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Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterway transport in the river Rhine area

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ABSTRACT

Future climate change is expected to affect inland waterway transport in most main natural waterways in Europe. For the river Rhine it is expected that, in summer, more and longer periods with low water levels will occur. In periods of low water levels inland waterway vessels have to reduce their load factors and, as a result, transport prices per tonne will increase. One possible consequence of these higher transport prices is a deterioration of the competitive position of inland waterway transport compared with rail and road transport, and thus a change in modal split. We study this issue using a GIS-based software model called NODUS which provides a tool for the detailed analysis of freight transportation over extensive multimodal networks. We assess the effect of low water levels on the costs of transport operations for inland waterway transport in North West Europe under several climate scenarios. It turns out, that the effect on the modal split is limited. Under the most extreme climate scenario, inland waterway transport would lose about 5.4% of the quantity that is currently being transported annually in the part of the European inland waterway transport market considered. The very dry year of 2003 can be seen as an analogue for this scenario.

1. Introduction

During the last decade discussions on climate change and transport were mainly focused on mitigation strategies. The central question was: In which ways can the greenhouse gas emissions of the transport sector be reduced? More recently another element has been added to the discussion on climate change: it is plausible that the climate is changing rather rapidly, and that raises the issue of what adaptations will be called for in the transport sector. In the present paper, we focus in particular on water transport, since here the climate change impacts may be substantial. Some impacts may be positive. For example, the increase of global temperatures may make water transport in the Arctic areas possible and economic viable (Johannessen et al., 2004; Somanathan et al., 2007). However, there are also potential negative effects. In particular, inland waterway transport may experience problems related to higher volatilities in water levels in rivers.

The current study focuses on the potential effects of climate change on modal split in countries where inland waterway transport is an important transport mode. In Europe, this holds true for countries such as Germany and the Netherlands, where the river Rhine is used for the transport of large amounts of bulk products and containers.

An obvious problem with studies on the effects of climate change is that we do not know exactly how the climate will be in the future. A means of dealing with this uncertainty is the construction of climate scenarios. These scenarios are pictures

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Table 1
Values for the steering parameters of the KNMI'06 climate scenarios for 2050 relative to 1990.

Scenario	Global temperature increase in 2050	Change of atmospheric circulation
M	+1 °C	Weak
M+	+1 °C	Strong
W	+2 °C	Weak
W+	+2 °C	Strong

Source: KNMI (2006).
Note: see the text below for an explanation of the notation used in this table.

of what the climate may look like in the future (IPCC, 2001). For the Netherlands, the KNMI (the Royal Dutch Meteorological Institute) has developed climate scenarios which focus on changes for 2050. The main dimensions underlying the scenarios are described in Table 1 (KNMI, 2006).

In these climate scenarios, two main uncertainties are considered: the level of global temperature increase and the extent of change in atmospheric circulation (wind direction). A strong change in circulation induces warmer and moister winter seasons and dryer and warmer summertime situations than a weak change in circulation. The different combinations of global temperature increase and change in circulation result in four scenarios.

The scenario label "M" stands for "Moderate", while "W" stands for "Warm". The '+' indicates that these scenarios include a strong change in atmospheric circulation. The four scenarios form the starting point for our study. Although the climate scenarios have been specifically constructed for the Netherlands, they are based on the outcomes of several international climate models for Western Europe, and thus they also give a good indication of possible climate conditions in the river Rhine area (KNMI, 2006).

The river Rhine is a combined rain–snow river. As a result of climate change, it is expected that the Rhine will be more rain-oriented in the future. More specifically, it is expected that in winter average water levels will be higher and in summer they will be lower, implying more days with load factor restrictions for inland waterway transport (Middelkoop et al., 2000, 2001). The current paper starts with the observation that low water levels occur more often and have more severe impacts on loads than high water levels, so it concentrates only on the consequences of low water levels on the modal split.

A consequence of load factor restrictions for barges is that the costs per tonne transported rise. As the inland waterway transport market can be characterized as a perfectly competitive market, the increase in costs per tonne is assumed to be equal to the increase in price per tonne (Jonkeren et al., 2007). Increased transportation costs for inland waterway transport imply that other modes become more competitive and take over a certain amount of cargo originally transported by barge.

We model the effect of low water levels on modal split using a Geographical Information System- (GIS-)based software model called NODUS which provides a tool for the detailed analysis of freight transportation over extensive multimodal networks. It is built around the systematic use of the concept of "virtual links" which enables the development of a network analysis covering all transport operations by different modes, means and routes, including all interface services in nodal platforms and terminals. Cost functions are attributed to every operation (loading, unloading, moving, waiting and/or transit, transshipping) in the virtual network. It is then possible to minimize the corresponding total cost of freight transportation with respect to the choices of modes, means and routes, with intermodal combinations included in the choice set. Hence, we assess the impact of low water levels on the cost functions for inland waterway transport between combinations of origins and destinations under several climate scenarios.

The area (the set of origins and destinations) under research covers the Kaub-related Rhine market. Kaub is a town situated along the river Rhine (see Fig. 1). We have chosen Kaub as a reference point, because it is here that restrictions related to low water levels are most severe. For the barge trips that pass Kaub, the water level at Kaub is the critical point for the maximum possible load factor and thus also for the costs (or price) per tonne transported. The Kaub-related Rhine market is a geographical market area and is formed by all regions that are the origin or destination of a trip made by barge that passes Kaub. Consequently, all trips made by road and rail between those origins and destinations also belong to the Kaub-related Rhine market.

The purpose of this paper is to gain insight into the effect of climate change on modal split. One effect may be that a loss in quantity transported by inland waterways results in an increase in quantity transported by rail and road, which could possibly lead to higher levels of congestion for these modes. In addition, an increase in CO_2 emissions may be expected because inland waterway transport is a more environmental friendly mode than road transport. These consequences would be highly undesirable from the viewpoint of the European Commission transport policy, which is aimed at reducing the emission of greenhouse gasses and shifting freight from road to rail, inland waterways, and short sea shipping (European Communities, 2006).

2. Modelling freight transport

Freight transport demand models can be classified in a number of different ways. A common classification is the one that distinguishes between aggregate and disaggregate models where the distinction lies in the nature of the data used; in the