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Bikeability – Urban structures supporting cycling. Effects of local, urban and regional scale urban form factors on cycling from home and workplace locations in Denmark

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ABSTRACT

This study applies micro-level transport survey data to assess the significance of Bikeability variables on the probability of cycling in trips to or from residential and workplace locations. The data and analysis were prepared to include measures at different spatial scales, including measures of density/accessibility and infrastructure provision for network distances from up to 1 km to up to 5 km from the origin of a trip, as well as the regional position of the city. The probability of cycling is affected by urban structure variables at the local, urban and regional scale. The local scale, which includes the positive effects from population density and cycling infrastructures, is the most important in influencing cycling, but there are substantial additional contributions from access to retail and train stations within a range of 3–4 km, as well as from the relative size of the city within the region. The effect of the regional scale most likely reflects the reliance upon motorized modes to connect to distant important nodes. Factors at the local, urban and regional scales may pull cycling in opposite directions and thus all need to be considered to adequately assess the possibilities for promoting cycling in an urban area or neighbourhood.

1. Introduction

Bikeability – the ability of a person to bike or the ability of the urban landscape to be biked – has been used as a baseline notion of the likelihood that individuals or groups of citizens will choose the bicycle as a mode of transport or leisure. Beyond providing an indicator that enables the comparison of cities or zones to highlight differences and areas requiring particular attention (Saelens et al., 2003; Ewing et al., 2006), many studies regard Bikeability as a predictor of the choice of cycling as a transport mode for individual citizens or the cycling mode share of the population in a given area (Krizek et al., 2009; Winters et al., 2013).

Whereas Bikeability is a relatively new term, its sibling 'Walkability' (Saelens et al., 2003) has a longer history in research and planning related to active and non-motorized transport and serves as the main inspiration for studies on the relation between cycling and the built environment (Muhs and Clifton, 2016). Even though several authors apply the two terms almost interchangeably (Pikora et al., 2003; Saelens et al., 2003; Greenberg and Renne, 2005; Ewing et al., 2006), several recently published studies call for a distinction between the terms (Krenn et al., 2015; Muhs and Clifton, 2016). Walking and cycling indeed share a number of characteristics: a) both are human powered; b) the individuals are 'soft' and in direct contact with their environment and therefore vulnerable to harm and the weather; c) both modes are environmentally friendly; d) both can be part of multimodal transport, for instance, in combination with public transport (Muhs and Clifton, 2016); and compared to motorized transport, e) cycling and walking share a relatively short travel range due to their low speed and required physical efforts. Accordingly, Walkability and Bikeability share multiple features and conditions. Several studies have suggested that areas with higher population densities, high connectivity, and mixed land use have a higher share of non-motorized travel. For further references, see Saelens et al. (2003) and Muhs and Clifton (2016). The latter also provides a comprehensive review of studies on the relation between Bikeability and the share of cycling.

There are a number of dissimilarities between walking and cycling (partly based on Muhs and Clifton, 2016): a) Cycling does, to a greater extent than walking, require certain skills and equipment. In the present study and in other parts of the world where the transport share of cycling is high, access to a bicycle and the ability to cycle are expected

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to apply to most (80% of the Danish population has a bicycle) (Nielsen et al., 2013). b) The presence and quality of a mode-specific infrastructure appears to be a crucial topic in relation to cycling but much less so when it comes to walking. This is probably because facilities for walking generally have been present along roads, at least in downtown areas, whereas cyclists and cycling facilities have to find their place within existing and increasingly congested road spaces. c) Walking does not require parking facilities, which is an important issue in relation to bicycle planning – in terms of both the allocation of space (for instance, at public transport hubs, shopping centres, and workplaces) and a facility to maintain an operational standard and secure bicycles from theft. d) The most striking difference between walking and cycling is the speed of movement, which again influences the potential distances and the range of activities that can potentially be accessed. These differences influence the relevance of the specific factors and the spatial scales underlying aggregate indicators of Walkability or Bikeability. The remainder of this study will address Bikeability.

The way the term Bikeability is applied varies significantly with respect to the spatial scale. In its most spatially disaggregated form, Bikeability addresses a person's ability to actually sit on and ride a bicycle. In the UK-based training program, 'Bikeability' specifically addresses citizens' ability to bike, and the program aims to increase Bikeability by teaching children how to ride a bicycle and act in traffic while cycling (Department of Transport, 2016; Hamilton and Palmer, 2014). Beyond this, the term has been attributed to the environment in which cycling takes place. Describing the Bikeability of an environment has included the following characteristics:

- Single elements of the townscape or the infrastructure, such as bicycle tracks, crossings, and parking facilities, which are referred to by Lowry et al. (2012) as 'bicycle suitability'.
- Neighbourhoods delineated based on airline/Euclidian distance rather than network distance (Nielsen et al., 2013; Greenberg and Renne, 2005).
- Explicit polygon features generated around specific trajectories of individual respondents – e.g., as recorded by GPS. Such features can be purely geometric, such as buffers or ellipsoids, or be based on the topology of a transport network (Madsen et al., 2014; Frank et al., 2017).
- Connected infrastructures as a functional component of entire towns and urban fabrics (Lowry et al., 2012). According to Lowry et al. (2012), this is in fact what covers the term 'Bikeability'.

In our study, we further extend this Bikeability in scale to include the interurban context at a regional scale.

Approaches to connecting Bikeability as a feature of the environment to a behaviour vary, and their adequacy and validity have received increasing attention in recent years. Realizing that the environment/area that effectively influences a human behaviour can vary, Kwan (2012) generalizes the problems relating to the inference of individual or aggregated behaviour, based on characteristics of area units, as the 'Uncertain geographic context problem' (UGCoP). Kwan claims that no objective area unit – with a given location, size and shape – can be generically applied for behavioural studies. She argues that studying each type of behaviour – and ultimately each individual in different temporal domains – requires reconsideration and redesign of the area units applied to study the effects of the environment. In our study, we further extend this line of thought to embrace the fact that different amenities and assets of the urban (interurban) environment are perceived and utilized at different scales and ranges of activities. Accordingly, we investigate not only which characteristics influence the mode choice of bicyclists but also at which spatial scale or travel range they are most influential. To assess/quantify the effects, we apply area units based on network distances originating from the home and/or workplace locations of respondents, which is in line with the 'network buffers' described by Frank et al. (2017) and Madsen et al. (2014) and methods generally applied to accessibility modelling (see below).

Many studies of Bikeability (and Walkability) include rather simple indicators of connectedness, such as the number of intersections per area unit (Nielsen et al., 2013), which is sometimes constrained to include only those nodes in a network that connect > 3 segments in the network (Winters et al., 2013). When quantifying the features and services of connected townscapes, accessibility appears as a focal term. Accessibility can, in disaggregated form, be defined as the ease of reaching an important destination from a given origin, given a radius of activity based on a distance or time budget (Hansen, 1959; Lowry et al., 2012). Aggregated accessibility sums up the amount of services that can be reached, provided a similar set of constraints (see, for instance, Skov-Petersen, 2002; Geurs and Ritsema van Eck, 2001).

This study applies micro-level transport survey data to assess the significance of Bikeability variables at a range of scales (including accessibility, infrastructure, and city size relative to the regional surroundings) on the probability of cycling in trips to or from residential and workplace locations. The analysis encompasses cities of different sizes and in different regional contexts. The data and analysis were developed to include accessibility and regional location measures based on different spatial/distance scales locally and regionally. Thus, it is assumed that the specific features of the bicycle, and its suitability for travel ranges in between walking and motorized modes, will have implications for the spatial scale at which accessibility/density measures are most suitably represented in measures and analyses of Bikeability. The inclusion of a regional scale is a suggested extension of the prevailing neighbourhood and local accessibility-based approaches to the study of Bikeability. The probability of cycling to or from any location is here hypothesized to be affected by its regional context in addition to smaller scale aspects of Bikeability, and even though this will be difficult to change or control through infrastructure planning or urban planning, it may still be important for explaining or anticipating cycling outcomes of local development and provide knowledge on variations between cities in the preconditions for cycling.

The data sources applied in this study, the methodology, the results of the statistical analysis, a discussion of the results and their implications and use, and finally the conclusion are presented in the following sections.

2. Data

The source of cycling data is the Danish National Travel survey and its representative sample of 10- to 85-year-old Danish residents who were interviewed through the year regarding their travel activities on the previous day (Christiansen, 2012). The survey provides a detailed account of one day of travel activities including trip stages, trips, journeys and the travel purposes to which they connect – in addition to the socio-economic and demographic background of the respondents (Christiansen and Skougaard, 2015). This paper relies on the series from 2006 to 2014, where a total of 59,000 respondents living or working in cities with > 9000 inhabitants were surveyed. The survey's account of cycling includes cycling as the main mode of transport as well as cycling as a stage mode, e.g., connecting to public transport and leisure cycling without a destination purpose. Bicycles are, however, mainly used for everyday purposes, including commuting to work, and leisure cycling is limited to approximately 10% of total cycling (km) in the Danish population (Nielsen et al., 2013).

A detailed transport network (see below), addresses and the Danish reference grid-based geostatistical datasets provided the opportunity to develop measures of urban structures and accessibility. Specifically, we used the addresses, business codes, and number of jobs in almost 1 mill. employment locations recorded in the Danish business register (Erhvervsstyrelsen, 2014), population data for 100 × 100 meter grid cells provided by Statistics Denmark (Danmarks Statistik, 2017), as well as elevation data for 0.4 × 0.4 meter cells from the remote-sensing (LIDAR)-based digital elevation model (Danish Geodata Agency, 2014).