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Cycling in a changed climate

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ABSTRACT

The use of bicycle is substantially affected by the weather patterns, which is expected to change in the future as a result of climate change. It is therefore important to understand the resulting potential changes in bicycle flows in order to accommodate adaptation planning for cycling. We propose a framework to model the changes in bicycle flow in London by developing a negative binomial count-data model and by incorporating future projected weather data from downscaled global climate models, a first such approach in this area. High temporal resolution (hourly) of our model allows us to decipher changes not only on an annual basis, but also on a seasonal and daily basis. We find that there will be a modest 0.5% increase in the average annual hourly bicycle flows in London's network due to a changed climate. The increase is primarily driven by a higher temperature due to a changed climate, although the increase is tempered due to a higher rainfall. The annual average masks the differences of impacts between seasons though – bicycle flows are expected to increase during the summer and winter months (by 1.6%), decrease during the spring (by 2%) and remain nearly unchanged during the autumn. Leisure cycling will be more affected by a changed climate, with an increase of around 7% during the weekend and holiday cycle flows in the summer months.

1. Introduction

Reducing carbon emissions to mitigate climate change and adapting to the potential impacts of climate change have become a major policy goal in many countries in the world. For example, the UK Government has made a commitment of an 80% reduction in its carbon emissions by 2050. The government is also expected to publish its first National Adaptation Programme (NAP) to climate change at the end of 2013 (UK Government, 2013). Since personal transport is responsible for a major share of global carbon emissions, reducing carbon emissions from transport is an important area of action. Within the personal transport sector, cycling has received significant attention from the transport and city planners and policymakers due to its zero-carbon credentials. Cycling also does not emit any harmful criteria air pollutants, and contributes toward a healthier life. A significant increase in cycling as a mode share can also alleviate congestion in road spaces or reduce the burden on a crowded public transport system. Thus cycling as a transport mode has multiple co-benefits.

In the context of climate change, cycling's role so far has been primarily for carbon mitigation. Despite a few studies indicating that the energy use and carbon reduction potential for cycling may not be very large (e.g. less than 5% in the UK, Pooley et al., 2010), there are still strong campaigns to encourage cycling in different countries because of the multiple benefits (Wittink, 2010; ECF, 2011). The emphasis on cycling for carbon mitigation has recently been reiterated in the UK: 'we see the encouragement of cycling and walking, along with improvements to public transport, as key to cutting carbon emissions and enhancing the quality of our urban areas' (UK Parliament, 2013). The other strategy to combat climate change – adaptation – has not received much attention yet, except for some cursory mention, in the context of cycling (e.g. UKCIP, 2011).

The lack of interest in climate adaptation studies for cycling could be important. However, even before any adaptation plans can be made, it is necessary to know how cycling can be affected as a result of a change in the future climate. Cycling is an 'unsheltered' activity and cyclists are directly exposed to the various weather events such as rain, snowfall, gust or even high and low temperatures. Therefore, the effectiveness of the use of bicycles as a transport mode is often affected by day to day changes in local weather. A change in the climate can alter the future weather pattern, which can affect cycling in either a positive or a negative way. It is quite possible that the future weather pattern would discourage cycling, e.g. if the precipitation increases, as predicted in the UK (Met Office, 2011). This would require adaptation strategies ahead in time either to ensure that cycling continues as a strong transport mode in the future or to accommodate the modal shift from cycling to other transport modes. On the other hand, it is also

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conceivable that the future weather pattern will be conducive to a large uptake of cycling (e.g. due to an increase in temperature in colder regions or vice versa), and this would also require planning to ensure adequate cycling infrastructure in place in time. Unfortunately, there is a lack of studies on the potential weather-induced impact (either on the direction or on the magnitude) of climate change on bicycle flows, although two recent studies looked into future mode choices (including cycling as a mode) in the Netherlands and Toronto (Bocker et al., 2013b; Saneinejad et al., 2012). This paper aims to address this gap by developing a framework to determine the weather-induced impacts of climate change on cycling and applying that model to London, UK. In doing so, we also develop a bicycle count model for London network, incorporating weather, as well as other explanatory variables that allows us to understand the impact of these additional variables too.

The paper is organized as follows. Section 2 reviews the literature on the impact of weather and climate change on cycling. Section 3 presents the modeling framework and the data used in the study. Section 4 presents the results with Section 5 drawing conclusions and limitations of the current approach.

2. Review of literature

Central to our research is the impact of the change in weather pattern induced by climate change. There are a number of studies documenting the impact of weather on travel behaviour, in different modes of travel. In light of the recent reviews covering all transport modes by Bocker et al. (2013a) and Koetse and Rietveld (2009), we focus only on those studies specific to cycling. One of the first studies to quantitatively investigate the impact of weather on cycling was by Hanson and Hanson (1977). Since then, the relationship between weather and cycling has received growing attention in at least five different disciplines: transportation, urban studies, geography, biometeorology and health. In addition to studies on the quantitative impacts of weather on reported or observed level of cycling in these disciplines, there are also studies that look into attitudes and barriers to cycling through questionnaire surveys (Pooley et al., 2011; Wardman et al., 2007), but this thread of literature is beyond the scope of the present work.

Different types of data with different spatial and temporal resolution have been used by various researchers to understand the impact of weather on cycling. These include travel survey data at an aggregate level (census tract, city, county, or state; Parkin et al., 2008; Pucher and Buehler, 2006; Dill and Carr, 2003), individual travel survey responses (Cervero and Duncan, 2003; Bergstrom and Magnussen, 2003; Winters et al., 2007; Rashad, 2009; Heinen et al., 2011; Flynn et al., 2012; Saneinejad et al., 2012), and bicycle count data at different temporal and spatial resolutions (Phung and Rose, 2007; Ahmed et al., 2010, 2012; Miranda-Moreno and Nosal, 2011; Smith and Kauermann, 2011; Tin et al., 2012; Thomas et al., 2013). Although both cross-sectional and time series data have been employed, the deployment of automatic cycle counters in many cities in the world has made finer resolution time series data readily available in recent years, and a number of recent studies used bicycle count data at a daily resolution (Phung and Rose, 2007; Ahmed et al., 2010, 2012); hourly resolution is not missing either (Smith and Kauermann, 2011; Miranda-Moreno and Nosal, 2011). Studies on mode choice using individual data from travel diary surveys and correlating them with weather data have also started to appear (Cervero and Duncan, 2003; Saneinejad et al., 2012).

There are a few studies (e.g. Goetzke and Rave, 2011) that investigate the effect of 'bad' weather to answer a given research question, but do not specify the parameters of bad weather. There are others which investigate the effect of specific weather variables and these studies are relevant to our review. The weather variables studied are, in various functional forms, rain, snow, temperature, wind speed, sunshine hours, fog, thunderstorms, and relative humidity. Most common among these are rain and temperature, which are present in almost all of the studies. Most studies found that cycling decreases in the presence of rain or with an increase in rainfall (Keay, 1992; Emmerson et al., 1998; Nankervis, 1999; Richardson, 2000; Cervero and Duncan, 2003; Dill and Carr, 2003; Pucher and Buehler, 2006; Brandenburg et al., 2007; Winters et al., 2007; Parkin et al., 2008; Phung and Rose, 2007; Ahmed et al., 2010, 2012; Heinen et al., 2011; Smith and Kauermann, 2011; Miranda-Moreno and Nosal, 2011; Buehler and Pucher, 2012; Flynn et al., 2012; Tin et al., 2012; Thomas et al., 2013). Only a few studies found that rain had no statistically significant effect on cycling, and most of those (e.g. Dill and Carr, 2003; Rashad, 2009; Buehler and Pucher, 2012) utilize cross-sectional inter-city or inter-county data, which could be prone to omitted variable bias.

There is also a consensus on the effect of temperature (except Buehler and Pucher, 2012): up to a certain temperature, an increase in the temperature increases bicycle ridership, but beyond that point ridership starts to decrease. Therefore, unlike in rain, temperature has a clear non-linear impact: high and low temperatures reduce bicycle use. However, the optimum temperature conducive to cycling can vary from country to country. Similarly, there is a universal agreement that an increase in wind speed has a negative impact on cycling, although some argue that this relationship is valid only at high wind speeds, indicating a non-linear effect (Phung and Rose, 2007; Sabir, 2011).

Among other variables, sunshine hours positively influence cycling, as reported by Rashad (2009), Heinen et al. (2011), Tin et al. (2012) and Thomas et al. (2013), although Ahmed et al. (2010) finds an opposite impact. Increases in relative humidity results in a decreased level of cycling (Gebhart and Noland, 2013), especially if it is accompanied by a high temperature (Miranda-Moreno and Nosal, 2011). Flynn et al., (2012) and Gebhart and Noland, (2013) find that snowfall substantially reduces cycling. Gebhart and Noland, (2013) also attempted to model the impact of fog and thunderstorm, but no statistically significant impact was noticed on hired bicycle trips. In addition, Bocker et al. (2013a) report that the impact of weather variables on cycling can be different depending on the purpose of the trip, with recreational cycling being more sensitive than commuting trips.

The number of studies that investigated the impact of climate change on cycling is few – Bocker et al. (2013b) for the Netherlands and Saneinejad et al. (2012) for Toronto. Both of these utilize a mode choice framework. In order to model the changed climate, Bocker et al. (2013b) select seasons from the past as representative of the changed climate in 2050 while Saneinejad et al. (2012) use ten scenarios of changed rainfall and temperature pattern. Neither makes use of finer resolution information from the climate change models, and only utilizes the aggregate level information.

3. Methodology and data

3.1. Modeling framework

The basic modeling framework involves developing a bicycle count model for London using not only weather, but also other explanatory factors, and then employing this model to predict the level of future cycling by plugging in future projected weather data from climate simulations. Since future weather pattern is not deterministic in nature, we also run various plausible weather patterns consistent with the changed climate to quantify the plausible distribution of the potential changes in the cycling flow in the changed climate. The modeling framework is explained graphically in Fig. 1, and the key components are described below.