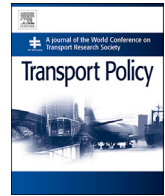


Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Urban form, demographic and socio-economic correlates of walking, cycling, and e-biking: Evidence from eight neighborhoods in Beijing

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ARTICLE INFO

Keywords:

Walking
Cycling and e-biking
Urban form
Sustainable mobility
Policy

ABSTRACT

This paper explores the urban form, demographic and socio-economic dependencies of walking, cycling and e-biking in Beijing based on a survey (N = 1427) of daily travel among residents in eight neighborhoods, enriched with urban form variables. The results show that walking is most frequently used, followed by cycling, which in turn is more frequent than e-biking. Walking and cycling are preferred when the accessibility of public facilities and services is good, while e-bikes are used when public transport provision is low. Urban form variables of population density, job employment density, and public facilities and services confirmed the experience from western countries that higher density mixed land use increases walking, cycling and e-biking. It is recommended that future sustainable transport policy addresses the maintenance of proximity environments at the neighborhood level. Furthermore, if the contribution of walking and cycling to sustainable urban mobility is to be maintained and repositioned, the younger generation requires substantial encouragement to get them to cycle more, while low education, low and middle income earners, non-hukou citizens are groups that should be encouraged to keep on walking, cycling and e-biking even if their income situation may improve in the future.

1. Introduction

Walking and cycling are recognized as sustainable transport modes which have the potential to contribute to energy efficiency, reducing congestion and pollution as well as improving public health (Cao et al., 2006, 2006; Krizek et al., 2009; Owen et al., 2004; Pooley, 2013; Tight et al., 2011). Electric bikes (e-bikes) are an emerging form of transport, which have received increasing interest in the field of sustainable cities and mobility as an alternative to motorized vehicles (Dill and Rose, 2012; Popovich et al., 2014; Rose, 2012). To explore the role of these transport modes in an urban, socio-economic, demographic context, studies have been carried out for decades, especially in developed countries, but not to the same extent in developing countries such as China (Boarnet and Crane, 2001; Cao, 2015; Cervero and Duncan, 2003; Cervero and Radisch, 1996; Handy, 1996; Horner, 2013). Under pressure from rapid urbanization, cities in developing countries in particular are now facing the challenge of navigating towards more sustainable mobility patterns.

Importantly, cycling is studied either as a specific travel mode or as an integrated part of sustainable travel modes, and an alternative to car-

driving (Bergström and Magnusson, 2003; Bongardt et al., 2010; Gössling and Choi, 2015; Olafsson et al., 2016; Rabl and de Nazelle, 2012; Nielsen et al., 2013a). Rapid urbanization and the growth in the number of vehicles have dramatically marginalized cycling in Chinese cities since the end of the 1990s. Cycling mode share in Beijing declined from 62.5% in the middle of the 1990s to 12.4% in 2015 (Beijing Municipal Commission of Transport, 2016). Deteriorating air quality and traffic congestion are two of the severe challenges facing the urban development of Beijing. These issues made the government acknowledge the importance of re-emphasizing the development of walking and cycling. Since 2005, walking and cycling have been reappearing in a series of political documents. This attention was enforced in 2015 with the implementation of a number of retrofitting projects (Beijing youth daily, 06.2016). Increasing cycling and walking became visible and gained prominence on the political agenda, although the role of e-biking is unclear as politicians are concerned about the higher speeds and the greater risk of accidents compared with ordinary bicycles (Campbell et al., 2016). In 2016, the use of e-bikes was restricted on ten main roads in Beijing, although some researchers were skeptical regarding this

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<https://doi.org/10.1016/j.tranpol.2018.01.018>

Received 19 January 2017; Received in revised form 24 January 2018; Accepted 25 January 2018

Available online xxx

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e-bike restriction strategy and were concerned that the restriction policy would result in other cities following suit (Tencent news, 04.2016). In order to make effective future strategies, policy makers in Beijing need a deeper understanding of the current level of walking, cycling and e-biking, as well as an identification of the factors that influence the choice regarding these three modes.

Against this background, the overall aim of this study is to analyze current walking and cycling travel behavior in order to identify the determinants of mode choice. The overall aim is addressed by the following two specific objectives:

- 1) To investigate the extent to which walking, cycling and e-biking are used as transport modes in residents' daily lives.
- 2) To analyze the urban form, demographic and socio-economic correlates of walking, cycling, and e-biking mode choice.

The paper contributes to the literature in two ways. Firstly, it targets the association between urban form and travel behavior in what is an insufficiently studied urban context – Beijing, which is a rapidly urbanizing city in a developing country. Secondly, it jointly addresses the choice to walk, cycle, or use an e-bike in order to elaborate their differences and dependencies. The policy relevance of the paper is that it provides an insight into the determinants of alternatives to cars in the Beijing urban context. This knowledge is useful for planners and policy makers because it can help them choose the correct strategies for promoting walking and cycling in Beijing or cities with similar challenges.

The paper is structured in five sections. The first section, the introduction, states the research objectives, while section 2 presents a literature review to determine the current level of knowledge and to identify any research gaps; the third section, the methodology, introduces the approaches used to collect the data and conduct the analysis. This is followed by the result section, which presents and interprets the analytical results. The fifth section concludes the study by discussing how Beijing may promote walking, cycling and e-biking.

2. Urban form and sustainable transport modes of walking, cycling and e-biking

According to (Ewing and Cervero, 2010), the correlations between urban form and travel behavior have mainly been studied in the field of urban planning, where they have been conceptualized into the five Ds - *density*, *diversity*, *design*, *destination accessibility* and *distance to the public transit*. Zhang et al. (2016) summarized the definition of each D's built environmental attributes in a Table, which is present below (Table 1). Previous studies which have targeted the urban and socio-economic factors associated with walking and cycling have considered the Ds to differing extents. Specifically, urban form, such as land use, neighborhood location, street network pattern, alternative transportation options, public transport services, and travel distance have received the most attention, while demographics and socio-economic factors have often been included as control elements (Beenackers et al., 2012; Cao et al., 2007; Crane and Crepeau, 1998; Frank et al., 2007; Handy et al., 2006; Hong et al., 2013; Wang and Lin, 2014).

For walking, the urban form factors of density, destination accessibility and distance to the public transit and urban design are the most frequently highlighted factors associated with high levels of walking. Within residential neighborhoods, good public service facilities next to the neighborhoods can enhance walking as a transport mode (Fishman, 2015; Fishman et al., 2015; Wang et al., 2016). It has also been shown that the design of neighborhoods influences the decision as to whether to travel by foot (Aditjandra et al., 2013). The proximity environment – the density of urban functions within and around the neighborhoods - has been highlighted as an important factor in increasing walking trips and it, therefore, contributes to the livability of cities (Marquet and Miralles-Guasch, 2015; Saelens et al., 2003). Further, studies indicate that population density and the physical design of the road network have

Table 1

The definition of the five Ds built environment variables and commonly used attributes. Source (Zhang et al., 2016).

Five Ds	Definition	Commonly used attributes
Density	The variable of interest per unit of area	Population density, density of dwelling units, employment density
Design	Street network characteristics within an area	Average block size, number of intersections per square mile, bike lane density, average building setbacks, average street width, number of pedestrian crossings, street trees
Diversity	The number of different land uses in a given area and the degree to which they are represented	Entropy measures of diversity, jobs-to-housing ratios, jobs-to-population ratios
Distance to transit	The level of transit service at the residences or workplaces	Distance from residences or workplaces to the nearest rail station or bus stop, transit route density, number of stations per unit area, bus service coverage rate
Destination accessibility	Ease of access to trip attractions	Distance to the central business district, number of jobs or other attractions reachable within a given travel time, distance from home to the closest store

an influence on whether children walk to school or not (De Vries et al., 2010; Ghekiere et al., 2015.; Li and Zhao, 2015; Rothman et al., 2014). In the Chinese city of Zhongshan, it was found that good public transport and access to public facilities contributed to increased walking among elderly people (Zhang et al., 2014).

Regarding cycling, in a US study, the choice to cycle was found to be only slightly associated with urban form factors, while socio-economic factors had a greater impact in that there were clear gender and generational differences in travel behavior (Moudon et al., 2005). However, in a Danish context, Nielsen et al. (2013) found that urban form factors and socio-economic factors substantially increased the probability of cycling. Thus, in Denmark, a high rate of cycling is related to flat terrain, a short distance to retail centers, population density and network connectivity. However, cycling also competes with alternative options as manifested by an effect of access to public transport as well as favorable conditions for walking. Thus, the results point to some competition between the 'sustainable travel modes' depending on the urban context. With regards to socio-economic associations, generally, cyclists have lower incomes, but are highly educated. Cycling is in the dual position of being a 'budget' mode, but also being the mode of transport of the highly educated urban population (Nielsen et al., 2013). In the case of Chinese cities, land use heterogeneity measures, local street connectivity and destination accessibility have a significant influence on the probability of cycling for commuting trips. In addition, low income citizens are the main users of cycling and walking (Zhao, 2014a). Gender and level of education have a slight influence on the decision to cycle for commuting trips, while road density and commuting distance are significant factors which influence the choice to cycle (Yang and Zacharias, 2015).

In this paper, the definition of e-bikes is in line with that of Weinert et al. (2007): 'a type of two-wheeled bike that is propelled by human pedaling, supplemented by electrical power from a storage battery, although low-speed scooters are solely powered by electricity (usually with perfunctory pedals to satisfy legal definitions)'. E-biking as an emerging travel mode is growing more slowly in cities in developed countries than in developing countries with China accounting for the main share of the growth in the global e-bike market (Campbell et al., 2016; Dill and Rose, 2012; Rose, 2012; Shaheen et al., 2013; Weinert et al., 2007, 2006). Most previous studies have focused on e-bike users' profiles and purpose rather than on built environments or

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