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Going a long way? On your bike! Comparing the distances for which public bicycle sharing system and private bicycles are used

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ABSTRACT

Cities are implementing an ever widening range of initiatives to promote bicycle use with the aim of improving the sustainability of urban journeys. One strategy that is achieving the most immediate results in the promotion of bicycle use, along with the construction of bicycle lanes and bicycle parking, is the implementation of Public Bicycle Sharing Systems (PBSS), which coexist with private bicycle use. As both these systems (PBSS and the private bicycles) have their advantages and disadvantages, this paper seeks to compare the distances for which PBSS and private bicycles are habitually used by applying a propensity score matching-based model. Our findings unequivocally demonstrate that the mean journey length made by private bicycle is 700–800 m (0.44–0.5 miles) greater than those made by public bicycle. We find robust empirical evidence that there is a complementarity relationship between the two modes of transport with regard to distance. The conclusions of this study are useful for the PBSS literature in spatial/geographical terms, for the management of PBSS hire charges, and in relation to the system's suitability for different city models.

1. Introduction

Many large cities worldwide have implemented Public Bicycle Sharing Systems (hereinafter PBSS) due to their potential to motivate bicycle use (Fishman, Washington, & Haworth, 2012, 2013) and their recognition as one of the most sustainable and economical modes of transport, providing many benefits in terms of health, urban traffic and the environment (Handy, Van Wee, & Kroesen, 2014; Pucher & Buehler, 2012).

The recent academic literature has examined PBSS in greater depth from a number of different perspectives and has identified the various aspects that affect the frequency of their use (Bachand-Marleau, Lee, & El-Geneidy, 2012), and the advantages and disadvantages that they offer. Among the advantages are the fact that they are flexible systems that are convenient for city-dwellers (Shaheen, Guzman, & Zhang, 2010); that the bicycle can be used in combination with public transport (Jäppinen, Toivonen, & Salonen, 2013), and that issues such as theft and lack of parking space are minimized (Fishman et al., 2012). Among the disadvantages that can be highlighted are the vandalism that they are subjected to (Castillo-Manzano & Sánchez-Braza, 2013b), the inadequate distribution of bicycles at docking stations and choice of sites for their location (Erdoğan, Laporte, & Wolfler Calvo, 2014; García-Palomares, Gutiérrez, & Latorre, 2012), and the imbalance between bicycle supply and demand (Castillo-Manzano & Sánchez-Braza, 2013a). Other researchers such as Lin and Yang (2011) have also analyzed certain limitations to PBSS systems with respect to urban planning (especially in city center districts), as sufficient space is needed to install the number of stations required to cover the demand for bicycles (see also Lin, Yang, & Chang, 2013).

However, following Fishman et al. (2013), studies that evaluate PBSS from the spatial point of view are scarce, including evaluations of the distance covered by users, for example, despite the fact that distance is a key factor that affects the choice to use the bicycle (Heinen, Maat, & Wee, 2011a). Journey distance is therefore pivotal when deciding whether to use the bicycle or not, and so might also act as a major barrier (Handy et al., 2014; Rybarczyk & Gallagher, 2014), with greater distances to work, school or other destinations resulting in fewer and less frequent journeys habitually made by bicycle (Gatersleben & Appleton, 2007; Handy & Xing, 2011; Zhao, 2014). Distance could also play a very different role in daily decisions to make bicycle journeys depending on the type of cyclist

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(Heinen, Maat, & Van Wee, 2011b) or the purpose of the journey (Iacono, Krizek, & El-Geneidy, 2008).

Along with distance, other studies have pointed to the decision to use the bicycle possibly being influenced by a variety of other factors that might act as facilitators or barriers. In the first group are demographic and personal characteristics, such as age (Ma, Liu, & Erdogan, 2015); cultural tradition (Rietveld & Daniel, 2004); car ownership (Wuerzer & Mason, 2015); individual activities, such as picking up/dropping off children or carrying the shopping (Mullan, 2012); bicycle users' personal preferences (Heinen et al., 2011a); or other social/psychological variables, such as the way cyclists are perceived socially in a world dominated by car transport (Nankervis, 1999). The second group includes aspects related to the terrain and design of the city, such as its size (Martens, 2004); the type of city and urban layout (Hansen & Nielsen, 2014; Ma et al., 2015); the pedestrian environment (Timperio et al., 2006); elevation of the work/study address (Cole-Hunter et al., 2015); greater residential density (Heinen, Van Wee, & Maat, 2010; Pucher & Buehler, 2006); level of urban greenness around the work/study address (Cole-Hunter et al., 2015); or mixed-use development (Pucher & Buehler, 2006); and even the city or country's socioeconomic features, such as the level of income or the costs involved in owning, driving and parking a car (Pucher & Buehler, 2006). In addition, environmental factors also play a core role, including temperature, light conditions, precipitation and wind (Spencer, Watts, Vivanco, & Flynn, 2013) and even human thermal perception (Bradenburg, Matzarakis, & Arnberger., 2004), with a distinction made between weather conditions and the climate and seasonal variation patterns (Nankervis, 1999). Finally, in a third group Pucher, Dill, and Handy (2010) highlight the crucial role of public policy in encouraging cycling, which requires many different and complementary interventions, including the bicycle infrastructure environment (Snizek, SickNielsen, & Skov-Petersen, 2013) and the spread of public bike sharing systems (Parkes, Marsden, Shaheen, & Cohen, 2013); safer cycling conditions, benefited by stricter police enforcement of traffic regulations and restrictions on car use (Pucher et al. 2010); and cycling training and traffic education programs (Pucher & Buehler, 2006). Firms and campuses can also overcome barriers to bicycle use by providing bike storage and showering and changing facilities (Ransdell, Mason, Wuerzer, & Leung, 2013).

Numerous other studies have sought to quantify the distance covered using the bicycle as a means of transport. For example, Keijer and Rietveld (2000), Rietveld (2000)find that bicycles are used more frequently for distances of 0.5–3.5 kms (0.31–2.17 miles), while Ma et al. (2015), van Wee, Rietveld, and Meurs (2006), Buehler (2012), Li, Wang, Yang, and Jiang (2013) and Millward, Spinney, and Scott (2013) state that bicycles seem to be used more frequently for medium distance journeys (2–5 km (1.24–3.1 miles)). Yang, Li, Wang, Zhao, and Chen (2013) consider that bicycle travel distance is less than 6 km (3.72 miles) and expected travel duration is 30 min or less. Greater distances are found in Akar and Clifton (2009), who consider a distance of 8 km (4.96 miles) as a limit for bicycle use; whereas Heinen et al. (2011a) state that most cycling journeys are less than 15 km (9.3 miles). Yet further studies analyze the distance to public transport connections, highlighting the role that the bicycle plays as an interconnector (Yang et al., 2013). In this respect, Martens (2004) explains that most bicycle users are willing to cycle 2–5 km (1.24–3.1 miles) to a public transport stop depending on the speed of the public transport in question. The bicycle therefore has an advantage for interconnections over short distances compared to its competitors, such as walking, for example (Keijer & Rietveld, 2000), with 2.5 km (1.55 miles) being the threshold when people switch from walking to cycling (Zacharias, 2005).

Focusing on PBSS, some studies quantify the distance covered by their users. The following can be cited: Jensen, Rouquier, Ovtracht, and Robardet (2010), who consider a mean journey distance of 2.49 km (1.5 miles) and a mean journey duration of just under 15 min for the Lyon PBSS; Ma et al. (2015), who find that the majority of journeys by public bicycle in Washington, D.C. are about 1.6 km (1 mile) in length; and Zhang, Xu, and Yang (2015), who establish that PBSS are designed for short journeys of 0.8–4.8 kms (0.5–3 miles).

However, prior studies that analyze the relationship between journey length and bicycle use do not detail the difference in the distance covered by PBSS users and private bicycle owners. Even when analyzing the important role of the bicycle in general as a commuter mode of transportation (Nkurunziza, Zuidgeest, Brussel, & Van Maarseveen, 2012) the academic literature highlights the greater prevalence of shorter distances (Heinen et al. 2010), but does not differentiate between the private bicycle and the PBSS. The latter has now also become an appropriate mode for the daily journey to work or school (Martin & Shaheen, 2014; Shaheen, Zhang, Martin, & Guzman, 2011, 2012), but short commutes are once again more prevalent (Karki & Tao, 2016; Shaheen et al., 2012) with the bicycle giving way to other modes of transport for longer commute distances (Martin & Shaheen, 2014).

Given the lack of literature comparing the two types of bicycle, the objective of this study is to establish the difference in the distance habitually covered using each. Taking as our case study the city of Seville (Spain), we believe that our research could shed light on this issue since, as Mullan (2012) states, more research needs to be conducted into distances for which bicycles are used, and this is perhaps especially interesting in the case of PBSS (Fishman et al., 2013).

In short, the purpose of our study is to assess the degree to which the implementation of a PBSS in Seville has influenced cyclists' decisions to opt for using one type of bicycle or the other depending on the number of meters to be covered. Applying a propensity score matching-based model to a database constructed from a survey of PBSS and private bicycle users in the city of Seville, our study makes an entirely original contribution by indicating a suitable level of public service contingent on journey distance.

A number of different focuses can be used to analyze the effect of any given transport policy action such as that analyzed in this paper, ranging from a simple descriptive analysis to more analytical approaches. In our case, the proposed methodology is framed within the area of statistical causal inference, which is based on the estimation of the causal effect that a specific measure or action has on one or more relevant variables (Pearl, 2000). We therefore follow the so-called "Rubin causal model" (Rubin, 1974) as it was initially developed, with the subsequent contributions made by Holland (1986) taken as the starting point for the use of this model. Compared to traditional or simply descriptive analyses, this methodology enables consistent estimators of an action's effects to be obtained and isolates the effects of any contaminating variables (Rotnitzky & Robins, 1995).

Based on processes that originated out of medical experimentation, causal inference techniques are currently widely used in multiple scientific disciplines, ranging from medicine itself (Christakis & Iwashyna, 2003; Hirano & Imbens, 2001;) to a number of areas in the field of the Social Sciences, such as sociology (Morgan & Harding, 2006); the political sciences (Duch & Stevenson, 2006; Imai, 2005); and the economic evaluation of public policies (Cansino, Lopez-Melendo, Pablo-Romero, & Sánchez-Braza, 2013), to cite but a few examples. In recent years the application of this methodology has spread further in the economic evaluation scenario to include the evaluation of actions and behaviors related to transportation policies.