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Where does bicycling for health happen? Analysing volunteered geographic information through place and plexus

Greg P. Griffin [a,b,*], Junfeng Jiao [b,1]

[a] Texas A&M Transportation Institute, Public Engagement Planning Program, 505 E. Huntland Drive, Suite 455, Austin, TX 78723, USA
[b] The University of Texas at Austin, Community and Regional Planning, 310 Inner Campus Drive, Austin, TX 78712-1009, USA

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ABSTRACT

Research on the role of bicycling for health through physical activity has been limited by the lack of information on where bicyclists ride. New big data sources available through smartphone-based applications provide a rich source to provide bicycle volume data more comparable to the scale of information available for automotive and public transit modes. In the case of smartphone apps for fitness tracking, results of this data can be used similar to the growing application of global positioning systems for automotive travel surveying. The authors evaluate data from Travis County, Texas for the purpose of determining where bicyclists ride, primarily for fitness purposes. Ride trip volumes are evaluated with residential and employment density, land use diversity, bicycle facilities and terrain to characterize places chosen for bicycling for health. Though limited to bicycle rides and routes voluntarily logged using the smartphone app, this method provides promise for applications in multi-modal transportation planning and health impact assessment studies.

1. Introduction

Research on bicycle travel choices are beginning to connect volume data with routing information, recently bolstered by the use of global positioning systems (GPS). This study evaluates a burgeoning big data source of volunteered geographic information (VGI) through a popular smartphone application with the combination of land-based activities and complex of transport networks that Levinson and Krizek (2008) dubbed *Place and Plexus* (2008). They use the term plexus to refer "…to the complex of networks that connect people and places", which is an important distinction from merely speaking of a given roadway segment or group of segments (2008, p. 1). In transport for health as in other purposes, a full complex of networks provides the combination of access and mobility that allow pursuit of goals. In the case of bicycling for health, this could include seeking routes for physical challenge and fun as much as personal safety (Buehler and Pucher, 2011; Lusk et al., 2014; Winters et al., 2010). However, few studies have evaluated revealed bicycling behaviours with a large-scale data set.

This study aims to uncover characteristics of fitness-oriented bicycling route and context choices as recorded through the Strava smartphone application. The study also evaluates the use of passively-collected mobile application data as resource for transportation planning. Researchers use a combination of network-based roadway characteristics anticipated to attract bicycling for health, along with contextual attributes of density, diversity, and design that have been associated with active transportation, (Cervero and Kockelman, 1997; Ewing and Cervero, 2010).

Though the use of smartphone applications to evaluate mobility is relatively new, observational methods were popularized in the field of planning beginning in the 1960s (Gehl and Svarre, 2013; Jacobs, 1961; Whyte, 1980). The use of GPS provided a framework for digital analysis of personal paths on a new level of detail and breadth simultaneously, enabling analysis of bicycling beginning in Portland, Oregon in 2007 (Broach et al., 2012; Dill, 2009; Hood et al., 2011; Hudson et al., 2012). Each of these studies specifically recruited participants, and used specialized equipment or software. This study is the first to passively collect GPS data for analysing bicycling trips, focusing on a sample dataset in Travis County, Texas.

* Corresponding author. Tel.: +1 (512) 407 1111.
E-mail addresses: g-griffin@ttimail.tamu.edu (G.P. Griffin), jjiao@austin.utexas.edu (J. Jiao).
[1] Tel.: +1 (512) 475 6158

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1.1. Monitoring bicycling as a form of monitoring community health

Though the relationship between bicycling as active transportation and positive health outcomes is well established (Calise et al., 2012; Edwards and Mason, 2014; Rojas-Rueda et al., 2011; Sallis et al., 2004), the use of individual monitoring methods to evaluate health impacts was first employed by Dill using GPS (2009). Most of the trips in Dill's study were for transportation rather than fitness purposes, and 59% of the participants recorded at least 150 min of bicycling over a 7-day period. They averaged 16–21 km per hour, equating to 6–8 metabolic equivalents (Dill, 2009, p. S101). Bicycling's health benefits extend to physical and social health, as well (Underwood et al., 2014), and planners have an important role in fostering health through transportation infrastructure and programmes (Cohen et al., 2014).

Monitoring health at the level of a state or nation often incorporates aggregation of statistics on health outcomes directly from the medical community, but the behavioural risk factors more commonly employ residential surveys. The world's largest on-going health survey system is the United States' Behavioral Risk Factor Surveillance System (BRFSS), which includes a core set of questions from the Centers for Disease Control and Prevention, and states may add questions of local interest as well (U.S. Centers for Disease Control and Prevention, n.d.-a). The BRFSS includes several components of interest to physical activity researchers, such as obesity and diseases related to inactivity. The Texas edition includes a single question related to exercise: “During the past month, did you participate in any physical activities?” to which 80.2% of respondents in the region of this study, the Austin-Round Rock, TX Metropolitan Statistical Area, responded affirmatively (U.S. Centers for Disease Control and Prevention, n.d.-b). Surveys of travel provide additional insights on physical activity from bicycling and walking. The American Community Survey also asks a single question related to active travel: “How did this person usually get to work LAST WEEK?” (McKenzie, 2014), which obscures active commutes taken under half of the days in a workweek or active travel for any other purpose (Griffin et al., 2014). The National Household Travel Survey (NHTS) provides the most in-depth standard survey in the United States, asking questions related to the frequency of bicycling or walking for multiple trip purposes, trip distance, time, and other factors (Federal Highway Administration, 2010). The 2012 National Survey of Bicyclist and Pedestrian Attitudes and Behavior provides the most comprehensive and recent nationwide study of active travel, including the extent to which respondents engaged in bicycling and walking outdoors; the availability and use of bike paths and lanes in the community; and changes in bicycling and pedestrian behaviour and attitudes since 2002 (Schroeder and Wilbur, 2013). Several other valuable surveys and methods are reviewed in “The Colorado Mile Markers” report (Charlier et al., 2012). Each of these surveys can be a source of population-level monitoring with substantial time gaps, but local methods need to be included to understand facility-level behaviours (Lindsey et al., 2014).

Though regular bicycle traffic monitoring is not yet regularly practiced by most transport agencies, many are beginning to do so for multiple reasons, such as evaluating the sufficiency of infrastructure; to provide justification for funding allocation; to evaluate crash rates; to compare traffic volumes in various cities and other reasons (Luukkonen, 2011). Traditional means of monitoring bicycling include manual counts (Nordback et al., 2013), intercept and mail-back surveys (Forsyth et al., 2010), pneumatic tube counters similar to vehicle counters but calibrated for bicyclists (Hyde-Wright et al., 2014) and others (Griffin et al., 2014). Each of these methods has its advantages, but each is almost impossible to accomplish over a broad area simultaneously, which is why crowdsourced methods are gaining interest in planning.

1.2. Crowdsourcing bicyclist traffic and participation in planning

Recent advancements in information and communication technologies (ICT) have created new opportunities to study bicyclist behaviour and improve transportation plans with their contributions. San Francisco County first developed a smartphone application specifically for bicycle travel surveys (Hood et al., 2011), which was adopted by several others for use in research and bicycle transportation planning (e.g. Hudson et al., 2012; Duthie and Unnikrishnan 2014). Third-generation bicycle sharing systems employing electronic check-out systems provide a rich source for origin and destination data, in addition to volume flows (DeMaio, 2009). Several of these existing and emerging traffic volume methods are reviewed in a recent Transportation Research Board Circular (Griffin et al., 2014), and there is at least one ongoing research project to advance crowdsourced bicycle traffic as of this writing (Figliozzi, 2014).

For all its apparent advantages, researchers also offer cautions on the use of volunteered geographic information. First is the potential for the digital divide to create or foster inequities in planning (Sui et al., 2013). Any volunteered dataset by its nature only represents the input of the participants, and planners need to understand the representation of each dataset used, and its limits for a particular application, such as bicycle transportation planning and health. Also, each dataset can be expected to have different levels of individual privacy, and researchers and planners should identify personally identifiable information that can be gleaned from the data, and follow applicable protocols to protect human subjects (Goranson et al., 2013). Part of respect for humans and participants for planners also includes using data appropriately to provide equitable analysis for different populations and travel modes, and new datasets offer additional opportunities to more effectively plan for diverse, healthy and sustainable communities.

Various aspects of crowdsourcing and “Web 2.0” technologies including social media have been studied in transportation planning (Evans-Cowley and Griffin, 2012; Krykewycz et al., 2011; Twitchen and Adams, 2011), and a few studies are emerging in the health and informatics fields (Kamel Boulos and Al-Shorbaji, 2014; Kamel Boulos et al., 2011; Kass-Hout & Alhinnawi, 2013). The transportation studies have primarily focused on increasing public involvement or crowdsourcing problem areas, rather than technologies for estimating bicycle volumes and locations. There are also several studies on the use of social media for advanced disease surveillance (Moorhead et al., 2013; e.g. Stoll et al., 2013), but few have yet to mention the prospect of using personal monitoring devices or apps for studies of large areas or populations. One such study posits “…Internet-connected, gamified fitness gadgets and apps are good examples of this ‘connected health/care’ vision realised through IoT [Internet of Things] technology” (Kamel Boulos and Al-Shorbaji, 2014). Rooksby et al. see many of these personal tracking methods as ‘lived informatics’ that may have utility not only for the individual, but also for activity research (Rooksby et al., 2014). The present study employs a novel analysis of data aggregated from a smartphone app with more traditional geographic data, as described in the next section focusing on methods.

2. Integrating volunteered bicycling data and the built environment

This study makes use of bicycle volume data based on an interconnected complex of networks, described as a “plexus”, and other attributes tied to block group areas denoted as “place”. Geographic information systems (GIS) provide an analytical environment for large,

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