DELIVERABLE 4.1: LITERATURE REVIEW OF PREVIOUS PROJECTS AND STUDIES ON THE ECONOMIC EFFECTS OF CLIMATE CHANGE ON INLAND WATERWAY TRANSPORT

CONFIDENTIAL

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1. Introduction

This first task of work package 4 task involves preparatory work for the rest of the work package. A review of the available and relevant literature on economic effects of climate change on inland waterway transport allows us to paint a clear picture of the type of output ECCONET can produce and the kind of results that can be expected.

2. Literature on economic effects of climate change on inland waterway transport

2.1 "Climate change and inland waterway transport - welfare effects of low water levels on the river Rhine." (Jonkeren et al., 2007)

This document has been referenced in earlier deliverables of ECCONET. It discusses the effect of climate change on social welfare through inland waterway transport on the Rhine river. The impact chain covers a decrease of water levels at the most critical point (Kaub) and an increase in transport prices (per tonne and per trip) as a result of this.

The effect of low water levels on transport prices was estimated employing a data set which contains information on trips made by inland waterway carriers in North West Europe in the period 2003 until mid-2005 (about 9,000 observations). Second, the change in welfare as a result of the estimated change in transport prices was calculated, using a microeconomic theoretical model. All 152 inland ships that pass Kaub are restricted in their load factor by the water level at this location when the water level is below a threshold level of 260 cm.

It appears from the regression analysis that the transport price per tonne may increase by 74% at extreme low water levels, compared with water levels at which inland ships are not restricted in their load factor. This percentage applies to an inland ship of average size. Estimating an interaction effect between the water level and the ship size shows that, for larger ships, the transport price per tonne increases even more.

The welfare analysis calculates the change in economic surplus as a result of the higher transport prices, assuming a perfectly competitive inland waterway transport market with perfect elastic supply, while demand elasticity was estimated at -0.6. It was found that, in an average year (for the period 1987 – 2004), the annual welfare loss due to low water levels in the Kaub-related Rhine market is equal to €28 million. For the year 2003, which was characterized by a very dry summer and can be seen as a typical year in the most extreme climate scenario, the welfare loss was €91 million. Extending the estimation to the total Rhine market, we find a welfare loss of €227 million.

This estimate is based on the assumptions that: (1) the increase in transport price for trips in the total Rhine market is equal to the increase in transport price for trips in the Kaub market; and (2) the number of days with low water levels per year in the total Rhine market is equal to the number of days with low water levels per year in the Kaub market. So, it is an overestimate. Because it is plausible that dry years like 2003 will happen more often as a result of climate change, annual welfare losses via the inland waterway transport sector are likely to increase.

From the same (co-)author, a few other publications also discuss the effects of climate change on inland waterway networks, but from a different perspective, and less relevant for the purpose of ECCONET. One of them covers the direction of transport flows, where an imbalance in either upstream or downstream flow would create different prices and different reactions to climate change.

2.2 "The economic impact of climate change on Canadian commercial navigation on the Great Lakes" (Millerd, 2005) and "Global Climate Change and Great Lakes International Shipping" (Millerd, 2007)

The two main IWT systems in North America are the Mississippi/Missouri system and the Great Lakes system. The climate conditions expected in the Great Lakes area are similar to those in Rhine/Danube area, so the problems they stand to face in coming decades are alike – the most relevant for ECCONET being the lower water levels during summer in harbours and canals connecting the lakes.

The study described in the 2005 paper covers only traffic within the Great Lakes system, on dedicated vessels. It applied a number of GCMs to form 3 climate change scenarios, with water level changes:

Table 1: Average depth of Great Lakes in relation to climate change

Location	Basis of Comparison Average annual level, metres	Average annual decrease from BOC, metres		
		CCC GCM1	CCCma 2030	CCCma 2050
Lake Superior	183.34	0.23	0.22	0.31
Lakes Michigan and Huron	176.44	1.62	0.72	1.01
Lake Erie	174.18	1.36	0.60	0.83
Lake Ontario	74.84	1.30	0.35	0.53
Montreal Harbour	6.49	1.41	0.45	0.62

Several routes and commodities are considered, but all routes are within the Great Lakes system.

The impact of lower water levels is estimated by computing the operating costs for commercial navigation for the representative year of 2001 and for each of the climate change scenarios.

For each origin-destination-commodity combination, shipping costs depend on the tonnage shipped, from the 2001 transportation data; the number of voyages needed, dependent on vessel capacity; and the time required for each voyage, determined by distance, route, and loading and unloading times. Tonnages shipped and voyage times are given and independent of changes in water levels and depths; vessel capacity varies by water level and depth and is the determining variable. The approach of bottlenecks at harbours, channels, locks and other spots as extra factors limiting load capacity is applied.

The model used in this study gives average cost increases of 16% to 35% depending on the water level scenario.

The 2007 covers international shipping, i.e. from the Great Lakes system to countries other than the USA or Canada. The volume of international shipping is about 1/5 of shipping within the system. About 60% of the international shipping is done directly with ocean-going vessels, the other 40% (mainly grain and agricultural products) are transhipped.

Apart from water level changes, it also discusses ice cover periods and consequences of CC for local flora and fauna (which are not of interest for ECCONET). The setup and base data of the rest of the paper is similar to the previous paper.

The cost increases found in this case were lower, between 5% and 22%. The main reasons for the difference are that ocean-going vessel are usually foreign registered, with lower wages, lower taxes and lower capital costs as a result, and that no transhipment is needed.

The assumptions for both studies imply that these cost increases are probably underestimated, as they do not take into account the empty backhaul, which may increase due to the fact that lower load factors and a fixed transport volume lead to more single runs.

2.3 "Climatic change and Great Lakes levels: The impact on shipping" (Marchand et al., 1986)

This study is a condensed version of the research done in ECCONET, and follows the entire impact chain from CO2 emissions over temperature and hydrology to transport costs in the Great Lakes system. It applies 5 scenarios that differ on their inclusion climate change phenomena and economic growth rates.
This paper provides more insight in the navigation conditions in the system: 8.2 m depth in the main channels above Montreal, 7.9 m draft in the Welland Canal, 0.46 m minimum allowable underkeel clearance in all parts of the system except the Welland Canal as well as the maximum dimensions of the locks and no shipping in any section of the system in January, February or March.

The model to calculate shipping costs is the ILER commercial navigation model. The maximum cost increase that is found is just over 33%.
This study also mentions a few policy options, i.a. increases in dredging and changes to the facilities within the waterway (including ship design and design of locks), but they are not discussed in any detail. An important indication is given about expected behaviour of the sector towards adaptation: *"Variability in water levels and flows are expected and given the number of interests at stake it seems more likely that short term solutions would be advocated until the situation was seen to be persistent. Past and present reactions to water level changes indicate that two or three years may be a sufficient time for this perception to develop."*

2.4 "Climate Impacts on Inland Waterways" (Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, VA, 2005)

This comprehensive study of the waterway manager for the Middle Mississippi river, a 195 mile long stretch between Cairo, Illinois and St. Louis, Missouri, covers the potential impacts of climate change on river transport, including an economic evaluation based on incremental transport costs during periods with restricted navigation. The cargo transported on the river stretch is similar to what is mainly transported on inland waterways: coal and agricultural products.

The study does not make explicit projections on the expected effects of climate change, which may cause either higher or lower flows on the Mississippi river. Both cause problems, the former through an increased risk of flooding, the latter by forcing ships to load less or even halt altogether. In contrast to the European IWW axis, low flows are most likely to occur in fall and winter (Jan, Dec, and Oct), and have been happening less frequently since the 1960's. Low flows in winter can be accompanied by ice formation. Floods are a common problem in the area as well, and occur mainly during spring and in recent years, summer.

Two methods to calculate the economic benefits of inland navigation are presented. The first uses Spatial Equilibrium Models, based on estimated demand and supply curves for all domestic and international commodity markets that are connected by a transportation network. The second is the one actually applied in the study, and calculates the rate savings for individual shipment, assuming perfectly inelastic demand. The rate savings per movement is calculated as the difference in consumer surplus that accrues at the current barge rate and at the rate of the next least costly alternative mode of transportation. Using a Monte Carlo simulation, the losses due to low flow and floods were calculated for two periods in the past: 1933-1968 and 1968-2002 (the total is also added).

Table 2: Simulation of losses in shipper savings, using Monte Carlo analysis over 1933-1968 and 1968-2002

	Period of Record October 1933-September 2002	Dry Half of Record: October 1933 to September 1968	Wet Half of Record: October 1968 to September 2002
Average Number of Months in 50-Year Period Flows below 80,000 cfs	70	114	27
Average Number of Months in 50-Year Period Flows below 70,000 cfs	45	78	15
Average Number of Months in 50-Year Period Flows below 60,000 cfs	26	46	7
Average Number of Months River Closed due to Low Flow	40	69	13
Loss in Shipper Savings due to Low Flow: Net Present Value	$1,411,690,608	$2,397,006,065	$471,525,254
Loss in Shipper Savings due to Low Flow: Annual Equivalent	$77,327,803	$131,300,167	$25,828,614
	Period of Record October 1933-September 2002	Dry Half of Record: October 1933 to September 1968	Wet Half of Record: October 1968 to September 2002
Average Number of Months in 50-Year Period Flows above 800,000 cfs	1.2	0.5	2.1
Average Number of Months in 50-Year Period Flows above 600,000 cfs	6	3	10
Loss in Shipper Savings due to Floods: Net Present Value	$211,497,545	$109,943,240	$325,517,639
Loss in Shipper Savings due to Floods: Annual Equivalent	$11,585,145	$6,022,332	$17,830,794
	Period of Record October 1933-September 2002	Dry Half of Record: October 1933 to September 1968	Wet Half of Record: October 1968 to September 2002
Total Loss in Shipper Savings Net Present Value	$1,623,188,153	$2,506,949,305	$797,042,893
Total Loss in Shipper Savings Annual Equivalent Value	$88,912,948	$137,322,499	$43,659,408

Results based on three GCMs were calculated as well:

Table 3: Simulation of losses in shipper savings, using Monte Carlo analysis over 1933-1968 and 1968-2002 by climate scenario

	Period of Record October 1933-September 2002	BMRC GCM (2.5 C)	UIUC GCM (2.5 C)	HadCM2
Average Number of Months in 50-Year Period Flows below 80,000 cfs	70	98	11	25
Average Number of Months in 50-Year Period Flows below 70,000 cfs	45	63	6	14
Average Number of Months in 50-Year Period Flows below 60,000 cfs	26	36	3	7
Average Number of Months River Closed due to Low Flow	40	56	5	12
Loss in Shipper Savings due to Low Flow: Net Present Value	$1,411,690,608	$2,146,865,196	$173,242,398	$439,109,169
Loss in Shipper Savings due to Low Flow: Annual Equivalent	$77,327,803	$117,598,267	$9,489,653	$24,052,967

	Period of Record October 1933-September 2002	BMRC GCM (2.5 C)	UIUC GCM (2.5 C)	HadCM2
Average Number of Months in 50-Year Period Flows above 800,000 cfs	1.2	0.1	5	4
Average Number of Months in 50-Year Period Flows above 600,000 cfs	6	1	23	15
Loss in Shipper Savings due to Floods: Net Present Value	$211,497,545	$27,448,438	$753,749,662	$484,855,930
Loss in Shipper Savings due to Floods: Annual Equivalent	$11,585,145	$1,503,536	$41,287,946	$26,558,825

	Period of Record October 1933-September 2002	BMRC GCM (2.5 C)	UIUC GCM (2.5 C)	HadCM2
Total Loss in Shipper Savings Net Present Value	$1,623,188,153	$2,174,313,634	$926,992,061	$923,965,098
Total Loss in Shipper Savings Annual Equivalent Value	$88,912,948	$119,101,803	$50,777,599	$50,611,792

Adaptation measures are not a focus of this study, but a few are discussed nonetheless. As losses due to low flows have been higher than losses due to floods, the main adaptation measure has (successfully) attempted to alleviate the low flows. This was achieved by creating upstream water reservoirs that can be tapped during dry periods. Diverting water from the Great Lakes is also seen as a potential solution, but competing demands for water have made this difficult. Dredging has also been a workable solution to better cope with low flow periods.

3. Significance of IWT for the EU27 economy

The modal share of IWT is small, about 5.9% in 2009 according to EUROSTAT. However, the inland waterway network covers only a small share of the territory. In the countries of the Rhine/Meuse basin (Germany, Netherlands, Belgium), the share of IWT in total transport volume (tkm) is at least double that EU average, and up to 35% in the Netherlands. In most of the Danube countries, modal shares are much lower, only about 2-6%. However, in a few of the new members states with access to the Danube, IWT's share has grown significantly the past few years, up to more than 20% in Bulgaria and Romania. With more and more goods becoming containerised, the potential for further expansion of IWT's modal share is high.

4. Important lessons for ECCONET

The impact of changes in water levels on the economy can be split into a direct effect – through transport prices - and an indirect effect – through non-transport logistic costs for shippers, including stock breaks, storage costs, lost production time, etc.

Transport prices directly impact consumer surplus by narrowing the gap between the cheapest/preferred and second cheapest/preferred mode choice (provided other modes do not suffer from the low water caused by climate change). Two of the reviewed papers apply this approach to estimate the impact of climate change on the economy through IWT. The other papers do not calculate total economic losses due to water level variability, but present indications of the cost increases for IWT alone.

Calculating the indirect effects as described above would require information on all companies using inland waterway transport on the Rhine and the Danube, including their transported volumes, the value of the goods they transport (inbound and outbound), the stock size they keep and the modal split they use.
With this kind of information out of reach, the focus of ECCONET will be on the valuation of adaptation measures using the direct approach only. There are then 2 ways to apply this knowledge. The first is to investigate measures which can generate a certain transport volume equal to the volume without climate change, at the lowest possible cost. This would be akin to a cost-effectiveness analysis, where a target is set for transport volume, and the goal is to do this at minimal cost. Another way to assess adaptation measures is a cost-benefit analysis, in which not volume but cost (savings) would be the principal criterion for evaluation. This type of assessment can take two forms again: a full CBA, in which all costs and benefits have to be considered and calculated, or a delimited CBA, in which only cost relevant for the actors, in this case the shipping sector, are retained.