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Tracking global bicycle ownership patterns

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ABSTRACT

Over the past four decades, bicycle ownership has been documented in various countries but not globally analyzed. This paper presents an effort to fill this gap by tracking household bicycle possession. First, we gather survey data from 150 countries and extract percentage household bicycle ownership values. Performing cluster analysis, we determined four groups with the weighted mean percentage ownership ranging from 20% to 81%. Generally, bicycle ownership was highest in Northern Europe and lowest in West, Central and North Africa, and Central Asia. We determine worldwide household ownership patterns and demonstrate a basis for understanding the global impact of cycling as a sustainable transit mode. Furthermore, we find a lower-bound estimate of the number of bicycles available to the world's households. We establish that at the global level 42% of households own at least one bicycle, and thus there are at least 580 million bicycles in private household ownership. Our data are publicly available and amenable for future analyses.

1. Introduction

Bicycles have been an enduring and beloved mode of human-powered travel for over 125 years. Since the late 19th century, bicycles have been seen as a vehicle for social change, for example, empowering women's emancipation (Herlihy, 2006). Historically, significant fractions of populations around the world, particularly in Asia, have used cycling for transportation. Requests for paved roads came first from the cycling community, in some cases predating automobiles (Herlihy, 2006).

In the past century, however, both developed and developing countries have undergone rapid transitions towards motorization, which have disfavored bicycle use (Schäfer et al., 2009; Koglin and Rye, 2014). Simultaneously, there have been transitions in population health away from mostly infectious disease in children to non-communicable diseases (NCDs) and injuries that affect adults (Murray et al., 2013; Lozano et al., 2013). NCDs and injuries now comprise 94% of all deaths in China, 65% in India, and 34% in sub-Saharan Africa (Lozano et al., 2013). Increasing motorization leads to injuries from road traffic crashes, growing vehicular air pollution, and declining physical activity (Bhalla et al., 2014). As countries rapidly urbanize, people living in high-density populations are more vulnerable to vehicular air pollution. There is a growing need to address the rise of NCDs and injuries globally, and the public health community has begun engaging with transportation and urban planning professionals to search for solutions (Pratt et al., 2012; UN, 2011).

In the mid-1970s, Danish population and city planners embraced a novel experiment: a reversal of policies promoting motorization was made in favor of policies promoting cycling as a way to address traffic fatalities, looming energy crises, and environmental concerns (Fietsberaad, 2006). After decades of study, the research community has validated this approach and has shown that cycling creates a virtuous cycle with numerous positive feedback loops (Krizek, 2007). The movement of people and goods by bicycle reduces vehicular air pollution and motor vehicle traffic congestion (ESCAP, 2013). Cycling is a key element to "livable cities" (Geller, 2003), it connects easily to other modes of transit, and it can stimulate local businesses via the addition of new cycling routes (Litman, 2014). From a public health perspective, cycling promotes wellness (Oja et al., 2011), and the benefits of cycling outweigh the risks (de Hartog et al., 2010; Rojas-Rueda

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Table 1
Survey sources for bicycle ownership data and the number of countries and country–years available from each.

Survey source	Acronym	Years	Countries	Country-years
Demographic and Health Surveys (DHS, 2014)	DHS	1990–2011	68	169
Enquête Démographique et de Santé et à Indicateurs Multiples (EDSM, 2013)	EDSM	2006	1	1
India National Census (IndiaStat, 2014)	INC	2001, 2011	1	2
Integrated Public Use Microdata Services (IPUMS, 2013)	IPUMS	1990–2006, 2008, 2009	21	26
Integrated Survey on the Welfare of the Population (IBEP, 2013)s	IBEP	2008–2009	1	1
International Crime Victim Surveys (ICVS, 2000)	ICVS	1989–2002	62	130
Malaria Indicator Surveys (MIS, 2014)	MIS	2006–2009	3	3
Multiple Indicator Cluster Surveys 4 (MICS4, 2013)	MICS4	2010–2011	17	17
Multiple Indicator Cluster Surveys 3 (MICS3, 2013)	MICS3	2005–2009	39	39
Study on Global Ageing and Adult Health (SAGE, 2012)	SAGE	2007–2011	5	12
World Health Surveys (WHS, 2013)	WHS	2002	65	65

et al., 2011). As more cyclists use roads, the safer the roads become, following the "safety in numbers" hypothesis (Jacobsen, 2013). On a global scale, cycling as a form of low-carbon transportation combats climate change (Woodcock, 2009; Bannister, 2011; Sheppard, 2011).

Globally, there is ample information about motor vehicles. Nearly every country tracks vehicle registration—some for tax purposes—and global data are gathered by the International Road Federation, the World Bank (via World Development Indicators), the World Health Organization (Global Status Reports on Road Safety), among other agencies. Bicycles, however, have never been systematically counted and presented in the peer-reviewed literature. This study aims to do that by compiling data on household bicycle availability and by grouping nations based on ownership levels.

2. Methods

2.1. Data collection

We obtained data on percentage bicycle ownership (PBO) from national and international surveys conducted at various times from 1971 to 2012 in 150 countries. However, we only consider for analysis the years 1989–2012, as only four countries have data available prior to 1989. Our sources for household bicycle ownership data include the World Health Surveys (WHS, 2013), Demographic and Health Surveys (DHS, 2014), Malaria Indicator Surveys (MIS, 2014), Integrated Public Use Microdata Services (IPUMS, 2013), International Crime Victim Surveys (ICVS, 2000), Multiple Indicator Cluster Surveys (MICS4, 2013; MICS3, 2013), and the India National Census (IndiaStat, 2014). We also had data available from the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ, 2009, 2012), but we did not include these in our analyses, as the respondents were schoolchildren and not representative of the national populations. Table 1 lists the surveys mined for our analyses, indicating the contribution of each source to the dataset. Fig. 1 shows the number of datapoints obtained from each country, showing the density and geographical distribution of the survey data obtained. (Supplementary Table S1 contains a list of all the countries for which data were collected.) Table 2 summarizes the objectives and sampling methodologies of the contributing surveys, most of which were global in scope. All were nationally representative, employing probability sampling of census enumeration areas (EAs) or otherwise determined zones, except for the INC, which involved an actual count. The household bicycle ownership questions vary little. Based on these, the survey data are fairly comparable.

We also collected household population numbers for the country–years in our dataset where available. Our sources primarily included IPUMS (2013) and the United Nations (UN, 2013; UNECE, 2014). In cases where direct household numbers were unavailable for certain country–years, we used a simple heuristic to find an approximation from nearest values or multiply average household sizes and corresponding national population (World Bank, 2015b) totals. (See Supplementary Material Section 1.2.)

2.2. Cluster analysis

The bicycle ownership data obtained[1] were sparse and time series varied considerably in length from one country to another. To find similarities in ownership across geographical regions, clustering presented itself as an effective pattern recognition tool (Jain et al., September 1999). Hierarchical or agglomerative clustering relies on a matrix of pairwise distances between vectors in the dataset, which were nontrivial to compute in our case due to their nonalignment. The number of clusters must also be specified.

First, we used the dynamic time warping algorithm (Sakoe and Chiba, 1978; Giorgino, 2009) to obtain distance alignments between countries. Using the goodness-of-fit test proposed by Mérigot et al. (2001), we then found the best agglomerative clustering method, which produced the minimum separation between the original distance matrix and that obtained from the tree. Of four possibilities, the unweighted pair-group method with arithmetic means (UPGMA) emerged as the best fit. The gap statistic and test (Tibshirani et al., 2001) determined the optimal number of clusters for the data. We performed ordinary least squares regression on the PBO in each cluster but found no significant temporal dependencies on bicycle ownership. Thus, we used the rolling mean with five-year windows to observe possible ownership trends. From household estimates for all the country–years, we were able to determine a lower bound on the number of available bicycles in the world. (See Appendix A for more details on the clustering steps described. The UPGMA dendrogram is shown in Supplementary Fig. S2.)

[1] The data and supporting code are available at http://www.hce.jhu.edu/sauleh/obls-gbu

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