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Exploring bikesharing travel time and trip chain by gender and day of the week

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ABSTRACT

As a pinnacle of green transportation with transit attributes, bikesharing has become particularly popular since the mid-2000s. Taking the opportunity of accessing to a large-scale and smart-card-based dataset from Nanjing, China, this paper explores bikesharing travel time and trip chain patterns by gender and day of the week. Bikesharing trip chain is defined and classified into four types according to the complexity of chain. *Z*-score analysis and visual analytic techniques, as well as chi-statistic, are adopted to explore the variation of bikesharing travel time and trip chain. The results suggest that the residential areas are the primary fountainhead where bikesharing demands generate, whilst the rail stations are the most attractive hubs that the bikesharing trips terminate at. The travel time between the same bikesharing station can be two times longer than it is from one station to another. Bikesharing travel time also differs significantly in terms of gender and day of the week. With respect to bikesharing trip chain patterns, significant variation is observed between men and women, as well as between weekdays and weekends. Findings indicate that women are more likely to make multiple-circle bikesharing trip chains than men, especially on weekdays. Moreover, the visual analytic gives bikesharing operators direct sense of the variation of bikesharing trip chain patterns with respect to gender and day of the week. Last but not least, this paper finds that there is big gap between bikesharing demand and supply in the adjacent area of rail stations in Nanjing, in particular, during afternoon peak hours.

1. Introduction

As a pinnacle of green transportation with transit attributes, bikesharing has become particularly popular since the mid-2000s (Parkes et al., 2013). Targeting at facilitating daily trips, bikesharing provides people flexible short-term public bicycle access where the users get the service at multiple bikesharing stations on an “as-needed” basis (Shaheen et al., 2010; Zhang et al., 2014). By encouraging the use of bicycles for regular trips, public bikesharing not only provides a cost-effective solution for mitigating CO_2 emissions but also extends the reach of motorized public transportation systems (Shaheen et al., 2013).

In most recent bikesharing schemes, the bike usage information can be continuously reported to the central “IT-based” databases through smart card (Beecham and Wood, 2014). The new databases produced by this emerging urban transport

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technology enables us to study the cycling behavior in a continuous, large-scale and non-invasive way (Beecham and Wood, 2014; Wood et al., 2011), which is more instructive for implications in the planning, operation, management and maintenance of bikesharing systems.

To elucidate the complicacy of bikesharing systems and generate insights into sustainable transport systems, the technique of bikesharing data mining is widely studied and adopted recently. Bikesharing data mining could be found in studying bikesharing travel speed and paths (Jensen et al., 2010), dynamic use statuses (Wood et al., 2011), gendered travel behaviors (Beecham and Wood, 2014), and the benefits of "opening policy" (Lathia et al., 2012). However, the real-time data (usually the number of available bikes and docking spaces) used in these studies are generally collected from the schemes' web sites (Lathia et al., 2012; O'Brien et al., 2014). With the advances in science and information technique, we now embrace more sophisticated means for data collection, of which smart-card-based journey information is a classic one and is given substantial attention in recent studies (see e.g. Beecham and Wood, 2014; Wood et al., 2011; Jensen et al., 2010). The comprehensive and precise big data regarding trip-related information provided by smart-card-based records enables researchers to study the more complex motivations and barriers that might affect bikesharing adoption and level of service (Beecham and Wood, 2014).

To improve the performance of existing bikesharing program and inform future development policy, the operator of a bikesharing system in Nanjing – the Transportation Authority of Jiangning District – entrusts our researchers with the proposal of appraisal and improvement of Jiangning's Public Bike System. A full set of customer records containing individual's membership ID, name, gender, and home address were provided, along with a database of over 100 thousand customers' journeys and over 10 thousand managers' bicycle rebalancing activities observed between September 1th and October 31th 2012. This big-data availability enables us to explore bikesharing travel activities and patterns by using the bikesharing trip chain theory and visual analytics technology. In this introduction, after a brief review of trip chain theory and visual analytics technology, we present the outline of this paper.

One important tools for describing the feature of multiple travel activities in a day is the trip chain, which has been widely used for analysis of travel behavior (Strathman et al., 1994; McGuckin et al., 2005; Bricka et al., 2012; Shen and Stopher, 2013), public transport usage (Hensher and Reyes, 2000; Currie and Delbosc, 2011), and trip mode choice (Krygsman et al., 2007). As bikesharing smart card is capable to record customers' pickup and drop-off activities and trip starting/ending time at unattended bike stations, a bikesharing trip chain can thus be uniquely identified by tracking these activities and information.

Traditional trip chain analysis relies heavily on travel survey data (Golob, 2000; Primerano et al., 2008), which is very costly and difficult to be implemented at a multiday level due to the low response rate and accuracy (Ma et al., 2013). The presence of smart-card-based data resolves this problem to some extent by which the trip information can be recorded effortlessly. However, exploring individual trip behavior from this type of dataset is still a challenging topic (Munizaga and Palma, 2012; Morency et al., 2007; Kitamura et al., 2006), partially in cases when some variables measuring individual attributes (such as gender and home address) in the smart-card-based journey records are missing.

Despite the difficulties in data collecting and the diversity objectives in previous survey-based studies, a lot of common findings and conclusions are arrived at in some existing studies, such as the trip chain behavior are proved to be significantly affected by some individual attributes (McGuckin and Murakami, 1999; Golob and Hensher, 2007; Lee et al., 2007). In particular, numerous observational-based studies (e.g. Bonham and Wilson, 2012; Emond et al., 2009; Hensher and Reyes, 2000; McGuckin and Murakami, 1999) indicated that the gender gap in trip chain and cycling behavior is salient. While acknowledging that these findings and conclusions are reasonable and to some extent, elucidate the underlying trip patterns observed from corresponding trip data, the deficiencies inherited from the data collecting technique such as small size and low accuracy may significantly deteriorate the persuasion of those findings (Beecham and Wood, 2014; Dill, 2006). To further test those conclusions and explore the bikesharing trip pattern in depth, a large-scale and non-invasive smart card data is applied in this study, which simultaneously integrates customers' and journeys' information. Moreover, visual analytics technology is used to spatially present bikesharing's trip chain patterns.

Visual analytics, which can be realized through displaying hardware controlled by processing software, has been used extensively in microscopic and macroscopic simulations of pedestrian behavior (Galland et al., 2014; Zeng et al., 2014), vehicle driving (Hou et al., 2014), and traffic organization (Vanek et al., 2013). It assists both transportation agencies and researchers through visualizing intuitive perspective. By adopting visual analytics, Beecham and Wood (2014) found that in comparison with male users, female users of the London Cycle Hire Scheme appear to be highly spatially structured. It is worth noting that unlike global positioning system data, bikesharing smart card data provide no details about the specific travel pathway between docking stations (Wood et al., 2011). This is a main limitation of smart card data. To deal with this issue, this paper uses two types of curves – Elliptic curves and Bezier curves – to link bikesharing origin and destination. Moreover, we propose weighting factors to highlight the differences in travel time and flow magnitudes of various bikesharing trip chains. In short, the objective of the current paper is to assist both bikesharing operators and transit agencies by: (1) defining major types of bikesharing trip chains to classify users' travel activities and patterns in a whole day; (2) describing the heterogeneity of bikesharing travel time and trip chain with respect to gender and day of the week; and (3) analyzing the spatial visualization of bikesharing trip chain patterns differentiated by land use, gender, and day of the week. With these specific objectives, we aim to shed light on the improvement of bikesharing operation and management.

The remainder of this paper is organized as follows. Section 2 presents the scheme context and datasets used in this paper. Section 3 defines bikesharing trip chain types and introduces the analysis techniques. Section 4 describes the