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Route choice stickiness of public transport passengers: Measuring habitual bus ridership behaviour using smart card data ☆

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ABSTRACT

This paper explores how we can use smart card data for bus passengers to reveal individual and aggregate travel behaviour. More specifically, we measure the extent to which both individual and bus routes exhibit habitual behaviour. To achieve this, we introduce a metric called *Stickiness Index* to quantify the range of preferences of users that always select to travel on the same route (high stickiness) to those with a more varied patterns of route selection (low stickiness). Adopting a visual analytic and modelling approach using a suite of regression models we find evidence to suggest that stickiness varies across the metropolitan area and over a 24-h period wherein higher stickiness is associated with high frequency users where there is substantial variability of route travel times across all alternatives. We argue that our findings are important in their capacity to contribute to a new evidence base with the potential to inform the (re)-design and scheduling of a public transit systems through unveiling the complexities of transit behaviour.

1. Introduction

Collectively, our individual travel behaviour decisions have important consequences for transit systems. Modal selection, timing and route choice each combine to influence travel experience and contribute to congestion and environmental pollution. From a public transit system perspective, people's trip making behaviours have major implications for service delivery in their capacity to place loads in particular locations of a system, specific routes and at certain times. In order to design and operate efficient and effective public transit systems that offer a competitive alternate to private transit options, there is a need for us to both capture and develop analytic approaches to reveal transit behaviour decisions and travel experience.

What we know from travel behaviour scholarship is that people's trip making varies by a number of individual factors including gender (Gordon et al., 1989), age (Chudyk et al., 2015), occupation (Rasouli et al., 2015), household characteristics (Dieleman et al., 2002), socio-economics (Kotval-K and Vojnovic, 2015) and is conditioned by land use (Hong et al., 2014) and urban form (Handy, 1996). What is less evident from this literature is the spatio-temporal dimension of travel behaviour and how individual trip making decisions translate to spatial and temporal patterns across a transit system. Traditionally research in this area has been limited by the availability of suitable data sources, a lack of suitable analytic tools and

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restrained by computation capabilities (Yue et al., 2014). Whereas data and computational constraints have now eased, what has become increasingly apparent in the advent of 'big data' is the growing role played by algorithms to mine data and reveal travel behaviour dynamics placing them in the context of system-wide patterns (Kwan, 2016).

The emergence of smart card systems for automated fare collection has been increasingly recognised by transport researchers as a valuable source of (big) data to understand a growing range of public transit dynamics, including travel demand variability (Morency et al., 2007), origin-destination estimation (Munizaga and Palma, 2012), trip purpose inference (Lee and Hickman, 2013), spatio-temporal patterns (Tao et al., 2014a), service reliability (Ma et al., 2015), modal transfer behaviour (Sun et al., 2015), and passenger experience (Chu and Lomone, 2016), to name only a few. Advantages of these data have been noted in their capacity to contribute to strategic, tactical and operational system management (Pelletier et al., 2011).

Despite a growing body of literature on the use of smart cards in travel behaviour research, a relatively little attention has been paid to investigating habitual aspects of travel behaviours. It has been noted that daily travellers tend to make the same choices over and over again (Gärling and Axhausen, 2003; Schlich and Axhausen, 2003). Such habit effects can lead travellers to make decisions that are not optimal, from an economical point of view. This poses a great challenge to transport modelling and planning as these behavioural tendencies do not conform to the basic assumption of conventional choice models that passengers make rational decisions to maximize expected utility. As such, there is a need to accurately measure and analyse habitual travel behaviour to take this into account in travel choice models and, thus, to design travel demand management strategies that can effectively influence travel choices. Most existing studies addressing this issue, however, focus on car drivers—habit effects on drivers' mode choice (Innocenti et al., 2013; Thøgersen, 2006) and route choice (Prato et al., 2011; Vacca and Meloni, 2015)—and habitual behaviours of bus passengers remain largely unexplored.

The goal of this study is to fill this gap by investigating habitual behaviours of bus passengers' route choice decisions using smart card data. The main difficulty in studying habitual travel behaviour has traditionally been the lack of suitable data that allow the observation and identification of intrapersonal and interpersonal variability in travel behaviour over a sufficiently long period of time. This issue is addressed in this study through the use of smart card data that cover a period of six months. Drawing on a single large smart card database of bus ridership, we first construct travel trajectories for individual passengers across a metropolis. Travel trajectories comprise a set of spatio-temporal points describing a stop-to-stop sequence of an individual bus passenger travelling through the network. By tracking travel trajectories of each passenger over the six-month period and matching them with other passengers' trajectories, we identify a set of routes that are available for each origin-destination (OD) pair and investigate how those routes are utilized by each passenger. We introduce the concept of *stickiness* to describe an individuals' tendency towards 'sticking' to only one route regardless of the availability of multiple alternative routes. We define a metric called the *Stickiness Index* (SI) to quantify the range of preferences from users that always travel on the same route (high stickiness) to those with a more varied pattern of route selection (low stickiness).

The contributions of this paper to the existing literature are as follows: First, we mine travel patterns based on *trajectories* of individual passengers, rather than boarding and alighting points that many existing studies have focused on. Detecting travel regularities and identifying similar travel behaviours based only on start and end points of journey arguably falls short of being able to consider a full picture of individual journeys. In this study, whole trajectories of individual passengers are constructed from smart card transaction records and a trajectory clustering method is used to identify travel regularities in travellers' day-to-day route choice patterns. This allows us to capture travellers' perceived route choice sets by taking into account the actual shape of a path in defining similar routes. Second, we take a *big data* approach to understanding habitual route choice behaviour, performing both longitudinal and cross-sectional analyses at a metropolitan-wide scale. Using a six-month smart card dataset that yields 24 million trajectories that were generated by 814 thousand users, we measure the route choice stickiness of individual users for about 5500 unique OD-pairs and compare each across users and ODs to reveal the key factors that explain route stickiness. Given that most previous studies investigate route choice behaviour from only a few selected OD-pairs with data that covers a few days or weeks, this study extends the scale in terms of the length of the observation period and completeness of geographical coverage and passenger population to offer a more comprehensive examination. Third, we propose a simple metric, the *Stickiness Index*, to measure and quantify individual bus passengers' route stickiness tendency. By extending this metric to the OD-level, gives an indication of the collective behaviour of travellers of a particular OD, this study also reveals individual travel behaviours in the context of system-wide patterns.

The remainder of the paper is organised as follows: The next section provides an overview of the current scholarship on the use of smart card data in travel behaviour studies. Section three proposes a methodology for measuring habitual route choice behaviours of bus passengers by introducing the notion of stickiness and the associated metrics. The case study area (Brisbane, Australia) is introduced in section four along with a discussion of the data and empirical approach. Section five presents the results in terms of both user-level characteristics and system-wide patterns before offering a set of tentative conclusions and avenues for future research in section six.

2. Background literature: The use of smart card data in travel behaviour studies

A rich and growing body of literature has emerged in recent years that discusses the use of smart card data in travel behaviour analysis and modelling. In an early piece, Bagchi and White (2005) discuss the potential of public transport smart card data for travel behaviour analysis in which they summarise their various benefits and limitations over traditional survey