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Bicycle-metro integration in a growing city: The determinants of cycling as a transfer mode in metro station areas in Beijing

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ABSTRACT

Bicycle-transit integration, in which cycling is used to as a transfer mode to/from transit station is widely believed to be one very important way of promoting a transit city and achieving efficient and sustainable urban transport systems. However, the empirical evidence for the determinants of people's choices to transfer by bicycle as a travel mode remain largely unstudied. This paper investigates this issue, using Beijing and its metro system as a case study. Using a multilevel logistic model, we found that travel distance is the most important influence on rates of cycling for transfer trips between metro stations and home or workplace. There were also socioeconomic influences, with young people being less likely to cycle and more likely to use buses. Middle- and high-income earners were more likely to drive than cycle, while low-income earners were more likely to take the bus. Personal attitudes are also influential—those who prefer cheap travel were more likely to cycle. Above results suggest that the increasing city size and urban expansion are great challenges to cycling systems in growing cities. The presence of bicycle-sharing programs, mixed land use, and green parks in metro station areas were associated with greater rates of cycling transfer. In order to promote Bicycle-and-Ride schemes in metro station areas, education initiatives designed to influence behavior should be integrated with investment in bicycle infrastructure.

1. Introduction

Cycling is considered to be a sustainable, economic and convenient mode of transport because of its low cost and moderate degrees of travel speed and flexibility (Akar and Clifton, 2009). It also contributes to people's physical health and decreases their likelihood of being overweight (Lawlor et al., 2003). Compared with motorized transportation modes, cycling generates no air pollution and consumes no fossil fuels. Moreover, cycling is considered to be the most equitable form of transportation (Pucher and Buehler, 2008) because it is affordable for most low-income earners. In some developing countries, cycling is now regarded as a travel mode used mainly by people with low incomes (Nkurunziza et al., 2012; de Dios Ortuzar et al., 2000). The renaissance of cycling is regarded as an effective way to alleviate transportation problems caused by car dependence, such as air pollution and traffic congestion (Moudon et al., 2005).

There are many policies designed to encourage cycling, such as bicycle-sharing programs (for a review, see DeMaio, 2009), the improvement or provision of bicycle lanes (e.g. Pucher and Buehler, 2008) and the improvement or creation of

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a cycling-friendly environment (Cervero and Duncan, 2003). Additionally, policies designed to discourage car use, such as congestion charging and road pricing, could benefit the promotion of cycling (Buehler et al., 2016). Recently, attention has turned to the integration of bicycle and transit systems (e.g. Martens, 2004; Rietveld and Daniel, 2004; Wang and Liu, 2013; Singleton and Clifton, 2014). This integration aims to encourage transit passengers to use a bicycle as a transfer mode to and from transit stations. In such integrated systems, the bicycle is a desirable feeder mode of travel for trips to and from transit stations (Rietveld, 2000a). One reason is that cycling has a higher speed than walking and a more flexible service than public transport (Keijer and Rietveld, 2000). Another reason is that in most countries, cycling is free or much cheaper than buses for trips to transit stations. A third reason is that in large cities, for example, Paris, London, Beijing, and Amsterdam, many residents live in the suburbs. The "last mile" between home and train or metro stations is a major factor influencing residents' usage of train or metro systems. "Bicycle + transit" provides a chance to promote transit ridership in large cities. Therefore, it is considered to be an effective way to promote both transit and cycling (Bachand-Marleau et al., 2011), and to reduce car use in transit station corridors (Martens, 2004). This has been promoted by policymakers and planners worldwide, for example, in northern European countries such as the Netherlands and Denmark, and in some developing countries, for instance, China, Colombia, and Brazil. "Bicycle + transit" is also encouraged in some car-dependent cities, such as in the USA, Australia, and New Zealand, although bicycle trips to/from stations still account for only a small proportion of all trips in these countries (Wang and Liu, 2013). Bicycle-transit integration has recently become an important research theme attracting greater research attention (La Paix and Geurs, 2015; Keijer and Rietveld, 2000).

In the field of research on bicycle-transit integration, several research gaps need to be filled. Firstly, studies exploring use of bicycles as a transfer mode to underground train (metro) station areas in cities remain scarce. The existing literature mainly focuses on the use of cycling to and from regional railway or bus stations (e.g. La Paix and Geurs, 2015; Wang and Liu, 2013; Heinen and Bohte, 2014). There are differences in using bicycles as a transfer mode between metro station areas and railway/bus stations areas. In a city with metro lines, especially in large cities, bicycle-metro integration could be more important than bicycle-railway integration. The amount of cycling needed for metro trips could be much higher than for trips to railway stations in a city. One reason for this is that metro stations are more numerous than railway stations. Another reason is that urban metro services are usually intended for daily intra-city transport, such as commuting. Therefore, integration with cycling will be advantageous for most residents. However, railway stations mainly provide services for inter-city transport. Bicycle-bus integration is also an important way of using bicycles as a transfer mode in some countries, in particular, cities in Europe. However, in some dense Asian cities, "bus + bicycle" systems play a limited role in promoting cycling. One reason is that bus stops are densely distributed and most bus passengers integrate bus travel with walking, rather than cycling, as a transfer mode. Another reason is that bus stops are usually small spaces, and parking spaces for bicycles are very limited, particularly in central city areas. This makes cycling unattractive to many bus passengers. The other reason is that buses provide a lower proportion of trips for long distance travel than metro trains in large cities. Metro systems have much higher speeds and are more punctual than buses. Increasing road traffic congestion tends to make road buses less attractive in dense Asian cities, such as those in China. As a result, the rate of cycling to buses stations is much lower than to metro stations. In this sense, studies on bicycle-metro integration could be more important to policymaking and promoting cycling in large Asian cities such as Tokyo, Beijing and Seoul. Secondly, attitude variables, especially respondents' attitudes towards bicycles, have rarely been taken into account in the existing literature. Thirdly, the impacts of public bicycle sharing programs in transit station areas have scarcely been examined. Public bicycle-sharing programs have been implemented in many countries. It has been claimed that bicycle sharing could significantly promote bicycle-transit integration (DeMaio, 2009; DeMaio and Gifford, 2004). However, empirical evidence for this claim remains lacking in the literature.

Fourthly, the existing literature on bicycle-metro integration has mainly been conducted in Western countries, which are characterized by high car prevalence. However, case studies in growing cities in developing countries are absent. In developing countries, cycling used to be a major travel mode, including as a transfer mode to access transit services. However, cycling rates have been declining in many countries such as China (Zhao, 2014; Kenworthy and Hu, 2002). Exploring the determinants of bicycle-metro integration in growing cities in developing countries will add to the exiting literature, and aid bicycle renaissances in these countries.

This paper attempts to fill the above research gaps by looking at the case of Beijing and exploring the determinants of metro passengers' use of the bicycle as a transfer mode for their trips to/from metro stations. China used to be called the 'kingdom of the bicycle', as cycling accounted for the largest proportion of trips in Chinese cities, even in the 1980s. However, it has since lost this title due to rapid motorization, particularly in large cities (SCMP, 2015). In Beijing, the share of all cycling trips decreased from 62.7% in 1980 to 13.9% in 2012 (BTRC, 2014). Both the central and Beijing municipal governments have introduced many policies to encourage cycling, such as a bicycle-sharing program and controls on car use. At the same time, a huge amount of investment has been put into improving metro services. Since 2007, on average, 100 km of new metro lines have been built annually. The total length of metro lines in Beijing will reach 550 km by the end of 2015. Trips by metro have already reached 10.73 million per day on work days, with an additional 1.5 million on Fridays (Du, 2015). This provides a great opportunity to encourage bicycle-metro integration in Beijing. However, to date, little attention has been paid to bicycle-metro integration as part of government policy. One of the reasons for this is that empirical evidence for cycling as a transfer mode to metro station areas in Chinese cities remains scarce. While there are some studies on cycling, they are mainly focused on people who only use bicycles for commuting (Zhao, 2014).

This paper aims to specifically examine the determinants of cycling as a transfer mode between metro stations and homes and workplaces in Beijing. It examines a passenger's transfer mode either for the trip between home to metro station or the