efficient. Lightweight structures, adjustable tunnels, side blisters and flat hulls are considered as feasible solutions in the (near) future. It has been possible for the first three of these options to assess costs per cm water level increase. The potential of these measures depends on the level of the investments (which are considerable and to be paid by ship owners), and expectations about the water level problems. However, when analysing costs in more detail also wider effects on maintenance and fuel efficiency should be taken into account.

Although Deliverable 2.1.1 has not explicitly addressed information management, there is scope for ICT systems to make inland shipping more efficient (see also Knowledge for Climate, 2011). This applies to the whole logistics chain (e.g. improved communication between freight transporters and provision of actual traffic information), but also specifically related to low water levels. River information systems may provide better information about particular water levels during a trip. This may even allow them to increase the cargo load and the corresponding draught of the ships. This is related to improved prediction methods which are discussed below. Experts have agreed that about 10 to 30 cm extra navigation depth can be gained if better information in the form of water depth maps is available (Knowledge for Climate, 2011). However, it remains difficult to assess costs of these innovative ICT systems which may be shared between public and private stakeholders. Information management as an adaptation measure is considered feasible (even in the short run), but with uncertain costs and benefits.

Modal shift (away from inland shipping) is not a response where the sector will aim for, and it is not in line with recent transport policies. However, in critical situations cooperation is a solution to waiting and storekeeping. ECCONET has reviewed and assessed this option. It appears that there is a difference between stakeholders. When asking ship owners about the option to transfer goods to rail or road, it is not a feasible solution. Reasons include the lack of capacity available and the involved costs for transhipping certain (bulk) goods. This also appears to be the case when analysing elasticities (which are rather low). However, when asking shippers (see Deliverable 2.1.4) and other stakeholders it appears that other modes are a realistic option and one of the first considered options when inland navigation is not possible or difficult. Most chemical companies along the Rhine are for instance accessible by road.

For smaller vessels with limited low water sensitivity a higher number of operational hours is also a way to improve the performance in low water periods. It is a measure that is relatively easy to implement depending on crew availability and corresponding accommodation. Potential benefits of navigating more hours are in preventing loss of revenues die to restricting load factors. It will lead to more labour costs, and possibly also more fuel costs when extra trips are involved. ECCONET did not assess costs and impacts on water levels in more detail, but a study by Jonkeren et al. 2010 showed a positive cost-benefit result for navigating more hours.

Finally, coupled convoys are a promising way of adaptation (instead of single propelled vessels only). They allow to serve the trend towards the use of larger units (scale effect) without increasing draught. The system of coupled convoys also provides high flexibility.

Infrastructure and maintenance measures

ECCONET has focused the analysis in Deliverable 2.1.2 at maintenance and river engineering possibilities. The construction of large infrastructural works (such as canalisation of the Rhine) is not considered as a feasible solution after a review and discussion with stakeholders. Navigability can more efficiently be improved by implementing technical measures such as maintenance (i.e. dredging) or groynes and training walls. Governments are legally obliged to maintain waterways, and to provide good and safe navigation possibilities. Costs and effects of these measures differ and depend on the length and morphology of the river section and the number of facilities that are needed. Via Donau estimates that about 20 to 30 cm’s of water level can be gained with dredging or river engineering works. Dredging costs amount between €4 and €12 per m^3. Knowledge for Climate (2011) gives a larger range of costs for dredging and assesses the costs for a groyne at €0.3 million. River engineering measures can be taken and dredging can be intensified to increase water levels, which makes this category feasible.

Prediction methods

Reducing uncertainty in the predictions of water levels for longer periods is very useful to both shippers and operators. The rather short term predictions (e.g. until one week) are used to establish the load factors. Longer term predictions (e.g. on seasonal horizon) would be helpful for shippers in their decisions about storekeeping and production planning. A literature review in Deliverable 2.1.3 shows that there is scope for better predictions, but that it is impossible to give an estimation of costs and benefits that fits within the developed framework. However, improved prediction methods are feasible and very much welcomed by the stakeholders.

Storekeeping/relocation

Another adaptation measure that can be taken by shippers/forwarders is to change the storage capacity to survive longer periods without being supplied or released from goods by inland ships. In the long run a relocation might even be considered. It is unclear whether storage capacity is seriously considered as an adaptation measure to low water levels by companies. Extension of capacity is considered within daily businesses and is not linked to water levels and climate change. Empirical work indicates that storage capacity is an alternative, but it is certainly not considered as the most attractive option given the considerable costs involved. Much depends also on circumstances such as type of goods transported and the dependency of firms on inland waterway transport in general.

Storekeeping can be feasible when capacity is readily available. Creating additional capacity becomes less feasible because of costs. We have no assessment of costs and effects. Much depends on the investment in capacity. Relocation of production processes is less feasible and not seriously considered as an alternative to climate change.

5. Conclusions on adaptation strategies

This deliverable presents the results from the task 2.2 work on the assessment of adaptation measures to climate change. ECCONET has developed a framework which focuses on costs of the measures and the impact on water level compensation. This framework has been useful to structure data collection, and will probably still be relevant to support the work on cost-effectiveness analyses in the near future of ECCONET. Unfortunately, it appeared to be very difficult to identify costs and effects in line with the framework, which gave the need to use additional sources of information to identify promising adaptation measures. Finally, we have identified the feasibility of the adaptation measures based on additional literature and a stakeholder consultation.

It seems as if very expensive measures, such as large infrastructural works and relocation of production processes are not feasible. This is caused by the large investment costs, but also by the limited importance that is given to climate change by the stakeholders. The first results of ECCONET suggest that the effects of climate change are rather modest until 2050, which reduces the need for intervention. Accordingly, at present, the inland shipping industry is not very much concerned with the impacts of climate change, and doesn't show much interest in compensating behaviour.

We have also assessed prediction methods, storekeeping, relocation of production processes and cooperation with other modes. The feasibility of these measures very much depends on the decision maker, the urgency of the (climate change/water level) problem and the costs involved. The forwarder/shipper will usually choose the cheapest solution in the short term, which may be waiting or using available storage capacity. Only when problems continue, the shipper will consider other mode which is generally a more costly solution. Forecasting of water levels is considered as a responsibility of the governmental agencies where shippers and ship-owners do not have an impact on. However, improvements are considered very valuable to the sector.

The aim of ECCONET is to assess the impact of adaptation measures and identify the cost-effectiveness for inland navigation. To understand the impacts on the transport sector, the use of a model is needed. ECCONET applies the NODUS model to forecast effects of climate change, but also to assess the impacts of the adaptation measures. This deliverable has shown which measures are promising, and which are less feasible. For only a few feasible measures we have information about the impact on cost functions of ship types. The most feasible measures for which we have information to assess costs and effects, and which can be modelled with NODUS are:

- Maintenance and river engineering measures;
- Improved vessel design.

These measures will be assessed with NODUS in the next steps of the ECCONET project.

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