Transportation Research Part A 100 (2017) 202–214

Contents lists available at ScienceDirect

Transportation Research Part A

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

Bicycle sharing system ‘success’ determinants

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ARTICLE INFO

Article history:
Received 30 August 2016
Received in revised form 11 April 2017
Accepted 21 April 2017

Keywords:
Bicycle-sharing systems
Bike-share
Success
Determinants
Performance

ABSTRACT

Many municipalities assert bicycle sharing systems (BSS) as having many benefits, justifying their adoption, yet few explicitly state the purpose of their system making comparison or determination of success impossible. In addition, the apprehension of many BSS operators to share data further hinders comparison. This paper estimates the number of daily trips from publicly available data for 75 BSS case studies across the world and provides trips per bike per day scores as a comparison of performance and success. Results reveal that a third of case studies have fewer than the psychologically important one trip per bicycle per day. To ascertain what factors are associated with this metric we estimate models with independent variables related to system attributes, station density, weather, geography and transportation infrastructure. Our analysis provides strong evidence undermining the 'network effect' promoted by influential BSS policy makers that expanding system size increases performance. Finally our results describe and discuss causal variables associated with higher BSS performance.

1. Introduction

Many bicycle sharing systems (BSS) are regularly called successful by operators and politicians without providing a reason or metric. While statistics are sometimes quoted, they often lack comparative potential or the methodologies and assumptions used to derive these values appear dubious. As most BSS operators do not provide consistent and comparable metrics of system use, mainly the number of trips per day, the evaluation of individual systems against others is largely impossible. By using a common metric this paper provides a first comparison of a wide number of BSS in Australia, Europe and the Americas, followed by an analysis of what factors impact the metric.

The criteria for a BSS being successful depends on a purpose being defined, something that is done vaguely or typically not at all (Ricci, 2015). New York City's BSS's purpose is to offer an affordable transportation alternative at no cost to taxpayers (New York City, 2012) yet is called a success based on trips completed and unspecified emission reductions (New York City, 2013). There exist many reported benefits of BSS related to road and public transit congestion, carbon emissions, cycling modal share, health and equity, among others (Fishman et al., 2013; Ricci, 2015; Shaheen et al., 2010). Unfortunately some suggested benefits have been shown to be hard to measure, trivial or non-existent.

While social equity is a plausible effect of BSS due to the relatively low costs of the service, Fishman (2015) and Ricci (2015) summarize recent demographic studies from North America, Europe and Australia showing members to more likely be wealthier, younger, white, male and own a car, compared to the local population. Hoffmann (2016) call BSS in the US "one

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http://dx.doi.org/10.1016/j.tra.2017.04.020
0965-8564/

of the most inequitable forms of sustainable transportation infrastructures" (p. 121). Gender disequity is also present. Inadequate cycling infrastructure decreases BSS and private utility cycling due to women being more risk averse (Garrard et al., 2012; Goodman and Cheshire, 2014). Additionally, women using London's BSS have reduced health benefits, compared to men, owing to increased rates of injury (Woodcock et al., 2014). The cost of BSS membership also impacts user demographics and equity (Goodman and Cheshire, 2014). Membership discounts are present available for BSS in Chicago, Boston, New York and Washington, among a few others, but do not address larger issues of access and station placement (Hoffmann, 2016). The shift from sedentary travel modes to cycling has clear health benefits but net quantities are overstated due to the reduction in walking, which has greater health benefits for a fixed distance travelled (Fishman et al., 2015a; Murphy and Usher, 2014; Woodcock et al., 2014). Reduction in other public transport systems is not consistent, the use of rail by BSS users has been shown to increase in some cities and decrease in others (Ricci, 2015). Reductions in road congestion are also unproven (Ricci, 2015). Perhaps the most exaggerated BSS benefit is the reduction in carbon emissions. Multiple studies have shown that publicized estimates of carbon dioxide reductions are often overstated as only a small portion of car trips are replaced using BSS (Ricci, 2015). In the case of London it is estimated that the vehicles rebalancing bicycles within the system may surpass any emission reductions from modal shift (Fishman et al., 2014a). So while BSS appear to have many benefits some are not consistent or as salient under scrutiny.

Bicycle sharing systems do have indisputable benefits however. They provide an alternative mode of transport, increase accessibility, trip resilience and flexibility, lower the barrier to exploring urban cycling, increase the visibility of bicycles, bicycle awareness by drivers and normalizing the image of cyclists in casual clothing (Fishman et al., 2013; Goodman et al., 2014; Murphy and Usher, 2014; Ricci, 2015). These benefits, however, do not spread evenly among classes and race (Hoffmann, 2016).

Between their promoted 'benefits' and the lack of goals, stating that an individual BSS is successful is challenging and the comparison of multiple systems arduous. Media (Bialick, 2013; Cripps, 2013; Goodyear, 2013; Mead, 2016), reports (Curran, 2008; Gauthier et al., 2013) and publications (Fishman, 2015; Fishman et al., 2013; Ricci, 2015; Zhao et al., 2014) use the number of trips per day per bike (TDB) as a comparable measure of success for small numbers of BSS. As success depends on a goal however, we refer to this metric as one of *performance*.

The first goal of this work is to provide a comparison of a large number of BSS using the TDB performance metric to encourage debate, especially, but not only for low performance systems, regarding what purpose their BSS has. Contention of economic, social equity and environmental benefits may irrelevant if systems are little used.

Our second goal is to determine what attributes impact BSS performance. Past research has studied the effect of weather, infrastructure, station density and demographics on trips within individual BSS (Corcoran et al., 2014; Faghih-Imani et al., 2014; Gebhart and Noland, 2014). Zhao et al. (2014) evaluates the effects of demographics, employment, system members and size as well as quality of service over one month for 69 BSS in China. We provide a comparison of BSS attributes, system compactness, geographic variables, weather and transportation infrastructure for 75 case studies around the world over a period of 12 months. Beyond simply describing which variables are related to performance we also describe those that are explicitly not.

Given this context, we begin by detailing our data and performance metric as well as the choosing of independent variables and expected impact on TDB (Section 2). In the results (Section 3) we present and compare TDB scores across case studies, the effect of system size on performance and our model coefficients before discussing (Section 4) causality, limitations and policy recommendations.

2. Data

2.1. Case study selection and data collection

In March 2013 we selected BSS with a minimum of 10 stations that require bicycles be docked (not free floating as is common in Germany and some newer BSS in North America). Our 75 case studies (Table 3) are predominantly in Europe (49) and the United States (18), but also in Canada (3), Brazil (2), Australia (2) and Israel (1). While there are many BSS in Asia (Zhao et al., 2014) data access was limited.

We gathered the number of bikes and spaces available at each station at a ten minute interval between March 2013 and July 2014. As some BSS opened after March 2013 later the number of records varies between case studies, totalling 904 months of data. Only months with more than 15 days of valid data, each with 95% of daily records, are used. Using the station level data we can estimate the number of trips per day, T_d (Médard de Chardon and Caruso, 2015). The station level data also provides a good estimate of the number of bicycles in the system, B, as well as the quality of rebalancing in terms of outages, where stations have no docks or bicycles available (Médard de Chardon et al., 2016).

2.2. Performance metric

To compare performance we calculated a global trips per day per bike (TDB) score for each BSS. From T_d we calculate a monthly mean, $\overline{T_d}$, normalized by the maximum number of bicycles observed docked during the month, B_M, i.e., $TDB_M = \overline{T_d}/B_M$. As BSS usage varies with season we take the average of any duplicate months across years. The mean of