Socio-economic effects of climate change on mainports and on urban infrastructure networks

Work package leader: prof.dr. P. Rietveld, VU Amsterdam

Content

1 Description work package

1.1 Problem definition, aim and central research questions

Problem definition

WP1 determines which infrastructure networks are affected most by climate change. Next, the impact of climate change on the physical infrastructure (WP2), on the functioning and on the use of those infrastructures (WP3) is modeled. WP4 will study the socio-economic consequences of those impacts on several geographical levels: local (city, mainport), regional (city, mainport + surrounding region) and Randstad. Economic information on the impact of climate variability and extremes is of great relevance for policy makers on the local, regional and national level. The point is that policy makers want to avoid both overshooting and undershooting in their adaptation policies. For this purpose it is not only important to know the costs of adaptive measures, but also the benefits. The main problem addressed in this WP is a lack of knowledge on the size of the damages that may occur as a result of the impact of climate change on infrastructures. Our analysis concerns a monetization of the impacts of climate change on the physical networks (transport and electricity) and on the reliability and usability of these networks, given uncertain futures, using information from WP's 1-3 and external sources like the adjacent projects mentioned in part 6C of the proposal. In addition, further economic impacts on transport and electricity network related industries will be addressed.

Aim

Based on present research questions formulated by the hotspots we foresee analysis of socioeconomic effects in three separate projects. A fourth project is set up to coordinate the research in this WP. In the first project we will assess the economic impact of changes in reliability and usability of land side transport infrastructures in the hotspot regions due to climate change. This also includes studying the costs associated with changes in behavior of decision making actors (passengers, freight forwarders, shippers). The project entails analysis of revealed preference data on those changes in reliability/ usability and behavior. Survey-based stated preference data and network economic loss analysis to assess the impact on the broader economy will complete the project.
A second project will focus on changes in reliability and usability of electricity infrastructure in the hotspot regions due to climate change. This entails the theme of how firms and residents will react to changes in the quality of this infrastructure service. Similar research approaches as in the first project will be used.
The third project will study flexibility oriented adaptation approaches. Given various long run uncertainties, adaptation strategies involve taking preventive measures to increase flexibility of infrastructure; an example being spatial reservations for zoning schemes around the Schiphol airport to cope with future uncertainty on wind directions.

Research questions

What are the socio-economic effects of climate change via changes in the reliability and usability of transport and electricity infrastructures and via the physical infrastructure in the hotspot regions and what are potential flexibility oriented adaptation approaches?

1.2 Interdisciplinarity and coherence between the projects

The projects within this WP are strongly coherent. The common basis consists of economic concepts of costs and benefits of adaptation measures and the associated methods: stated preference and revealed preference research and network economic loss analysis. Coherence will also be achieved by using the same research approach to various types of infrastructure and networks (various transport modes and electricity). Where possible, cross fertilization will take place so that the analysis in one network domain can benefit from specific concepts and methods that have been developed in other network domains.

Within this WP the focus is on economic aspects of adaptation strategies. The interdisciplinary aspects can be found in the linkages with WP1-3 and 4. It is essential that the analysis in this WP is linked to research on the physical aspects of climate change and associated damages, carried out in these WP's, because only on the basis of this information, economics can contribute in a meaningful way.

1.3 Stakeholders

The research projects outlined below will be applied to cases that are relevant for the following stakeholders:

- Port of Rotterdam
- Municipality of Rotterdam
- Schiphol Airport
- Province of Noord-Holland
- Ministry of Transport and Water Management
- ProRail

The evaluation of the reliability and usability of land side infrastructures (transport and electricity) is relevant for all stakeholders but particularly interesting for the Port of Rotterdam, the municipality of Rotterdam and Schiphol Airport as the reliability and usability of those infrastructures have a direct impact on the functioning of the (air)port and city (projects 1 and 2).

The Port of Rotterdam showed special interest in the effects of placing locks in the seaport waterways (project 3) and the Ministry of Transport and Water Management on the spatial reservation of land around Schiphol issue (project 3). Finally, ProRail is eager to know when and how much to invest in rail infrastructure in order to make the network more robust to climate change (project 3).

2 Project 4.1 Socio-economic effects of changes in reliability/usability of land based transport infrastructure in the hotspot regions due to climate change

Project leader: prof.dr. P. Rietveld, VU Amsterdam

2.1 Problem definition, aim and central research questions

Problem definition

The Schiphol and Rotterdam hotspot regions can be characterized as regions with a high level of economic activity and with high density transport networks for roads, railways and inland waterways. The pressure on the road and railway networks is high, often leading to congestion, which deteriorates the landside accessibility of the mainports, the Port of Rotterdam and Schiphol Airport.

Climate change (temperature and sea level rise, but also in the form of adverse weather) may not only lead to damages to the transport infrastructures itself, it may also imply a reduced reliability and usability of the various (already intensively used) transport networks implying higher costs for the users (passengers + freight) of the infrastructure. An example is the cancellation and delay of trains as a result of wind storms, lightning or heat leading to longer and less reliable travel times for passengers (Duijnmeijer and Bouwknegt, 2004; Rosetti, 2002). As a result, more air passengers, who use the train to get to Schiphol airport, might miss their flight or they may decide to leave earlier from home leading to higher scheduling costs.

In case of the Port of Rotterdam, the supply of cargo to the seaport by road may take longer because of increased congestion on the motorway A15 due to a higher frequency of heavy showers. Inland waterway transport to and from the port may suffer from low and high water levels leading to reduced capacity of barge freight transport.

As a result of those climate change impacts, travelers and freight carriers may decide to change their behavior. Train passengers may switch to car, freight forwarders might decide to make use of another seaport and shippers may relocate for example. Recent work on the effects of climate change on transport (infrastructure) can be found in Jonkeren et al., (2007, 2009) and Koetse and Rietveld (2009).

In this project we will evaluate the costs associated with damage to the infrastructure, the reduced reliability and usability of land side transport networks and with changes in behavior of decision making actors (passengers, freight forwarders, shippers) on the local, regional or Randstad geographical level as a result of climate change.

Aim

For now, we foresee to assess:

1. The socio-economic consequences of climate change impacts for car and train travelers with destination Schiphol. The geographical scope is the Randstad level (as Schiphol attracts passengers from all around the Netherlands) but we may also focus on specific (local) bottlenecks in the network.

2. The socio-economic consequences of climate change impacts for freight transport (truck, train, barge) to and from the Port of Rotterdam. The geographical scope is the west-east corridor Rotterdam – German hinterland but we may also focus on specific (local) bottlenecks in the corridor.

Research question

1. What is the size of the costs associated with transport infrastructure damage and a reduction in the reliability and usability of the road and railway transport networks for travelers to Schiphol airport, as a result of climate change.
2. What is the size of the costs associated with transport infrastructure damage and a reduction in the reliability and usability of the road, railway and waterway corridors for freight transport to and from the Port of Rotterdam, as a result of climate change.

2.2 Approach and methodology

Analyzing the questions defined under A will be done by means of revealed preference data on how actors cope with changes in the reliability and usability of the networks. The Ph.D. student will also collect survey-based stated preference data so that insight is gained into for example valuations of uncertainty of travel times in departure time (from home) for travelers to Schiphol. For background information on the methods used we refer to Hensher et al (2006) and Tseng (2008). Those approaches will provide the researcher with valuations of travel time and its reliability. These valuations can be used to study behavioral changes of travelers when reliability of transport systems will change due to climate change. The information will be enriched with data on future transport networks and their operation/ failure as obtained in projects 2 and 3 of WP3 and with information on the impact on the physical infrastructure (from WP2). Together with data on the value of time (VOT) and value of reliability (VOR) for passenger-and freight transport this information allows the researcher to estimate the change in total costs of travel time and travel reliability due to climate change under different adaptation strategies. A role is reserved here for our Belgian international partner. FUCaM provides a powerful tool to analyse freight transport flows in Europe called NODUS (Jourquin, 2005; Jourquin and Limbourg, 2006; Limbourg and Jourquin, 2009). By means of this software device we will be able to examine the change in generalized freight transport costs (via changes in travel time and travel reliability) as a result of climate change. In addition, the NODUS model can be used to predict changes in modal split in freight transport.

Next, we will perform network economic loss analysis (Lee and Kim, 2007). The impacts of damage of a climate event may spread across several regions via import-export relationships. The final demand loss due to disruption of the network is estimated. By means of a resiliency factor, the extent to which production of a certain economic sector is affected by a disruption of network links that disrupt the commodity flows for a zone is determined. This latter approach ties in with research carried out in Theme 8 of the Adaptation to Climate Change programme.

The above results are essential elements of a cost benefit analysis of adaptation strategies in the transport domain to cope with climate change.

2.3 Scientific deliverables and results

This project will result in about 4 research papers. The research papers will all be submitted to high quality journals in order to publish them. In addition, as usual in these types of projects, working papers will be presented at (inter)national conferences in order to receive comments with which the quality of the research papers can be improved.

2.4 Integration of general research questions with hotspot-specific questions

The hotspots are interested in the damage for national and regional economies if, as a result of climate change, the infrastructure networks and mainports are hindered in their proper functioning, or if certain main services (fixed-point infrastructures e.g.) break down for any length of time.

We will not only focus on the economic consequences of this deterioration of the functioning of infrastructures and the physical damage but we also address the costs associated with changes in behavior of the actors that make use of the networks.

2.5 Societal deliverables and results

The estimated costs as a result of infrastructure damage and reduced reliability and usability of infrastructures due to climate change can be considered as potential benefits of adaptation measures. So, the results will provide valuable input for cost-benefit-analysis.

2.6 Most important references

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3 Project 4.2 Socio-economic effects of changes in reliability/usability of electricity infrastructure in the hotspot regions due to climate change

Project leader: prof.dr. P. Rietveld, VU Amsterdam

Co-leader: prof.dr. E.T. Verhoef, VU Amsterdam

3.1 Problem definition, aim and central research questions

Problem definition

Climate change will affect, directly or indirectly, the reliability of services in the domain of public utilities such as electricity, telecommunication, gas transported by pipelines, drinking water, etc. Various strategies are available to address these changes, such as the introduction of redundancies in network capacities and cycles in network design (Murray and Grubesic, 2007). These strategies clearly have costs and benefits. Whereas much is known on the costs of adding capacity to improve its robustness and reliability, less is known about the benefits of such measures.

In electricity supply, the impact of climate change may be two-fold. First, adverse weather may damage the infrastructure (e.g. lightning which strikes into a high-tension cable) and as a result a part of the electricity network breaks down. Second, generation of electricity cannot meet demand anymore due to extreme weather. An example is the hot, dry summer of 2003, during which power stations ran short of cooling water in North West Europe. In the Netherlands, this reduced the power production capacity to such an extent that prices on the spot market increased strongly and TenneT – the Dutch transmission system operator (TSO) – asked the Dutch public to cut back on their electricity use in order to prevent the need to introduce rolling blackouts (De Nooij et al., 2007).

Climate change effects will also interact with other major developments such as liberalization of energy markets, the transition towards a sustainable energy system and an increasing dependence on electricity (Rose et al., 2005). Liberalization may stimulate a lower reserve capacity in generation and transport, environmentally sustainable energy sources such as wind and solar energy have an uneven supply pattern over time and even brief interruptions of electricity supply cause substantial damage (Balachandra and Chandru, 2002). These developments exacerbate the network problems in the electricity sector caused by climate change.

Aim

The project aims at estimating the benefits of improving reliability of the electricity network to urban areas (the Randstad) and the mainports Schiphol Airport and the Port of Rotterdam.

Research question

What is the size of the costs associated with electricity infrastructure damage and a reduction in the reliability and usability of the electricity infrastructure on the local-and Randstad level due to climate change?

3.2 Approach and methodology

The research will start with an international survey of policies that can be observed in the field of energy infrastructures that are relevant for the hotspots involved. In particular attention will be paid to ways of measuring the benefits of reducing vulnerability in the electricity domain. The survey will address adaptive behavior from the side of both the supplier (for example less vulnerable links in networks) and the client of services (for example, construct reserve capacity just in case). The survey will lead to conclusions on the appropriateness of valuation approaches for network robustness for various infrastructure types. Depending on the availability of a sufficient number of studies a meta-analysis will be carried out.

The second part of the project will analyze some specific cases of interest to be selected in collaboration with the hotspots and stakeholders. As a first case we consider valuing the reduction in vulnerability of electricity supply in an urban area. This reduction may be the result of investments in network infrastructure, but also of demand management, flexible pricing or improved rules for prioritizing regions in case of a supply shortage or reduced network capacity. Social cost-benefit analysis will be applied to these cases, including a business case for the energy companies involved. Differences between social and private benefits may point towards suboptimal incentives, prompting government intervention. Valuing the benefits is another point of attention. For example: although almost everybody considers the security of power supply to be very important, it is not known what value society places on it (De Nooij et al., 2007). By valuing the consequences of having no electricity for a period of time (Sanghvi, 1982; Serra and Fierro, 1997) for the Rotterdam and Schiphol regions, insight into the potential benefits of the mentioned adaptation measures is obtained. This can be done by determining the cost per unit of electricity for different users, at different moments in time (de Nooij et al., 2009).

Data on future electricity networks and their operation/ failure as obtained in projects 2 and 3 of WP3 are valuable inputs.

3.3 Scientific deliverables and results

This project will result in about 4 research papers. The research papers will be submitted to high quality journals. In addition, as usual in these types of projects, working papers will be presented at (inter)national conferences in order to receive comments with which the quality of the research papers can be improved.

3.4 Integration of general research questions with hotspot-specific questions

In answering the research questions, regional demand and supply characteristics of the electricity services will be analyzed. These will differ between hotspot regions and other regions. Also, regional input-output analysis may be used to get a full picture of the effects of climate induced network problems on the regional economy of hotspot regions.

3.5 Societal deliverables and results

The analysis of vulnerability, incentives and policy options in this project will be very useful for electricity suppliers, organizations responsible for the respective network, regional governments and national government in developing strategies to cope with climate change effects.

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4 Project 4.3 Socio-economic effects of flexibility oriented adaptation approaches

Project leader: prof.dr. P. Rietveld, VU Amsterdam

Co-leader: prof.dr. E.T. Verhoef, VU Amsterdam

4.1 Problem definition, aim and central research questions

Problem definition

Although we know that the future climate will be characterized by a higher mean annual temperature, we don't know exactly what the climate in the future will be. Therefore, the Royal Dutch Meteorological Institute developed four climate scenarios for the Netherlands for the year 2050. The same line of reasoning can be applied to the future economic situation.

Developing (transport and infrastructure) policies which produce favorable outcomes in most of the scenarios is the traditional way of coping with uncertain futures. These policies are called robust static policies. The problem with this approach however is that if the actual future falls outside the range of future scenarios considered when developing the policy, the negative consequences (e.g. overspending) might be large. A better approach may be developing a policy that is designed to adapt to the future course of (climate and economic) events and that fully exploits knowledge that becomes available as time proceeds. Such adaptive policies allow policy makers to cope with uncertainty by creating policies that respond to changes over time.

In the case of planning of infrastructure, preventive measures to increase flexibility should be taken. For example, when planning a road, the optimal location of the road (on top or next to a dike) might be dependent on an uncertain flood risk which becomes more certain over time. In this case the space on top as well as next to the dike must be reserved for the purpose of flood protection.

This approach calls for a different-from-traditional (static) cost-benefit-analysis of adaptation measures. Therefore, we apply a more dynamic way of assessing costs and benefits. In the example above, the reservation of space implies (opportunity) costs while at the same time the larger probability of ultimately constructing the road on the right place brings about benefits. These types of costs and benefits must be taken into account when assessing cost-benefit analysis of flexible adaptation policies/ measures.

Within the Schiphol and Rotterdam hotspots, research cases will be selected, on which dynamic cost-benefit-analysis will be applied.

Aim

This project aims to evaluate the benefits and costs of flexible adaptation measures within the hotspot regions in order to evaluate the economic feasibility of those measures.

Central research question

What are the benefits and costs of a flexible infrastructure adaptation strategy for specific cases in the Schiphol and Rotterdam hotspot regions?

4.2 Approach and methodology

We will start with an international survey on the use of the flexibility notion as an element of the development of infrastructure and land use alternatives. Important elements of such cases will be notions such as uncertainty on future developments, the definition of alternatives in terms of multi period implementation, and proactive measures

such as the introduction of redundancies or reservations to reduce costs of future policy changes. Special attention will be paid to projects where uncertainty on future climate plays a role, and projects that are similar to those that the hotspots involved are facing. The use of various methods to cope with the uncertainty in the decision making process will be assessed. Special attention will be paid to the use of option value approaches.

In a first research case we will analyze the effect of a change in future dominating wind directions on the distribution of noise around Schiphol and consequently on costs and benefits of land use reservations. We will develop an *integrated land use model for a stylized metropolitan area with an airport* in order to analyze the costs and benefits of land use restrictions. Both, monocentric and multicentric versions of the model will be considered. Also, multiple airport cases will be analyzed. This model will be developed along the lines of Fujita (1989), Cheshire and Sheppard (2004), Rouwendal and Vermeulen (2008). Welfare analysis will be used to determine optimal reservation and implementation strategies. The model will be developed for an abstract metropolitan system; some applications will be made under parameter configurations that are representative for the Randstad region. The above modeling approach will be enriched by the *introduction of uncertainty* on future demands of airports. For this purpose, the analysis will be transferred to the domain of *real option theory* (Dixit and Pindyck, 1994; Amran and Kulatilaka, 1999). This part of the project is a critical step towards developing a truly adaptive approach. Although incorporating the real option approach in this type of model implies substantial analytical challenges, it may at the same time claim a high degree of originality. The Knowledge for Climate projects HSMS02 and HSMS03 can deliver valuable data inputs on expected future wind directions in the Schiphol area.

A second research case concerns the construction of locks in the waterways in the Rotterdam port area in order to prevent the intrusion of salt water and high water levels in urban areas. As a result of climate change sea level will rise and consequently (1) salt water will penetrate deeper into the inland waterways and (2) water levels in the Rhine delta will be higher. This implies damage for the agricultural sector and lower safety standards in the urban areas. An adaptive measure to combat these negative effects is the construction of locks in the Rhine delta. However, a major side effect is that waterway traffic is highly likely to be negatively affected by such an adaptation measure: it implies an increase in waiting/ travel time for inland vessels and sea vessels, less ship movements and less transshipment of cargo which will deteriorate the competitive position of the Port of Rotterdam. As we do not know exactly how strongly sea level will rise, the location and the number of locks to be constructed is uncertain yet. In addition, the locks must be constructed on those locations so that hindrance for waterway traffic is minimized. Because of these uncertainties, also in this research case flexibility in adaptation is required. Monte Carlo-based simulation methods offer an attractive technique to analyze the consequences of different spatial configurations of locks for the competitive position of the Port of Rotterdam. Possible futures of sea level rise will be obtained from the projects in Theme 1 and the KfC project HSRR03B.

The third research case is developed in cooperation with ProRail, the Dutch railway administrator. ProRail observes that in countries like France, Switzerland and Germany, railways have financially been hit by extreme weather in recent years. Therefore, ProRail is confronting itself with questions like "should we already invest in adaptation measures right now or is it better to wait?" and "what are effective adaptation measures?" In project 2 of WP2 the impact of climate change on rail infrastructure will be examined. This project will deliver information on the availability of the infrastructure, differentiated across space (so that vulnerable parts of the railway network become visible), to WP3. Consequently, WP3 will assess the impact (of the reduced availability) on travel time/ travel reliability and communicate the outcome to project 1 of the current WP. The economic information from that project (costs of damage to physical rail infrastructure, costs of changes in reliability, usability and behavior) will then be valuable input to outline promising flexible adaptation measures. Costs and benefits will be made specific for both society and ProRail.

4.3 Scientific deliverables and results

This project will result in about 4 research papers. The research papers will all be submitted to high quality journals. In addition, as usual in these types of projects, working papers will be presented at (inter)national conferences in order to receive comments with which the quality of the research papers can be improved.

The objective of WP 4 is to get insight into the socio-economic effects of climate change impacts on infrastructures. In projects 1 and 2 of this WP these effects are estimated. In the current project the socio economic effects (potential benefits) are made dynamic and will be confronted with the dynamic costs (of flexible adaptation measures). The final result is the development of methods to arrive at flexible adaptation measures that are well based on economic valuations of costs, benefits and the pertaining uncertainties in a dynamic context.

4.4 Integration of general research questions with hotspot-specific questions

The hotspots are not only interested in possible adaptation measures, but also in the feasibility of these measures taking into account the timescale and the speed at which climate change is expected to occur. In other words, they ask for feasibility studies of particular adaptation measures in which the uncertainty on climate change must be dealt with. We will explicitly tackle this uncertainty issue by means of our dynamic cost-benefit-analysis approach. The hotspot specific case studies are spatial reservations around Schiphol airport and the construction of locks in the waterways in the Rotterdam seaport. A more general case (with respect to space) is the developing flexible adaptation measures to make the railway infrastructure more robust to climate change.

4.5 Societal deliverables and results

The project will deliver finished cost-benefit-analysis of the, on forehand determined, most promising adaptation measures for infrastructures (located in the hotspot regions), to climate change. The outcomes of the analyses will help policy makers deciding in where to invest their resources in.

4.6 Most important references

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5 Project 4.4 Costs and benefits as a result of adaptation

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5.1 Problem definition, aim and central research questions

Problem definition

Projects 1 – 3 must be well integrated instead of being executed on islands. To avoid the risk of fragmentation, a post-doc will take care of coordination and communication, both internal (between the projects and WP’s) and external (with stakeholders and hotspots). He or she will for example intensively support the Ph.D.’s with contacting ‘the field’ and tuning (empirical) research methodologies. In addition, after projects 1, 2 and 3 have been finalized, the results of those projects will be transferred to the systems model in WP1 where the research results of all WP’s will be integrated. Therefore, this project also has a processing function: it facilitates the intertwining of WP4 with WP1.

Aim

- Support projects 1-3 with coordination and communication with internal and external parties.
- Transfer and integrate the results from projects 1 – 3 of WP4 to WP1 in order to make them accessible to stakeholders and to develop comprehensive and flexible adaptation strategies for the participating hotspots.

Central research question

Not applicable here.

5.2 Approach and methodology

The post-doc will fulfill the role of process supporter for projects 1-3 in this WP. His/ her tasks will consist of:

- Securing data delivery
- Tuning the exact contents of the research, executed by the Ph.D.'s, with the hotspots/ stakeholders.
- Coordination of research methodologies: as the same research approaches (e.g. stated/ revealed preference) are foreseen to be used by different Ph.D. students, the post-doc will establish cooperation between the students.
- Monitoring work progress in WP's 1-3 in order to be up-to-date with work in those WP's.
- Transferring the output from WP4 to WP1 and developing adaptation strategies in cooperation with the other consortium partners.

5.3 Scientific deliverables and results

Not applicable here.

5.4 Integration of general research questions with hotspot-specific questions

Not applicable here.

5.5 Societal deliverables and results

The project will deliver a report in which the results from projects 1, 2 and 3 are clearly formulated. This report will be distributed to 1) WP1, the systems model and 2) the stakeholders. The report will contain the results on the costs of transport and electricity infrastructure failure and costs and benefits of promising adaptation measures.

5.6 Most important references

Not applicable here.