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Spatio-temporal patterns of a Public Bicycle Sharing Program: the effect of weather and calendar events

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ABSTRACT

Public Bicycle Sharing Programs (PBSPs) have become a prominent feature across city spaces worldwide. In less than a decade, PBSPs have grown from a small number of European cities to include five continents and in excess of 200 schemes. Despite the rapid rise of this new transport opportunity, there has been limited research on the underlying dynamics of these schemes, arguably reflecting a lack of detailed data available to researchers. The current paper redresses the observed deficit using trip level data from Brisbane's 'CityCycle', the largest PBSP in Australia. These data provide an opportunity to investigate the spatio-temporal dynamics of a large PBSP system, specifically the effects of weather and calendar events on the geographic and temporal patterning of public bicycle use.

Employing novel spatial analytical techniques we explore the impact of site specific weather conditions and calendar events on the spatio-temporal dynamics of the case study PBSP. We conclude by highlighting how the results from such analyses may form part of an evidence base for policy makers, providing insights into 'best practice' and potentially informing future PBSP expansions to further enhance uptake of this non-motorised urban transport mode.

1. Introduction

Public Bicycle Sharing Programs (PBSPs) have a long history dating back to an unsuccessful 1965 pilot scheme in Amsterdam, which was plagued by vandalism and theft (Shaheen et al., 2010). The recent explosion in the size and scale of PBSPs has been facilitated by the digital registration of PBSP users pioneered in a small scale program (25 bicycles during the scheme's pilot phase, eventually increasing to 75 bicycles) at Portsmouth University in 1996 (Black & Potter, n.d.), and subsequently rolled out at a city-wide scale in Renne in 1998, followed by Munich in 2000. These early programs were replicated at still larger scales in Lyon in 2005 (4000 bicycles in the scheme) and then Paris in 2007 (7000 bicycles initially expanding to 23,600) – see Henley (2005) and DeMaio (2009). Rapid growth in PBSPs followed and, at the time of writing, PBSPs can be found in five continents and include in excess of 200 schemes (Ahillen et al., accepted for publication). The system for tracking bicycles and the identity of bicycle users in the modern PBSP systems has resulted in rich datasets with the potential to unveil the underlying dynamics of PBSPs, and provide insights into the contribution of these schemes to urban public transport.

Two distinct types of data capturing the dynamics of PBSPs have emerged in recent years: data capturing *stocks*, and data capturing *flows*. Stock data track variations in the number of bicycles docked at stations within a PBSP network. Such data can provide insights into spatio-temporal fluctuations in demand across a system (see Kaltenbrunner et al., 2010), but do not capture the underlying mobility behaviour (e.g. trips). Flow or trip data have emerged much more recently, and are consequently more limited in their availability. At present, the use of PBSP trip level data has been confined to a small number of studies that have been restricted in scope to measuring operational dimensions of the PBSP. One example of such an operationally-focussed study is the analysis of spatial flows by Jensen et al. (2010). The primary focus of this work was to determine the average transport speed within the network. A second study of the Parisian PBSP (Vélib) by Nair et al. (2013) was concerned with the issue of establishing 'balance' across the bicycle network. To date, there has been little attempt to analyse these rich trip level datasets with the more generic goal of better understanding the spatio-temporal dynamics of human spatial mobility. It is the purpose of the current paper to demonstrate how trip level data can be interrogated to help shed insight into the dynamics of PBSP journeys. We

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demonstrate the utility of these data by exploring how external effects, including weather conditions and calendar events (i.e. public holidays and weekends) impact on the spatial distribution and timing of PBSP trips in Brisbane, Australia.

Weather conditions are known to exert an influence on cycling patterns. Previous studies have revealed the significant of role inclement weather as a detractor whereas warm and dry weather conditions were found to encourage both commuting and in particular recreational bicycle trips (see for example, Nankervis, 1999; Brandenburg et al., 2007; Parkin et al., 2008; Heinen et al., 2011; Thomas et al., 2013). In addition, calendar events such as public holidays and weekends have also been identified as a factor influencing cycling dynamics (see for example, Brandenburg et al., 2007; Borgnat et al., 2011). Studies have suggested such periods of time reflect changes in the routine activities of individuals and families which in turn have the potential to bring about both increased and reduced prevalence in the spatio-temporal patterns of bicycle trips. Taken together, weather conditions and calendar events (for example, a warm, dry and light wind public holiday versus a cool, wet and windy weekday) potentially have a significant role to play in explaining the spatial distribution and timing of PBSP trips.

The visualisation component of the analysis requires the integration of existing spatial exploratory analysis tools. In this paper we embed flow maps (Thompson and Lavin, 1996), which graphically present origin–destination flow matrices, into the comap (Brunsdon, 2001), which displays spatial information conditioned on one or more external variables. This new analysis technique, we term the *flow-comap,* which in combination with a regression modelling exercise and a suite of metrics is demonstrated to be capable of illuminating the underlying spatio-temporal dynamics of our case study PBSP, Brisbane's CityCycle Scheme. The *flow-comap* is able to graphically depict subtle changes in usage patterns under different weather conditions (for example, a hot versus a cold day), and across various calendar events (for example, a public holiday versus a 'normal' working day).

The remainder of the paper is structured as follows: In Section 2, the role and benefits that PBSPs potentially hold for our urban areas is outlined, along with the number of studies that have begun to explore the rich databases PBSPs are generating. In Section 3, the case study area and various data drawn upon in this paper are described in detail. In Section 4, results are presented, first at the system-wide or aggregate level, and second at the sub-system scale using the *flow-comap*. This is followed by a discussion of the insights that our exploratory data analyses bring in Section 4 and concluding remarks in Section 5.

2. Background

2.1. The rise and benefits of PBSPs

PBSPs have been in existence for the past 50 years, however, it is only in the last couple of years that these systems have gained currency as an important citywide transport strategy; addressing the twin challenge of reducing traffic congestion and providing sustainable transport alternatives in cities. From an estimated 70,000 bicycles in operation in 78 cities across 16 countries in 2009 (Midgley, 2009), this numbers increased to 139,300 bicycles spread across 125 cities in 5 continents (Europe, North America, Australia and Asia) a year later (Shaheen et al., 2010). A more recent count, of PBSPs with 100 or more bicycles and 10 or more stations, estimates that there are in the order of 200 PBSPs around the globe, of which 70 per cent were implemented between 2010 and 2012 (Ahillen et al., accepted for publication). Studies of PBSPs have lagged behind implementation reflecting the fact their datasets have only recently become available.

Nonetheless, there are a number of studies reporting the social and environmental benefits of PBSPs. For example, Montreal's bike sharing scheme has been found to save over 1.3 million kilograms of greenhouse gases since inception in May 2009 (DeMaio, 2009). More broadly, the implementation of PBSPs has been demonstrated to increase the overall cycling share in cities with the effect of decreasing carbon emissions and reducing urban traffic congestion (Shaheen et al., 2010; DeMaio, 2009; Cavill and Davis, 2007; Cavill et al., 2006). Barcelona (Romero, 2008) and Paris (Nadal, 2007), for example, have seen a 1 and 1.5 percentage point increase per annum in the proportion of bicycle journeys, respectively. In 2007, Lyon's bicycle count increased by 75 per cent contributing to a two percentage point increase in bicycle trips across the city. According to Cavill and Davis (2007), empirical results have shown that bicycle sharing has significantly improved individual fitness and contributed towards public health improvements, such as a risk reduction on a range of health problems, most notably heart disease and cancer (Cavill and Davis, 2007; Cavill et al., 2006).

While cataloguing the strengths and weaknesses of PBSPs undoubtedly assists in better understanding their role within larger urban transport systems, we argue that the ultimate success of PBSPs is dependent on improved knowledge of the fundamental dynamics of the system (e.g. volume, pattern and timing of trips) along with the extent to which various system attributes (e.g. number of stations, climate regime, etc.) affect usage. O'Brien et al. (2014) highlights the importance of developing such knowledge in their analysis of 38 PBSP located across Europe, the Middle East, Asia, Australasia and the Americas. Furthermore, they stress the need for a PBSP-specific understanding of dynamics given that flow patterns vary widely between systems, resulting in unique challenges for operators in maintaining an optimal distribution of bicycles to meet variations in demand.

To date, considerably less attention has been dedicated to empirically examining the underlying dynamics of these schemes than to exploring system-wide patterns (Borgnat et al., 2013). This situation is arguably underpinned by a general lack of data available to researchers, a status that is slowly changing as more PBSP operators open up access to both stock and flow data. It is crucial, however, that planners not only understand the contexts in which PBSPs are implemented, but also are able to draw on reliable tools and metrics to interrogate stock and flow data. Such tools and metrics will facilitate the implications of evolving policies affecting PBSPs use to be evaluated along with evidenced-based changes to schemes implemented that better respond to mobility needs of its catchment populace.

2.2. Spatial analytical research on PBSPs

Since 1965 PBSPs have evolved through four generations from the initial introduction of the first generation white bicycles (or free bicycle systems), to the coin-deposit systems of the second generation, followed by the integration of information technology-based systems in the third generation and most recently the roll-out of demand responsive systems as part of the fourth generation (DeMaio, 2009; Shaheen et al., 2010). As such, operators of third generation PBSPs onwards are now able to gain access to real-time usage data of their networks. Collected via mobile devices or other ICT-based measures, this information can then be drawn upon to enhance our understanding of individual traveller's behaviour, offer real-time travel information, and also present personalised location-based services. Moreover, fine-grained data on the status of shared bicycles also enables an empirical measurement of the impacts of proposed system improvements or policy changes (e.g. fare restructuring) as well as the results of force majeure on the system (e.g. flooding).