



Climate change impacts on mode choices and travelled distances: a comparison of present with 2050 weather conditions for the Randstad Holland

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ABSTRACT

In the light of climate change, scholars from various disciplines recently addressed the role of weather conditions for travel behaviour. However, existing studies lack assessments of combinations of weather parameters and direct links to projected climate change. With this paper, we investigate potential effects of climate change on mode choice and distances travelled in the Randstad Holland. Based on approximate combinations of weather conditions projected for 2050, we select seasons from the last decade, to represent current and future climate conditions. By using data from the Dutch National Travel survey for the selected seasons, we analyse travel behaviour under 2050-climate conditions compared to travel behaviour under present climate conditions. Results show increasing usage and travelled distances for open-air transport modes in milder and wetter 2050-winters, mainly at the expense of the car, whereas in hotter summers with more extreme precipitation patterns reversed effects are observed. Year-round analyses of effects from 2050-climate conditions show a “flattening out” of seasonal differences in modal split, while for cycling mode shares and distances travelled significantly increase.

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1. Introduction

With the increasing societal interest in climate change adaptation in addition to mitigation, studies from different disciplines have addressed the effects of weather on transportation. The majority of studies focuses on network performance and safety of road, rail and air infrastructure networks (see for reviews, e.g. [Transportation Research Board, 2008](#); [Koetse and Rietveld, 2009](#)). Fewer studies address the relevance of weather conditions for travel and activity behaviours on an individual level (for an extensive and critical review of these studies see Böcker and others, in press). Additionally, studies often focus on incidental weather extremes, whereas the role of normal weather variations on habitual travel behaviours is often overlooked.

Initially, contributions focused mostly on car travel (e.g. [Khattak and De Palma, 1997](#); [De Palma and Rochat, 1999](#)), but in the light of environmental and health issues, also active transportation attracted a great deal of interest (e.g. [Nankervis, 1999](#); [Bergström and Magnussen, 2003](#); [Brandenburg et al., 2004](#); [Aaheim and Hauge, 2005](#); [Sabir, 2011](#)). These studies, although sometimes contradicting, give useful insights into the separate roles of weather parameters – temperature, precipitation and, to a lesser extent, wind – for mode choices: Warm and dry weather stimulates

choices for active open-air modes walking and cycling at the expense of the car, whereas rainy, snowy, windy, cold or extreme hot weather conditions have opposite effects. However, most studies lack an assessment of combinations of co-occurring weather parameters and an integration of projected climate change effects. Additionally, the relevance of weather for aspects of travel decisions other than mode choices, such as travelled distances, has received far less attention. Finally, climates and weather conditions differ highly between countries. As a consequence, analytical results on the impact of weather parameters on mode choices and travelled distances from studies in Australia, Norway, Switzerland and other countries do not automatically apply on countries characterised by other climate and weather attributes, like the Netherlands.

To address these shortcomings, this paper aims to assess the potential effects of climate change – focusing on average seasons, which include both normal and extreme weather conditions – on habitual seasonal travel behaviours regarding the selection of transport modes and travelled distances. The research is situated in the Dutch metropolitan Randstad region, characterised by a warm-temperate climate with warm summers, mild winters and moderate year-round precipitation patterns ([Geiger and Pohl, 1953](#)). To evaluate climate change effects, seasons from the last decade are selected to represent combinations of weather conditions normal to the climate at present and as projected for 2050 by the Dutch Meteorological Institute ([KNMI, 2009](#)). Drawing on the Dutch National Travel survey (MON), we carry out seasonal

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analyses of travel behaviour under 2050-climate conditions compared to travel behaviour under present-climate conditions. In this paper, we first summarize the main findings from the literature on weather and mode choice. Next we describe the data and methods, followed by a documentation of main findings on modal shifts in the perspective of projected climate change. The final section provides conclusions and discussion.

2. Literature

This section briefly summarizes some of the relevant literature on the role of weather parameters for transport mode choices and travelled distances. For a more comprehensive review, see Böcker and others (*in press*) on the meaning of weather for individual activity and travel behaviours.

In the field of weather influences on travel behaviour, some studies look at annual variance in mode choices and relate this to seasonal weather patterns. For example, Müller and others (2008) find seasonal variations in travel-to-school trips with shares of walking and especially cycling more than doubling in summer compared to winter at the expense of car and public transport. Other studies report similar seasonal changes in the shares of cycling (Nankervis, 1999; Bergström and Magnussen, 2003) or other physical activities (Chan and Ryan, 2009). However, seasonal patterns cannot solely be attributed to weather. As some of the respective studies pointed out but did not control for, observed patterns may also result from factors like day/night length and the distribution of holidays.

Other scholars investigate the relationship between weather and travel choices by singling out respective impacts of different weather parameters, most notably precipitation and temperature. With regard to precipitation, studies from different national contexts and amongst different transport mode user groups generally point out that precipitation increases the use of motorized transport modes – most notably the private car – at the expense of active transport modes – most notably cycling (e.g. Bergström and Magnussen, 2003; Aaheim and Hauge, 2005; Sabir, 2011). According to some scholars, the relationship between precipitation and mode choice is nonlinear; however, related findings are contradicting: Keay (1992) and Phung and Rose (2008) find sharp declines in cycling with light precipitation, followed by lesser reductions with heavier precipitation, whereas Nankervis (1999) and Richardson (2000) document that only heavy precipitation has a negative effect on cycling. In addition to affecting mode choices, Aaheim and Hauge (2005) indicate precipitation negatively affects travelled distances. They do not specify for which modes.

In addition to precipitation, many projects investigate the relevance of temperature for mode choices. Comparison studies of relative explanatory values of weather parameters for travel behaviour changes point out that temperature generally seems to have a less distinct impact on mode choice than precipitation (Aaheim and Hauge, 2005; Cools et al., 2010; Sabir, 2011). Nevertheless, analyses in various national contexts find that higher temperatures significantly contribute to shares of active transport modes at the expense of the car and, to a lesser extent, public transport (e.g. Hanson and Hanson, 1977; Aaheim and Hauge, 2005; Sabir, 2011). Some scholars document parabolic effects of temperature, where not only low, but also high temperatures exceeding 25–30 °C thresholds, have negative effects on walking (Aultman-Hall et al., 2009) and cycling (Keay, 1992; Richardson, 2000; Phung and Rose, 2008; Ahmed et al., 2010). With respect to travelled distances, Aaheim and Hauge (2005) show negative effects of increasing temperatures on distances travelled for errands and positive effects on distances travelled for recreation, but again without specifying transport modes used.

Where almost all of the above-mentioned studies analyse weather parameters separately, Nankervis (1999) also investigates combined effects of co-occurring temperature, precipitation and wind, stressing that a combination of low or very high temperatures with precipitation and wind is most negative for cycling. The vast majority of analyses evaluate weather effects on mode choices without including a direct assessment of climate change. One notable exception is a study from Bergen, Norway (Aaheim and Hauge, 2005), which extrapolates weather effects on present-day mode choices into a projected 2030–2050 climate. Results for the Bergen city centre show a decreasing car usage under wetter and warmer future climate conditions. Active transport mode shares increase for work trips, while public transport usage increases for errands. Outside the city, climate change affects mode choices much less, mainly because of the current and future domination of car use.

From these findings it becomes clear that mode choices are clearly affected by temperature and precipitation. Based on the generally positive effect of temperature on active transport modes it may be expected that a warmer future climate will increase shares of walking and especially cycling at the expense of mostly car use. Given the nonlinearity of this effect pointed out by some studies, these increases may be larger for winters than for summers. However, with the higher relative importance of precipitation over temperature indicated by some articles, positive effects on active transport modes may be relativised in all seasons, if temperature rise is accompanied by an increase in precipitation. Whilst the literature gives indications for the effects of weather on transport modes, evidence of the effects of weather on travelled distances is mostly lacking, leaving us with the intuitive interpretation that daily distances travelled by active modes may increase when temperature and precipitation levels are suitable for walking and cycling.

3. Research design

Our research is set up in the Randstad Holland: a densely populated area around the four largest Dutch cities Amsterdam, Rotterdam, The Hague and Utrecht. It is the area of specific interest to the larger CESAR-project (Climate and Environmental change and Sustainable Accessibility of the Randstad) on sustainable urbanisation and accessibility in which this study is embedded (http://www.nwo.nl/nwohome.nsf/pages/NWOP_7YUHV3_Eng). Based on Randstad weather records (KNMI, 2011) and four climate change scenarios for this region with varying global temperature rise (+1 to +2 °C) and variations in prevailing wind patterns (KNMI, 2009), we estimate present and projected 2050 seasonal averages (Table 1). At present, the Randstad experiences a warm-temperate climate characterised by mild winters, warm summers and moderate, relatively stable year-round precipitation patterns. In 2050, winters will become much milder and wetter, springs will be warmer and a little wetter, summers are expected to be hotter with more rain over fewer days, and autumns will become warmer.

In order to analyse climate change effects on habitual travel patterns, we select entire seasons from the period 2004–2009 (the period for which we have survey data available) with (a) weather conditions that are in line with today's climate, and (b) currently unusual seasons with weather conditions projected to be normal in 2050 (KNMI, 2009). Selected seasons (Table 1) represent patterns in temperature and precipitation as accurately as possible. To address both amount and distribution of precipitation, we include total seasonal sums as well as numbers of precipitation-days (≥ 0.1 mm). For temperature, seasons with temperatures at the higher end of the projected 2050-bandwidth are preferred, as underlying climate scenarios for these are more likely to occur (KNMI, 2009). Winter 2004/2005, spring 2005, summer 2009 and

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