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spatial planning

Adaptation

Climate change impacts on inland transport systems

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Summary in Dutch

Kennis over de gevolgen van klimaatverandering op de economie is van groot belang voor nationale en internationale overheden omdat deze gevolgen wel eens verstrekkend van aard kunnen zijn. Een van de sectoren waarvan verwacht wordt dat ze gevoelig is voor klimaatverandering is de transport sector (vracht en passagiers).

Voor wat betreft vrachtvervoer ligt de focus in project A08 op de binnenvaart in noord west Europa. Het is namelijk waarschijnlijk dat klimaatverandering de bevaarbaarheid van de waterwegen zal beïnvloeden. Als gevolg daarvan zullen in perioden met lage waterstanden in de rivieren de transportprijzen voor vervoer over water stijgen en zullen er welvaartsverliezen ontstaan. Transportstromen passen zich vervolgens aan: een deel van de binnenvaartlading verschuift naar andere modaliteiten.

Met betrekking tot het vervoer van passagiers wordt verwacht dat klimaatverandering de vraag naar vervoer (negatief) zal beïnvloeden waarbij het forensen en zakelijk vervoer het minst zullen worden getroffen. Daarnaast beïnvloeden weersomstandigheden de reistijd van het forensenverkeer zowel per auto als met het openbaar vervoer. De hieruit voortkomende welvaartsverliezen kunnen aanzienlijk zijn in de spits in filegevoelige gebieden. Tenslotte wijzen de resultaten erop dat klimaat de modaliteitkeuze voor alle typen reizen beïnvloedt.

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Summary

Knowledge about the implications of climate change on the economy is highly important for national and international governments as these implications may be far reaching. One of the economic sectors that is thought to be sensitive to climate circumstances is the transport sector (freight and passengers).

Regarding freight transport, project A08 focuses on the inland waterway transport sector in North West Europe. It is likely that climate change will affect the navigability of the inland waterways. Consequently, inland waterway transport prices rise in periods with low water levels in rivers, leading to welfare losses. Transport flows seem to adapt to the increase in transport prices by shifting a part of the inland waterway cargo to competing transport modes.

Concerning passenger transport, climate change is expected to strongly affect transport demand, with commuting and business trips being least affected. In addition, weather conditions influence the travel time of commuting trips, both by car and public transport. The resulting welfare costs can be rather substantial during peak hours in congested areas. Last, the results indicate that weather conditions influence mode choice decisions for all kind of trips.

Extended summary

It is widely known that transport systems on the whole perform worse under adverse and extreme weather conditions. However, the empirical evidence on climate change effects on transport and their behavioural consequences is limited. Therefore, project A08, 'Climate change impacts on inland transport systems', develops a fuller view on the effects of climate change on transport making a distinction between freight and passenger transport.

Freight transport

Climate change is likely to affect inland waterway transport through variation in the water level of rivers in North West Europe. Low water levels imply restrictions on the load factor of inland ships, reducing effective supply in the market. Consequently, changes in transport prices are observed. The effect of low water levels on transport prices is estimated by means of OLS. In our study we focus on the river Rhine area. It appears from the regression analysis that the transport price per tonne may increase by 74 per cent at extreme low water levels, compared with a situation 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.

An issue which is also relevant in the light of climate change is the one on imbalances in transport flows. Imbalances affect transport prices differently depending on the direction of transport. So, the strength of the effect of low water levels on transport prices may be sensitive to the transport direction. We therefore analyse the effect of the interaction-effect of imbalances in trade and low water levels on the transport price per tonne. The result shows that the interaction effect is statistically significant. We find that, depending on the origin-destination combination (and thus on the degree of imbalance), the marginal effect of an increase in transport costs on transport prices in the high demand direction can be almost twice as large as in the low demand direction. We may therefore conclude that climate change will make transport by inland navigation from the Netherlands to Germany relatively more expensive than transport from Germany to the Netherlands.

Knowing to what extent transport prices for inland waterway transport rise due to the occurrence of low water levels, a welfare analysis can be carried out. The welfare analysis calculates the change in economic surplus as a result of the higher transport prices applying a microeconomic theoretical model and assuming a perfectly competitive inland waterway transport market with perfect elastic supply. We find that, 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 (W+), the welfare loss for the Rhine market plus the Moselle market, is estimated to lie between € 194 million and € 263 million.

Higher inland waterway transport prices may result in a shift of cargo from inland waterways to other transport modes. Using a strategic network model, called NODUS, we estimate how many tonnes the inland waterway transport market loses because of higher transport costs for shippers as a result of low water levels. NODUS is a Geographical Information System- (GIS-)based software model. It provides a tool for the detailed analysis of freight transportation over extensive multimodal networks. The model shows how annual transport flows in the Rhine market adapt to changes in inland waterway transport prices in a year under the two most extreme climate scenarios compared with the reference scenario which assumes a year under current climate conditions. The results demonstrate that demand for inland waterway transport (measured in tonnes) drops by 5.4 and 2.3 per cent in the most extreme and second-most extreme climate scenarios, respectively. The tonnes that are lost by inland waterways are shifted to road and rail. Concluding, we find that the loss of demand as a result of climate change is limited for the inland waterway transport sector. However, from a transport policy point of view, the reverse modal shift is highly undesirable.

Finally, we assess the effect of the transport price per trip on navigation speed as periods with high inland waterway transport prices may last longer due to climate change. Higher speeds imply a disproportionate increase in fuel consumption, leading to more emissions, which is undesirable from a climate mitigation perspective. The results of our econometric approach show that there exists a small effect of transport prices on navigation speed. A 10 per cent increase in the transport price leads to an increase in navigation speed of 1.7 per cent. Because we find a small effect, the increase in fuel consumption and thus the emission of greenhouse gases as a result of higher transport prices is small. However, as a consequence of an increase in the number of trips by barge of about 10 per cent in periods with low water levels as in 2003, an increase in the emission of greenhouse gases may be expected.

Passenger transport

Mode choice decisions are influenced by many factors, such as travel time, travel costs and socio-economic characteristics etc. Weather may also have its role for mode choice decision. In the Netherlands, over 90 percent of passenger transport is done by three modes of transportation (car, bike and walking), this makes the role of weather more important because, biking and walking are sensitive to weather conditions. Keeping in view the future climate scenarios and expected increase in average temperature plus more extreme weather events, the issue of mode choice becomes more important for the Netherlands. Econometric models were used to estimate the effect of weather on mode choice decisions. The results indicate that mode choice decisions for all kind of trips are influenced by weather conditions. Sports and recreational trips are most sensitive whereas business related trips are hardly affected. Strong wind negatively influences the probability of biking and precipitation reduces the use of bicycle but increase the use of car. In lower temperatures, people switch from biking to car and public transport, whereas people prefer walking and biking as temperatures increase.

Also, we focused on the impact of weather and climate on travel demand. We use the number of trips made by different modes of transportation during a single day as a measure of individual travel demand. In addition, we employed individual daily travel distance as a measure of travel demand. Our results suggest strong effects of weather on transportation demand. Commuting and business trips are least influenced by weather, whereas recreational trips are more sensitive to weather changes.

In transport literature, congestion is an often discussed issue as it leads to delay in travel time. There are many reasons for travel delay and among them weather is one. We consider commuting trips made by car and by public transport and we link those trips with the hourly weather conditions. Next, we investigate how weather conditions influence the travel time of commuting trips made by car and by public transport. We find that travelling through congested areas reduces car speed by about 7 percent. For most car commuters the welfare effects of adverse weather conditions are negative but small. However, the car commuters' welfare costs due to rain are rather substantial during the evening peak in congested areas (and up to 12 percent of the overall commuting costs). Snow, fog, wind and rain have a negative impact on the speed of bus/tram/metro trips.

1. Context

The Royal Netherlands Meteorological Institute (KNMI) predicts that temperature in the Netherlands will continue to rise in the future. Mild winters and hot summers are anticipated to become more common. There may be more extreme precipitation and on average winters may be wetter. Furthermore, the summer will likely have more intense rain with a reduction in the number of rainy days (KNMI, 2006).
It is quite plausible that these expected changes in climate change will affect the functioning of the transport sector. An obvious problem with studying the effects of climate change, however, 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. For the Netherlands, KNMI has developed a set of climate scenarios which focus on changes for 2050. The main dimensions underlying the scenarios are described in Table 1 (KNMI, 2006).

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).

In these climate scenarios, two main uncertainties are considered: the level of global temperature increase and the extent of change of atmospheric circulation (wind direction). A strong change of circulation induces warmer and moister winter seasons and drier and warmer summertime situations than a weak circulation change. The combinations of global temperature increase and change of circulation result in four scenarios. The scenario label "M" stands for "Moderate", while "W" stand for "Warm". The "+" indicates that these scenarios include a strong change of circulation.
Besides the need for mitigating climate change, realization has dawned that certain changes can no longer be prevented. There is a demand for better understanding the possible consequences of climate change for various sectors of the economy. Adaptation policies can then be built around these insights. Project A08 investigates possible effects of climate change for the transport sector, with an emphasis on inland waterway transport and road transport.

2. Goals

The aim of the project is to assess the effect of climate change on behavior of actors in inland transport systems. Damage to physical transport infrastructures due to climate change is not addressed. Within the project two themes are identified: freight transport, with an emphasis on inland waterway transport, and passenger transport. The research objectives are defined below:

1. A survey of climate change impacts on freight and passenger transport.
2. An estimation of the climate change implications for generalized transport costs for inland waterway (freight) transport.
3. An estimation of how a change in inland waterway transport costs results in adaptation of shipper behavior.
4. An estimation of the climate change implications for generalized transport costs for passenger transport.
5. An estimation of how a change in inland waterway transport costs results in adaptation of traveler behavior.

Besides the scientific interest in the various branches of the research in this project, other parties have expressed interest. The research on inland waterway transport may be of interest to the sector itself, the Port of Rotterdam, CBRB, CCNR and to policy makers. In the latter case, it could be relevant for decisions on building new locks and upgrading certain harbours and/or waterways if the demand for transport grows. Research on both themes has attracted the attention of organizations like DVS. This organization is responsible for efficient, safe and sustainable traffic on the roads and waterways. The SWOV (Dutch national road safety research institute) and the Ministry of Transport and Public works (knowledge centre KiM) have shown substantial interest in the research on climate change and passenger transport.

3. Methodology

The project started with a study (Koetse & Rietveld, 2009) describing the current state of the empirical literature on the effects of climate change and weather conditions on the transport sector was being carried out.[1]

At the same time a search for data to be used in empirical models was initiated. Rich data sets on travel behavior of individuals, inland waterway transport trips and cost data for transport were found at the Dutch Central Bureau of Statistics, Vaart.nl and NEA.

Most of the articles and papers produced in project A08 heavily rely on econometric estimation techniques which provide a sound scientific basis. The explanatory models estimated vary from OLS, IV, maximum likelyhood and Multinominal Logit to random effects models. In addition, Jonkeren et al. (2009) apply a strategic transport network model to assess the effects of climate change on mode choice for freight transport.

1 Koetse & Rietveld (2009) was the 'most downloaded' article in 2009 in the journal in which it appeared.

4. Synthesis

It is widely known that transport systems on the whole perform worse under adverse and extreme weather conditions. This is especially true in densely populated regions, such as many coastal areas around the globe, where one single event may lead to a chain of reactions that influence large parts of the transport system. Koetse and Rietveld (2009) provide a survey of the empirical literature on the effects of climate change on transport. An important finding of this study is that many of the effects are ambiguous, both in terms of the direction and the magnitude of the relationship. This is partly due to the fact that findings from different studies are contradictory and/or inconclusive, but most of the ambiguity is caused by the variation in the effects of climate change on future weather conditions.

With respect to road transport most studies focus on traffic safety and congestion. Precipitation is by far the most important weather variable for traffic safety. Most studies find that precipitation increases accident frequency, but decreases accident severity. The mediating effect in here is that it is likely that precipitation reduces traffic speed, thereby reducing the severity of an accident when it occurs. Furthermore, most studies show a reduction in traffic speed due to precipitation and especially snow. Interestingly, the effect is particularly large during peak hours and on congested roads. The few existing insights for rail transport show that high temperatures, icing, and strong winds, among others, may cause considerable delays. For the aviation sector, wind speeds, wind direction and visibility have clear effects on safety and delays and cancellations. This has large cost implications, both for airlines and travellers. However, climate change consequences for wind speeds and especially for wind directions and mist, fog and visibility, are highly uncertain. Finally, changes in temperature and precipitation have consequences for water levels in the river Rhine. Low water levels will force inland waterway vessels to use only part of their maximum capacity, which may considerably increase transportation costs in the future.

It is clear that changes in weather conditions due to climate change will affect the competitive positions of the different transport modes, both within passenger and freight transport.[2] As already mentioned, however, the net impact for most transport modes is ambiguous and very much region-specific. We observe opposing effects, e.g., with respect to traffic safety and congestion in road transport and infrastructure disruptions in rail transport, the magnitudes of which are largely unknown. Finally, the large majority of the studies on the impact of climate and weather focus on instantaneous or short term impacts. Less attention is paid to impacts at the seasonal level or long run effects by comparing regions that operate under different climate conditions. Overall, the empirical evidence reviewed in Koetse and Rietveld (2009) on climate change effects on transport and their behavioural consequences is limited. Therefore, more research into these directions is necessary to develop a fuller view on the effects of climate change on transport. Project A08, 'Climate change impacts on inland transport systems', contributes to this view.

In the remainder of this chapter a distinction will be made between the topics 'freight transport' (research objectives 2 and 3) and 'passenger transport' (research objectives 4 and 5).

4.1 Climate change and freight transport

Inland waterway transport

Inland waterway transport has received little attention in the scientific literature. However, in countries like the Netherlands, Belgium and Germany, this mode has a substantial share in the modal split (33, 16, and 12 per cent respectively). The most important waterway in Europe is the

2 Note that this also applies to competition between regions when negative effects of climate change differ across regions.

river Rhine on which 63 per cent of all inland waterway transport in Europe takes place.[3] It is a sector in which many carriers are operating who offer a relatively homogenous product, illustrating that the inland waterway transport market shows characteristics of a perfectly competitive market (Jonkeren, 2009).

All econometric analyses for the theme 'freight transport' are performed with a dataset called the 'Vaart!Vrachtindicator' which contains detailed information about trips made by inland waterway carriers in North West Europe (more information can be found on the website www.vaart.nl). The carriers report information (via the Internet) about their trips, such as the transport price, region and date of (un)loading, capacity of the ship, number of tonnes transported and type of cargo. The database contains about 22.000 observations of inland waterway trips in North West Europe, reported between January 2003 and January 2007. The data set contains information on inland waterway transport enterprises that operate in the spot market where the price per ton, and the number of tons transported are negotiated for each trip. Inland waterway transport enterprises that operate in the long-term market (and work under contract) and receive a fixed price per ton throughout the year are not included in the dataset. But also here we know that the contracts between shippers and carriers include clauses on higher prices when water levels are low. We do not consider costs of delays due to low water since these tend to be limited.

Climate change and costs of inland waterway transport

We start describing the results with regard to research objective no. 2. It is concluded in several hydrological studies that climate change will lead to lower water levels and longer periods with low water levels in rivers in Europe in future summers.[4] This is likely to affect inland waterway transport. Low water levels imply restrictions on the load factor of inland ships, reducing effective supply in the market. Consequently, changes in transport prices are observed. The effect of low water levels on transport prices is estimated by means of OLS using a log-linear specification which also includes dummy variables, in order to address non-linearity's. We focus on the part of the Rhine market that is most strongly affected by low water levels, the Kaub market. Kaub is a town located on the East bank of the Rhine. All 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. A map indicating the location of Kaub can be found below, in Figure 1.

3 In the EU27, the mode share (measured in ton-kilometers) of inland waterways for freight transport was about 6% in 2008.

4 The effect of climate change on the frequency of occurrence of high water levels is not addressed.

Figure 1.
Inland waterways in the river Rhine area.

It appears from the regression analysis that the transport price per tonne may increase by 74 per cent at extreme low water levels (< 180 cm water depth at Kaub), compared with a situation 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 (Jonkeren et al. 2007a; 2007b).

Imbalances in transport flows

An issue which is also relevant in the light of climate change is the one on imbalances in transport flows (between the Netherlands and Germany).[5] Imbalances affect transport prices differently depending on the direction of transport. So, the strength of the effect of low water levels on transport prices may be sensitive to the transport direction, as will be shown later on.

5 This issue is known as the 'back-haul problem' in the economic literature.

Starting with an analysis of the impact of an imbalance in transport flows on the transport price per tonne (using a log-linear specification), it turns out that the former plays a prominent role in the determination of the latter. We find that a 1 standard deviation increase in the imbalance measure from its mean value decreases the transport price by about 8 per cent (Jonkeren et al. 2010).[6]
As the physical flow of goods by inland waterways from regions along the North Sea coast (where seaports like Rotterdam and Antwerp are located) to regions in the hinterland is substantially larger than in the opposite direction, unit transport prices from the coast regions to the hinterland regions are substantially higher than the other way round (Jonkeren et al. 2010). This empirical finding is in line with the theoretical finding of Demirel et al. (2010a).
We now analyse the effect of the interaction-effect of imbalances in transport flows and low water levels on the transport price per tonne. We include only those trips in the analysis that pass at least one out of the three locations where the water level is measured: Duisburg, Koblenz or Kaub. The locations of these towns are shown in Figure 1. The results show that the three interaction effects (one for every location) are statistically equal to each other. Therefore, we also estimate a specification in which we do not allow the effects to be location-specific. With this specification it is more straightforward to interpret the results. We find a marginal effect of the water level which is equal to a 0.63 per cent increase in the transport price for the mean imbalance value when the water level drops by 1 centimeter, conditional on the fact that the water level is below the threshold value. We also find that, depending on the origin-destination combination (and thus on the degree of imbalance), the marginal effect of an increase in transport costs on transport prices in the high demand direction can be almost twice as large as in the low demand direction (Jonkeren et al. 20xxa). We compare these findings with the theoretical evidence from Demirel et al. (2010b). They show a similar result: the effect of decreases in water levels is increased when trips take place on the 'high demand direction for transport'. The effect is due to the combination of low water levels and the size of the transport imbalances. From both theoretical and empirical perspectives, we may therefore conclude that climate change will make transport by inland navigation from the Netherlands to Germany relatively more expensive than transport from Germany to the Netherlands. This may affect policy-related issues, such as infrastructural decisions on canalization, dredging, and the construction of barrages. As, under climate change, importing firms in Germany are faced with relatively higher freight prices than firms importing from Germany, Germany can be considered to benefit most from infrastructural investments to combat climate change. This result is important for discussions on optimal adaptation strategies. A difficult point may be that most of the transport on the Rhine takes place by Dutch barge operators. This might reduce political support for infrastructure measures in Germany (for the German part of the Rhine) even though the main beneficiaries of adaptive measures in the German part of the Rhine would be German consumers.[7]
These results underline the relevance of distributional issues in this domain of adaptation to climate change.

Welfare effects

Knowing to what extent transport prices for inland waterway transport rise due to the occurrence of low water levels, a welfare analysis can be carried out. The welfare analysis calculates the change in economic surplus as a result of the higher transport prices applying a microeconomic theoretical model and assuming a perfectly competitive inland waterway transport market with perfect elastic supply. We find 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

6 We refer to Jonkeren et al. 2010 for a detailed explanation of the imbalance measure.
7 The point is that in a competitive market the final consumer ultimately carries the complete burden of the cost increase. This is unavoidable since otherwise the carriers would go bankrupt.

climate scenario (W+), the welfare loss was € 91 million (Jonkeren et al. 2007a; 2007b).[8] Extending the estimation for the same year (and climate scenario) to the total Rhine market plus the Moselle market, the welfare loss is estimated to lie between € 194 million and € 263 million.[9] 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.

Modal shift consequences of climate change; freight transport

Referring to research objective number 3, we examined, together with our Belgian partner FUCaM, to what extent the estimated higher inland waterway transport prices result in a shift of cargo to other transport modes. Using a strategic network model, called NODUS, we estimate how many tonnes the Kaub-related inland waterway transport market loses because of higher transport costs for shippers as a result of low water levels. NODUS is a Geographical Information System- (GIS-) based software model. It provides a tool for the detailed analysis of freight transportation over extensive multimodal networks, and 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, mode types 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, transhipping) in the virtual network. It is then possible to minimize the corresponding total costs of freight transportation with respect to the choices of modes, means and routes, with intermodal combinations included in the choice set. The model shows how annual transport flows in the Kaub-related Rhine market adapt in a year under the two most extreme climate scenarios compared with the reference scenario which assumes a year under current climate conditions. The results demonstrate that demand for inland waterway transport (measured in tonnes) drops by 5.4 and 2.3 per cent in the most extreme (W+) and second-most extreme (G+) climate scenarios, respectively (Jonkeren et al. 2009). The loss of demand is negligible in climate scenarios G and W. The tonnes that are lost by inland waterways are shifted to road and rail. So, as a result of climate change, the shifted tonnes are transported over shorter distances, but by making use of more vehicles. Because the emission per truck or train tonne-kilometre is higher than per barge tonne-kilometre, the total annual CO_2 emissions in the total Kaub-related transport market increase by 1.1 per cent in the most extreme climate scenario. Concluding, we find that the loss of demand as a result of climate change is limited for the inland waterway transport sector. However, from a transport policy point of view, and from an environmental perspective, the reverse modal shift and the increase in CO_2 emissions are highly undesirable (Jonkeren et al. 2009).

Climate change and transportation speed

Finally, and also contributing to research objective 3, we assess the effect of the transport price per trip on navigation speed (a change in behavior of the carrier) in the light of climate change.[10] In the maritime transport sector, it is observed that the sea cargo fleet increases navigation speed in periods with high transport prices. As those periods are likely to occur more often in the inland waterway transport sector in North West Europe because of climate change, it is interesting to determine whether the above- mentioned phenomenon in the maritime sector is also present in the inland waterway transport sector. Higher speeds imply a disproportionate increase in fuel consumption, leading to more emissions, which is undesirable from a climate mitigation perspective. We construct an econometric model taking into account the endogeneity of the transport price variable. The results show that there exists a small effect of transport prices on navigation speed. A 10 per cent increase in the transport price leads to an increase in navigation speed of 1.7 per cent

8 The loss is about 14 per cent of total annual turnover in the Kaub-related inland waterway transport sector. An overview of the four climate scenarios can be found in Table 1.1.

9 The Moselle is a tributary of the Rhine.

10 Navigation speed is defined as the number of kilometers navigated per day.

(Jonkeren et al. 20xxb). Note that this effect applies less to the contract market where prices are less volatile. Because we find a small effect, the increase in fuel consumption and thus the emission of greenhouse gases as a result of higher transport prices is small. However, as a consequence of an increase in the number of trips by barge of about 10 per cent in periods with low water levels as in 2003, an increase in the emission of greenhouse gases may be expected.

4.2 Climate change and passenger transport

Historically, most of the research work related to passenger transport and climate change focuses on the effect of transport on climate change rather than the other way round. The research work done on the effect of weather and climate on transport mostly focuses on safety issues thus ignoring many important aspect of weather and climate and passenger transport. The main objective of this project is to focus on all such ignored issues of literature and provide some deeper in-depth analysis to impact of weather and climate change on passenger transport with special focus on the Netherlands. In this respect, a number of studies have been carried out, which are briefly explained below.

Climate change and mode choice decision

Choice of transport mode is an important issue in transport planning. It affects the general efficiency of travel and the space devoted to transport functions. Mode choice decisions are influenced by many factors, such as travel time, travel costs and socio-economic characteristics etc. Weather may have also its role for mode choice decision. In Netherlands, over 90 percent of passenger transport is done by three modes of transportation (car, bike and walking). This makes the role of weather more important because, biking and walking are sensitive to weather conditions. Keeping in view the future climate scenarios and expected increase in average temperature plus more extreme weather events, the issue of mode choice becomes more important for the Netherlands.

We used OVG/MON[11] transportation survey of CBS for 10 years period starting from 1996 till 2010. This survey provides information about travel behaviour during a certain day and important household and individual characteristics of individuals from different municipalities in the Netherlands. Weather data were obtained from KNMI. It contains weather conditions measured on hourly basis by 32 weather stations spread all over the Netherlands. The average distance to a weather station is about 12 to 13 km, which means that our measurement of weather conditions is very local. We linked the two weather data in such a way that each traveller was assigned the weather data from the weather station which was nearest to his place of departure and for the same hour and day during which the trip was made. Multinomial logit models were used to estimate the models for different trip purposes and for over all mode choice decision.

The results indicate that mode choice decisions for all kind of trips are influenced by weather conditions. Sports and recreational trips are most sensitive whereas business related trips are hardly affected. Strong wind negatively influences the probability of biking; precipitation reduces the use of bicycle but increase the use of car. In lower temperatures, people switch from biking to car and public transport, whereas people prefer walking and biking as temperatures increase. The intensity of substitution between biking and car trips during varying temperatures depends on trip purpose. It must be noted that, because the analyses are based on past data, the effects of future (technological) developments, like electrical bikes and changes in costs for car driving for example, have not been taken into account.

11 Onderzoek verplaatsingsgedrag, mobiliteitsonderzoek Nederland.

Climate change and passenger travel demand

Travel demand is a derived demand and it can therefore be altered directly, or indirectly, by a large number of factors including price of transportation, fuel prices, taxes and weather. Therefore, in this particular analysis we focused on the impact of weather and climate on individual travel demand, also addressing non-linear relations. We used the same OVG travel survey as mentioned above. Weather data was obtained from KNMI for same period. We use the number of trips made by different modes of transportation during a single day as a measure of individual travel demand. In addition, we used an alternative measure employing individual daily travel distance as a measure of travel demand. Different analyses were performed for different types of trips and for different modes of transportation.

Our results suggest strong effects of weather on transportation demand and strong substitution of travel modes at extreme temperatures. Precipitation enhances the modal shift from bicycle to public transport and car. Commuting and business trips are least influenced by weather, whereas recreational trips are more sensitive to weather changes. Other trip purposes assume an intermediate position. These results are intuitively appealing since commuting and business trips have a strong necessity and cannot easily be skipped or delayed, as opposed to recreational trips.

These studies (Sabir et al 2010a,b) imply that mode choice and travel demand are influenced by weather conditions and future climate changes may have even stronger effects. However, since people still use the bicycle, even under higher temperature ranges (temperature greater than 25° C), there will remain a considerable share of biking trips in total modal share during short-run (say 50-80 years). In the long-run, when there will be more frequent higher temperatures (such as above 30° C), people may switch to other modes of transportation from biking, which will have major implications for transport planning in the Netherlands. Additional roads will be required and also revision of investment done in paths/routes specifically constructed for bikes. In addition, the share of public transport in total modal share will increase which implies provision of extra (more extensive) supply of public transport along with modern air-conditioning system in urban transport.

Climate change and destination choice

Leisure activities are strongly affected by weather. For example, a nice sunny day may bring thousands of people to the beach, while a weather warning may restrict everyone to their houses. The importance of weather increases more with increasing knowledge about the weather forecasts and climate change. Climate change may change the weather of some countries considerably. In countries such as the Netherlands, summers are anticipated to be longer and warmer. This may increase the demand for domestic leisure trips and destinations.

This particular study (Sabir et al. 2010c) considers the impacts of weather conditions on beach trip choice and mode choice simultaneously. The paper considers leisure trips made by Dutch traveller during summer in a period of 10-years (1996 to 2005) and use hourly and locally measured weather conditions. The novelty of the study is that it combines distance of a trip along with destination choice and mode choice decisions in a standard discrete choice model. The results indicate that weather influences beach travel (the number of trip to the beach within a certain time period) and mode choice, in particular cycling. Wind and precipitation have a negative influence on beach travel, whereas higher temperatures encourage going to the beach for leisure activities[12]. We also find that the decision whether to travel to the beach or not and the mode choice decision are independent decisions. As expected, beach travel falls with distance to the beach and income and is higher during weekends.

12 We did not study interaction effects between the two.

Climate changes and cost of travel delays

In transport literature congestion is an often discussed issue as it leads to delay in travel time. There are many reasons for travel delay. Among them, weather is one. In these particular studies (Sabir et al 2010 d; e) we consider commuting trips made by car and by public transport and we link those trips with the hourly weather conditions. The idea is to investigate how weather conditions influence the travel time of commuting trips made by car and by public transport. Since commuters are making two trips per day, we were able to use panel data approach to estimate our models.

We find that travelling through congested areas reduces car speed by about 7 percent. For most car commuters the welfare effects of adverse weather conditions are negative but small. However, the car commuters' welfare costs due to rain are rather substantial during the evening peak in congested areas (and up to 12 percent of the overall commuting costs). Snow, fog, wind and rain indeed have an impact on the speed of bus/tram/metro trips. Part of the explanation is that the speed of these vehicles themselves will be affected, implying increases in in-vehicle time. Another part of the explanation is that adverse weather leads to longer waiting times at platforms, in particular when people miss a connection, and leads to longer access and egress times. At temperatures below 0° C train trips are 4 percent faster than train trips made at temperatures between 0° C and 25° C. Similarly, train commuting trips made during temperatures higher than 25° C are 4 percent slower compared to normal temperatures. Note that trip speeds are computed on the basis of the sum of in-vehicle time and other time components, including waiting times, delays, access and egress times to get to the station by foot, bicycle, bus, car, etc. A likely explanation is therefore that people may prefer to walk or bike rather than use public transport to go to or from a train station. Another reason may be that demand for train trips is lower in cold weather, which may result in a smaller number of people on access points, implying lower probabilities of delays. The highest welfare loss due to adverse weather is observed for bus, tram and metro trips. The welfare loss for these trips due to snow is € 0.76 per commuting trip per person.

Similarly, bus, tram and metro commuting trips made in rainy conditions and on congested routes experience a welfare loss of € 1.78[13] per commuting trip per person. Furthermore, the welfare loss due to limited visibility is around € 0.38 per commuting trip per person. The highest welfare loss for train trips is that of snow, which leads to a loss of € 0.50 per commuting trip per person[14]. Additionally, train trips made during high temperatures experience a loss of € 0.40 per commuting trip per person.

5. Conclusions and recommendations

Project A08 provides several innovative insights with respect to climate change effects on inland transport, thereby making a distinction between freight transport and passenger transport. Before the start of project A08 the number of scientific studies on climate change and inland water transport was very limited. Project A08 therefore clearly fills a gap. Also from the viewpoint of substance the project may claim novelty, in particular the analysis of the linkages between transport flow imbalances, water levels and transport prices is innovative, and it provides an excellent empirical illustration of the novel theme of endogenous trade costs.

13 These figures relate to 2005.
14 As indicated above temperatures below zero degrees as such do not negatively affect speed of railway trips, but when there is snow the effects are considerable.

It was shown that low water levels strongly affect prices for freight transport by inland waterways, the effect being stronger for large ships than for small ships. In addition, it appeared that the strength of the effect is sensitive for the transport direction: in the direction in which demand for transport is high, the effect is stronger. Climate change will therefore make transport by inland waterways from the Netherlands to Germany more expensive than transport the other way around. The higher transport prices imply the existence of a welfare loss which is estimated to lie between € 194 and € 263 million for the Rhine market in the W+ KNMI climate scenario, for which the year 2003 is said to be a representative year. With regard to adaptation it was demonstrated that as a result of the higher transport prices for inland waterway transport about 5% of its cargo is shifted to competing transport modes on an annual basis. In addition, in periods with low water levels the number of inland waterway trips increases by about 10% because ships must navigate with low load factors.

Passengers adapt their mode choice decisions for different trip types to changing weather conditions. Sports and recreational trips are most sensitive whereas business trips are hardly affected. The same pattern can be observed when it concerns the demand for passenger transport: commuting and business trips hardly react to changes in weather while recreational trips do. With regard to travel delays, weather conditions influence the travel time of commuting trips made by car and by public transport. For car commuters, the welfare costs due to rain during the evening peak in congested areas are rather substantial. Snow, fog, wind and rain negatively affect the speed of public transport trips and the highest welfare loss due to adverse weather is observed for this type of trips. Knowing that climate change also involves a more frequent occurrence of adverse weather, the annual welfare loss is expected to increase in the future.

This project has provided detailed insight into adaptive behavior of actors in the transport sector. Further research on physical adaptation measures (for example: barrages in the Rhine) is also recommended. In addition, for policy makers, it is recommended to take into account the estimated welfare losses when deciding on whether to invest in those physical adaptation measures.

6. References

Demirel, E., J. van Ommeren & P. Rietveld 2010a. A matching model for the backhaul problem, Transportation Research Part B, 44, 549-561.

Demirel, E., J. van Ommeren & P. Rietveld 2010b. Climate change and inland navigation between the Netherlands and Germany: An economic analysis, in P. Martens and C. Chang (eds). The Social and Behavioural Aspects of Climate Change: Linking Vulnerability, Adaptation and Mitigation, Greenleaf Publishing, Sheffield, pp. xx-xx.

Jonkeren, O., P. Rietveld & J. van Ommeren 2007a. Climate change and inland waterway transport; welfare effects of low water levels on the river Rhine, Journal of Transport Economics and Policy, 41 (3), 387-411.

Jonkeren, O., P. Rietveld & J. van Ommeren 2007. Klimaatverandering en binnenvaart, ESB, 92 (4518), 558-559.

Jonkeren, O., B. Jourquin, P. Rietveld 2009. 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, Transportation Research Part A, doi: 10.1016/j.tra.2009.01.004.

Jonkeren, O., E. Demirel, J. van Ommeren & P. Rietveld 2010. Endogenous transport prices and trade imbalances. Journal of Economic Geography, 11 (3), 509-527.

Jonkeren, O.E. 2009. Adaptation to Climate Change in Inland Waterway Transport. Thela Thesis. Vrije Universiteit, Amsterdam.

Jonkeren, O., J. van Ommeren & P. Rietveld 20xxa. Trade flows and the determination of freight prices, under review at Canadian Journal of Economics.

Jonkeren, O., J. van Ommeren & P. Rietveld 20xxb. Freight prices, fuel prices and speed, under review at Journal of Transport Economics and Policy.

Koetse, M.J & P. Rietveld 2009. The impact of climate change and weather on transport: An overview of empirical findings. Transportation Research Part D, 14, 205-221.

Sabir, M., P. Rietveld., M. Koetse and J. Van Ommeren 2010a. The Impact of Weather Conditions on Mode Choice. Under review at Climatic Change.

Sabir, M., J. Van Ommeren., M. Koetse and P. Rietveld. 2010b. Impact of weather on daily travel demand, Working Paper.

Sabir, M., P. Rietveld. M. Koetse and J. Van Ommeren., 2010c. Weather to Travel to the Beach. Working Paper.

Sabir, M., J. Van Ommeren., M. Koetse and P. Rietveld. 2010d. Adverse Weather and Commuting Speed, Network and Spatial Economics, DOI 10.1007/s11067-010-9130-y

Sabir, M., J. Van Ommeren., M. Koetse and P. Rietveld. 2010e. Weather and travel time of public transport trips: an empirical study for the Netherlands. Integrated transport: from policy to practice, editors Moshe Givoni and David Banister. Routledge Publisher, pp. 275-288.

Climate changes Spatial Planning

Climate change is one of the major environmental issues of this century. The Netherlands are expected to face climate change impacts on all land- and water related sectors. Therefore water management and spatial planning have to take climate change into account. The research programme 'Climate changes Spatial Planning', that ran from 2004 to 2011, aimed to create applied knowledge to support society to take the right decisions and measures to reduce the adverse impacts of climate change. It focused on enhancing joint learning between scientists and practitioners in the fields of spatial planning, nature, agriculture, and water- and flood risk management. Under the programme five themes were developed: climate scenarios; mitigation; adaptation; integration and communication. Of all scientific research projects synthesis reports were produced. This report is part of the Adaptation series.

Adaptation

Dutch climate research uses a 'climate proofing' approach for adaptation. Climate proofing does not mean reducing climate based risks to zero; that would be an unrealistic goal for any country. The idea is to use a combination of infrastructural, institutional, social and financial adaptation strategies to reduce risk and optimalise opportunities for large scale innovations. Climate changes Spatial Planning realised projects in a multidisciplinary network that jointly assessed impacts and developed adaptation strategies and measures. The following themes were central to the programme: water safety, extreme precipitation, nature and biodiversity, agriculture, urban areas, transport (inland and road transport) and the North Sea ecosystem. In special projects, the so called hotspots, location-specific measures were developed that focused on combining 'blue', 'green' and 'red' functions.

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