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How does our natural and built environment affect the use of bicycle sharing?

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ABSTRACT

Public bicycle-sharing programs (PBSP) are short-term bicycle hire systems. In recent years their popularity has soared. This study examined Brisbane's CityCycle scheme, the largest PBSP in Australia, and investigated the role of (natural and built) environmental features on usage. The study addressed four research questions: (1) What are dynamics of PBSP use in terms of travel time, speed, and distance? (2) What is the relationship between PBSP participation and cycling infrastructure? (3) How does land-use affect PBSP usage? (4) How does topography affect PBSP usage? To answer these four questions, the authors analysed large existing datasets on CityCycle usage, land-use, topography, and cycling infrastructure, which were each obtained through multiple sources. Correlation and regression analysis were employed to establish significant relationships amongst variables. It was found that: most users take short trips within the free initial period provided under the CityCycle scheme and do not incur any charges other than for membership; PBSP use is strongly correlated with the length of *off-road* bikeways near each CityCycle station; CityCycle is more frequently used on weekends and for recreational purposes; loop journeys, which are also associated with leisure trips, are popular in Brisbane, especially on weekends; leisure trips are taken at a relatively slower pace than utilitarian trips; during weekdays, a trimodal peak is clearly evident, with PBSP commute trips in the morning and evening peaks and a smaller but significant peak around lunchtime; and users avoid returning CityCycle bicycles to stations located on hilltops. These findings can collectively enhance both the siting and design of PBSP, thereby optimizing investments in sustainable mobility.

1. Introduction

Public bicycle-sharing programs (PBSP) are short-term bicycle hire schemes designed to complement mainstream transport modes. In one form or another, PBSP have existed for more than fifty years (Midgley, 2011), but it is only in the last decade that a rapid uptake has ensued in various cities across Europe, America, Asia and Australia (Corcoran and Li, 2014). The specificity of modern PBSP, compared to rental bicycle systems, is that stations can be accessed at any time and are fully automated and computerized. This allows for system-wide management allied with the capacity to monitor the state of the system in real-time (Borgnat et al., 2009).

The key phases that PBSP have undergone are referred to as generations. These include the first generation 'white bikes'; the second generation of coin-deposit systems; and the third generation, or information technology (IT) based systems.

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Recent technological and operational improvements are currently paving the way for a fourth generation, known as demand-responsive, multimodal PBSP (Shaheen et al., 2010). In its contemporary incarnation, PBSP has grown from an estimated 70,000 bicycles operating in 78 cities in 2009 (Midgley, 2009) to 139,300 bicycles operating in 125 cities in 2010 (Shaheen et al., 2010). As of 2016, a total of 1090 PBSP have been implemented in 60 countries worldwide (Meddin and DeMaio, 2016).

PBSP are increasingly framed as a climate-smart, sustainable form of transport investment. By encouraging cycling, they are purported to offer cities an opportunity to achieve transport, health and emissions goals (Kahn, 2012; DeMaio, 2009; Cavill et al., 2007; Lee and March, 2010; Shaheen et al., 2010). There is evidence that, upon the implementation of a PBSP, cities experience an increase in bicycle use and also in private bicycle ownership (Castillo-Manzano et al., 2015; Fishman et al., 2014). In Barcelona a 1% increase in the bicycle trip share was observed after the introduction of Bicing (Romero, 2008); in Paris, Vélib led to an increase of 1.5% and Lyon's Vélo'v was followed by a 2% increase in bicycle trip share (Nadal, 2007).

However, to date there is surprisingly limited evidence on the factors that influence PBSP use patterns and ridership levels. This article aims to redress this research gap through an examination of Brisbane's CityCycle scheme, the largest PBSP in Australia. The authors focus on environmental factors: in particular, incorporating both the natural (e.g. topography) and the built environment (e.g. land use, infrastructure). Personal and cultural characteristics which might also affect users' relation to PBSP (Fishman et al., 2015) are not considered in this article.

The study addresses four research questions: (1) What are the dynamics of PBSP use in terms of travel time, speed, and distance? (2) What is the relationship between PBSP participation and cycling infrastructure? (3) How does topography affect PBSP usage dynamics? (4) How does land use affect PBSP usage dynamics? To answer these questions, datasets describing CityCycle usage, land use, topography, and cycling infrastructure were each obtained and spatially integrated. The findings of this study have the potential to inform design and planning of PBSP, in their capacity to support planning for sustainable transport infrastructure. Perhaps most importantly, this study provides a starting point for a large-scale analysis of PBSP performance worldwide to support smarter and innovative urban systems.

This article is arranged in the following manner: The next section summarizes our current knowledge on PBSP, which is arguably limited. This review of the literature is followed by an overview of our case study context, the various data sets drawn upon, and the study methods. The article concludes with a discussion of the findings and charts some avenues of future research.

2. Literature review

A review of the available literature suggests that features of both the natural and the built environment (i.e., land use, topography, and cycling infrastructure) influence users' decision to use PBSP, as well as their choice of route (Schoner and Levinson, 2013). The impact of built environment attributes (such as bicycle lanes, land uses, urban location, residential density, and the like) has been studied more extensively, while the impact of the natural environment (including topography, slope, and weather) is under-researched.

Two studies, one of the Capital Bikeshare scheme in Washington DC and the other of the Bixi scheme in Montreal, found a significant correlation between the presence of bicycle lanes and PBSP usage (Buehler and Pucher, 2011; Buck and Buehler, 2012; Faghih-Imani et al., 2013). However, it remains unclear whether only segregated or off-road lanes were considered in these studies. A study of the Bicing scheme in Barcelona found that the proximity of stations to specific land uses, such as retail shops, schools, and employment centres, determined peak bicycle use (Kaltenbrunner et al., 2010). Another study set in Barcelona found that stations generally become more active as one moves from the outward edges of the city into the downtown. Also, the more central stations become noticeably more active as the day advances (Froehlich et al., 2009).

A study of PBSP spatial and temporal dynamics in London, Minneapolis, Boston, Denver, and Washington DC found significant variations in flow volumes over the course of a day. All five cities exhibit a trimodal distribution on weekdays, with strong peaks at the morning and evening rush hour, and a slightly lower peak at lunchtime, contrasting with the more normal distribution that dominates weekends - the hallmark of tourist and/or leisure activities. Usage is concentrated at the major activity nodes and commuter stations. The systems show similarity in the distribution of journey displacements and durations, despite differing climates and spatial extents (Zaltz et al., 2013). A study of the Vélo'v scheme in Lyon confirmed a trimodal distribution of trips on weekdays (Borgnat et al., 2009).

Higher residential densities around stations significantly increase the likelihood of PBSP use (Fuller et al., 2013; Bachand-Marleau et al., 2011). The siting of PBSP stations adjacent to affordable housing or within minority neighbourhoods, such as in the case of the NiceRide scheme in Minneapolis, can potentially tap into latent demand (Buck, 2013). Also, proximity of stations to public transport stations increases the likelihood of PBSP use as commuters can seamlessly switch between modes (Rissel, 2003; Martens, 2004). More generally, residential density, land use diversity, and street design (the 3D paradigm) influence the distance that cyclists and pedestrians are willing to travel from an origin to a destination point (Cervero and Kockelman, 1997; Hess et al., 2000; Krizek, 2003). Not only do land uses need to be mixed but also complementary (i.e. residential and retail, but not agricultural and industrial) in order to link potential PBSP origins and destinations (Ahillen et al., 2016).