Western Michigan University
ScholarWorks at WMU

Transportation Research Center Reports

Transportation Research Center for Livable Communities

8-31-2015

14-01 Exploring the Equity Dimensions of US Bicycle Sharing Systems

C. Scott Smith
Western Michigan University, c.scott.smith@wmich.edu

Jun-Seok Oh
Western Michigan University, jun.oh@wmich.edu

Cheyenne Lei

Follow this and additional works at: https://scholarworks.wmich.edu/transportation-reports

 Part of the Transportation Engineering Commons

WMU ScholarWorks Citation

Smith, C. Scott; Oh, Jun-Seok; and Lei, Cheyenne, "14-01 Exploring the Equity Dimensions of US Bicycle Sharing Systems" (2015). *Transportation Research Center Reports*. 39.
https://scholarworks.wmich.edu/transportation-reports/39

This Report is brought to you for free and open access by the Transportation Research Center for Livable Communities at ScholarWorks at WMU. It has been accepted for inclusion in Transportation Research Center Reports by an authorized administrator of ScholarWorks at WMU. For more information, please contact wmu-scholarworks@wmich.edu.

TRCLC 14-01

August 31, 2015

Exploring the Equity Dimensions of US Bicycle Sharing Systems

FINAL REPORT

C. Scott Smith, Jun-Seok Oh, Cheyenne Lei

Western Michigan University

Transportation Research Center for Livable Communities
Western Michigan University

Western Michigan University | University of Texas at Arlington | Utah State University | Wayne State University | Tennessee State University

Technical Report
Documentation Page

1. Report No. TRCLC 14-01	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Exploring the Equity Dimensions of US Bicycle Sharing Systems		**5. Report Date** August 31, 2015
		6. Performing Organization Code N/A
7. Author(s) C. Scott Smith, Jun-Seok Oh, Cheyenne Lei		**8. Performing Org. Report No.** N/A
9. Performing Organization Name and Address Western Michigan University 1903 West Michigan Avenue Kalamazoo, MI 49008		**10. Work Unit No. (TRAIS)** N/A
		11. Contract No. TRCLC 14-01
12. Sponsoring Agency Name and Address Transportation Research Center for Livable Communities (TRCLC) 1903 W. Michigan Ave., Kalamazoo, MI 49008-5316		**13. Type of Report & Period Covered** Final Report 7/1/2014 – 8/1/2015
		14. Sponsoring Agency Code N/A
15. Supplementary Notes		

16. Abstract

Research over the past several decades has made it increasingly clear that livable communities are inextricably linked with the provision of opportunities for active and/or non-motorized transportation; i.e., walking, cycling and their variants. An emerging phenomena that is working within the broader movement of active transportation is public bicycle sharing systems (BSS). Such systems have grown considerably in the US in recent years and, in some cases, are dramatically changing the ecology of urban transport. Alongside celebrations of the early successes of US BSS, have been criticisms that these systems have not been adequately integrated into lower-income communities; a pattern that mirrors (motorized) transportation injustices-both past and present-that have burdened lower-income while simultaneously advantaging middle to higher-income communities. And while diverse communities are embracing non-motorized transportation, there is valid concern that traditionally underserved populations will again be marginalized or unable to share in the full benefits of existing and future bicycle- and pedestrian-oriented infrastructure including BSS. This research explores the spatial arrangements and allocations of US BSS and examines the extent to which lower-income communities experience differential access to bike-sharing infrastructure. Spatial regression models are employed to examine the degree to which race, ethnicity and/or economic hardship explain variations in the distribution of bike-sharing stations.

17. Key Words transportation equity; bike-sharing; accessibility; shared use mobility	**18. Distribution Statement** No restrictions. This document is available to the public through the Michigan Department of Transportation.

19. Security Classification - report Unclassified	**20. Security Classification - page** Unclassified	**21. No. of Pages** 31	**22. Price** N/A

Disclaimer

The contents of this report reflect the views of the authors, who are solely responsible for the facts and the accuracy of the information presented herein. This publication is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. This report does not necessarily reflect the official views or policies of the U.S. government, or the Transportation Research Center for Livable Communities, who assume no liability for the contents or use thereof. This report does not represent standards, specifications, or regulations.

Acknowledgments

This research was funded by the US Department of Transportation through the Transportation Research Center for Livable Communities (TRCLC), a Tier 1 University Transportation Center.

Exploring the Equity Dimensions of US Bicycle Sharing Systems

by

Principal Investigator
C. Scott Smith, PhD AICP
Research Professor
Western Michigan University
Kalamazoo, MI 49008
c.scott.smith@wmich.edu
Tel: (562) 221-5107

Co-Principal Investigator
Jun-Seok Oh, Ph.D., P.E. PTOE
Professor, Department of Civil and Construction Engineering
Western Michigan University
Kalamazoo, MI 49008-5316
jun.oh@wmich.edu
Tel: (269) 276-3216

Graduate Research Assistant
Cheyenne I Stewart (Lei), M.S. Candidate
Department of Geography
Western Michigan University
Kalamazoo, MI 49008-5424
cheyenne.i.lei@wmich.edu

Background

Research over the past several decades has made it increasingly clear that livable communities are inextricably linked to the provision of opportunities for active and/or non-motorized transportation; i.e., walking, cycling and their variants (Congress for the New Urbanism 2000; Ellin 2012; Ewing and Cervero 2001; Handy 2005; McCann 2013; Schwartz and Rosen 2015). Indeed, investments in non-motorized transportation including pedestrian (e.g., sidewalks, paths and crosswalks) and bicycle (e.g., paths, bike lanes and bike parking) facilities together with related education and encouragement programs have shown to be critical components of sustainable transport (America Walks and Sam Schwartz Engineering 2012; Litman 2015; Speck 2012; Tolley 2003; U.S. Department of Health and Human Services 2015).

A synergetic force working within the broader movement of active transportation is the recent emergence and widespread diffusion of public bicycle sharing systems (BSS). Such systems—which make bicycles available to the general public on an as-needed basis at convenient locations and without the costs and responsibilities of bicycle ownership—have grown considerably over the past four decades (Midgley 2011; Parkes et al. 2013; Shaheen, Guzman, and Zhang 2010; Toole Design Group and Pedestrian and Bicycle Information Center 2012) and, in some cases, are dramatically changing the ecology of urban transport. Similar to walking, increasing cycling through BSS promises to enhance quality of life by improving public health (by creating convenient opportunities to engage in active transportation), reducing harmful emissions (especially greenhouse gas) and boosting mobility and accessibility, especially for populations with limited incomes (Dill and Carr 2003; Kaplan, Giacomo Prato, and Nielsen 2015; Institute for Transportation and Development Policy 2013; League of American Bicyclists 2013; Wojan and Hamrick 2015). For example, bike-sharing systems have become convenient

intermediaries that mitigate "first and last mile" problems by connecting commuters and/or recreational users to public transit networks (DeMaio 2009; Liu, Jia, and Cheng 2012; Martin and Shaheen 2014a; Pucher and Buliung 2014).

The popularity of bicycle sharing is most clearly evidenced by the quickening pace of BSS investments by cities and private companies throughout Europe, Asia and, more recently, North America (Pucher and Buehler 2008; Pucher, Garrard, and Greaves 2011). A 2011 assessment states that, "[t]en years ago, there were five schemes operating in five countries (Denmark, France, Germany, Italy and Portugal) with a total fleet of 4,000 bicycles (the largest was Copenhagen with 2,000 bicycles). [Whereas], [t]oday there are an estimated 375 bicycle - sharing schemes operating in 33 countries in almost every region of the world using around 236,000 bicycles" (Midgley 2011, 1). A more recent inventory shows that more than 600 cities worldwide had a bike-sharing system in 2014, including 132 in Spain, 104 in Italy, and 79 in China, for a total global fleet of 633,241 bicycles, the largest system composed of 78,000 bicycles in Hangzhou, China (Wikipedia 2014).

A relative late-comer to BSS, the US began only recently to grow its bike-share infrastructure. At the time of this writing there were approximately 42 active bike-sharing systems in the US; more than half of which were established since 2012. The two largest systems—Citi Bike in New York City (with 6,300 bicycles) and Divvy in Chicago (approximately 4,680 bicycles)—began service in May and June 2013, respectively. Other larger American cities such as Seattle, Tampa Bay, Pittsburg and Philadelphia opened their public bike-shares within the past year whereas Baltimore, Los Angeles, Portland and Atlanta have plans to activate systems in 2016.

One explanation for the rapid adoption and diffusion of BSS is that contemporary, "fourth-generation" systems have overcome many of the technical challenges that constrained widespread use in earlier generations. Fourth generation systems are characterized by: improved methods of (re)distribution (e.g., solving the diurnal high supply/low demand and push-pull effects and/or balancing of bike supply between stations); ease of installation (e.g., use of solar panels on station kiosks no longer require expensive and time-consuming underground electrical wiring); better bicycle design (e.g., bicycles are uniquely designed, stations have sophisticated and secure locking mechanisms); improved tracking (e.g., GPS now allows for improved collection of stolen bicycles and credit card usage eliminates anonymity and reduces vandalism); ease of customer use (e.g., many systems now have automated payment and checkout systems as well as mobile apps that make it easy to identify station location and bicycle availability in real time); and creative business models (e.g., many BSS are public-private partnerships that leverage short-term federal capital investments with longer-term investments by local governments and entities) that make possible a wide range of system designs that are dramatically changing the way people and non-human objects interact within urban environments (DeMaio 2009; Institute for Transportation and Development Policy 2013; Parkes et al. 2013). In addition to these technological and supply-side improvements, BSS have been bolstered by demand-side trends such as demographic shifts and preferences in the US population that favor (re)urbanization (especially among younger populations) and a willingness to engage in networked, sharing economies connected via mobile technologies (Barth and Shaheen 2002; Beatley 1999; TED Books 2013; Townsend 2013; Wolfe 2013).

Equity concerns in the planning and performance of US public bike-sharing systems

Parallel with media reports celebrating the openings and early successes of US BSS, have come criticisms that these same systems have not been adequately integrated into lower-income communities. Such criticisms mirror transportation injustices—both past and present—that have burdened (e.g., via higher emissions concentrations and pollution exposure) lower-income communities while simultaneously advantaging (e.g., via greater accessibility and lower relative tax burden) middle to higher-income communities (Bullard 2004; Bullard and Johnson 1997). Despite the widespread adoption of environmental justice, citizen participation initiatives, open meeting laws and other social policies designed to increase transparency and reduce disparities in planning processes and outcomes, research suggests that transportation inequities persist across income, racial and ethnic groups (Brulle and Pellow 2006; Corburn 2009; Fainstein 2005; Forkenbrock and Schweitzer 1999; Hodge and Hanson 1995; Litman 2015).

Continuing this trend, recent and growing active transportation and active living plans and programs—including bike-share—have largely targeted middle- and upper-class communities for improvements despite the fact that low-income, Black, and Latino communities tend to experience: (1) lower rates of mobility/accessibility; (2) higher rates of obesity and related health risks; and (3) higher rates of pedestrian- and bicycle-related fatalities (Day 2006; Fishman 2015; League of American Bicyclists 2013). And while diverse communities are embracing non-motorized transportation, there is valid concern that traditionally underserved populations will again be marginalized or unable to share in the full benefits of existing and future bicycle- and pedestrian-oriented planning efforts.

Because public bike-share is still a rather new phenomena in American cities, few studies and/or reports have systematically examined the equity implications of BSS, particularly at the

neighborhood scale and national scope. Rather, the focus of bike-share-related academic studies tend to fall into one of three categories: (1) *descriptive studies* that inventory and report the characteristics of existing systems such as their respective locations (typically at the city-scale), sizes (i.e., number of bicycles and docks) and business models (Susan A. Shaheen, Ph.D et al. 2014; Toole Design Group and Pedestrian and Bicycle Information Center 2012); (2) *operations-related analyses* which examine and, at times, offer solutions to widespread funding, public safety and/or logistics challenges (e.g., balancing supply and demand across stations, ensuring fiscal sustainability, accommodating and improving helmet use) posed by BSS (Fishman, Washington, and Haworth 2013; Friedman et al. 2015; Kraemer, Roffenbender, and Anderko 2012; Rainer-Harbach et al. 2013; Siavash Shahsavaripour 2015); and (3) *transportation system impacts* which explore the impacts (e.g., mode shifts) that BSS has on the functioning of the broader transportation system (Martin and Shaheen 2014b). And while there are multiple ways to evaluate transport equity in relation to bike-share systems (Litman 2015), present studies—academic or otherwise—have been limited in the depth of demographic information used (NACTO 2015) and/or the number of systems evaluated (Goodman and Cheshire 2014).

Research questions

This study builds on previous research by responding to four questions that concern the geographic allocations of bike-share infrastructure in relation to surrounding communities. Specifically, questions 1-3 speak to the distributional equity of BSS infrastructure and the processes underlying these distributions at a neighborhood scale and national scope. Here we ask,

1) *What are the spatial arrangements and allocations of bicycle sharing stations in US cities?*

2) *To what extent do lower-income communities experience differential access to bike-sharing infrastructure (i.e., stations) in US cities?*
3) *How does race, ethnicity and/or economic hardship explain variations in access to bike-sharing infrastructure (relative to other potentially relevant factors)?*

For question four we use Chicago's Divvy system as a case study to explore the role of equity analysis in analyzing and planning for bicycle sharing systems. Here, we ask

4) *To what degree did Divvy's spring/summer 2015 expansion improve access to its bike share system for lower-income communities?*

Methodological design

This project evaluates bike-share systems through a transportation equity lens in four parts. In part one BSS spatial data and census geographies are collected, processed and analyzed to produce an informational framework by which the spatial arrangements and categories of bike-share systems throughout the country can be defined and explored. In part two we use census population and housing data to divine an economic hardship index that is used to evaluate—at a neighborhood-scale—the distribution of bicycle sharing infrastructure across socioeconomic groups. In part three we collect and process a broader set of relevant predictor variables to explain, via a series of spatial regression models, variations in the locations of bike-sharing infrastructure, paying special attention to the roles of income, race and ethnicity while controlling for other potentially relevant factors. We conclude with part four, an accessibility-based examination of distributional changes before and after Chicago's recent expansion of its Divvy BSS. A more thorough account of the procedures used in the aforementioned analyses follows.

Part One: System-level identification, summary and analysis

In part one we gathered and combined system-specific station location and capacity (i.e., number of docks available per station) information together with cartographic data in order to explore the distribution of bicycle sharing infrastructure across the US. Since there exists no single, comprehensive and regularly updated spatial inventory of bike-share systems, it was necessary to gather BSS data from a variety of sources. In some cases, system-specific BSS data were made available to the public via the operator's or city authority's website in geographic information system (GIS) format. For example, Chicago's Divvy network and New York City's Citibike system can be downloaded as ESRI Shapefiles via online data portals; Divvy data were downloaded from the City of Chicago's Data Portal (https://data.cityofchicago.org/), whereas Citibike system information was downloaded from the NYC OpenData website (https://nycopendata.socrata.com/). In other cases it was necessary to request an access code (i.e., an application programming interface [API] key) to retrieve BSS information. For example, BCycle (https://www.bcycle.com) provided the researchers an access code that we embedded into a Python script. The script was then used to retrieve system-level information in JavaScript Objection Notation or JSON format for 26 US BSS. For the remaining cities we used a third party data collector (e.g., citybik.es via PyBikes) to download the necessary BSS information. The BSS information was then compiled into a single spatial dataset that included system name, location, station locations and associated capacity (i.e., number of docks) information. In all, geographic coordinates and associated attributes were collected for 42 US bike-share systems composed of 2,137 docking stations and 39,394 docks.

In addition to the BSS information, we collected boundaries for the incorporated or Census Designated Places or CDPs that host the 42 bike-share systems. These boundaries are extracts of

selected geographic and cartographic information from the 2013 US Census Bureau's Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) database and were made available for download by the US Census Bureau TIGER/Line program in Shapefile format (https://www.census.gov/geo/maps-data/data/tiger-line.html) for each state.

Host municipalities were extracted from the larger statewide place boundaries files via a spatial selection process; i.e., by intersecting BSS stations with place boundaries the latter of which were subsequently used to form unified *BSS planning areas*. In some cases a single BSS spanned multiple jurisdictions (e.g., Capital Bike-share's 350 stations and 5,772 docks were allocated across eleven incorporated places and two states). Adjacent place boundaries that hosted a single system were combined to form a single BSS planning area. Alternatively, if bike-share systems had stations located in non-adjacent places, the BSS was split into multiple planning areas. Altogether the 42 US BSS which spanned over 72 places were reallocated to 47 planning areas (and a corresponding number of BSS) for analytical purposes.

For this study, BSS planning areas represent politically homogenous jurisdictions within which a governing land use authority (i.e., the municipality[ies]) could feasibly and legally locate a station. The planning areas also served a second function of constraining calculations of accessibility, area-based measures and other standardized descriptive statistics (such as station densities, etc.) within contiguous boundaries thereby allowing more meaningful comparisons across systems.

In addition to the geographic characteristic of the planning areas (e.g., area, perimeter), we calculated BSS-specific summaries and distributional characteristics that were used to compare systems. A partial list of system- and place-level calculations that were performed include: BSS planning area (in square miles); system service area (i.e., sum of area of ¼ mile buffers radiating

from bike stations); service area coverage (i.e., system service area as a percentage of total planning area); convex hull of stations (i.e., area of smallest convex envelope connecting all stations in Euclidean space); minimum, average and standard deviation of distance(s) between BSS stations. Factor analytic techniques were then applied to these and related descriptive statistics to detect structure, commonalities and variability across BSS.

Part Two: Evaluating equity in bike-share

After identifying and categorizing the various BSS, the subsequent step was to examine the degree to which lower-income communities experience differential access to bike-sharing infrastructure (i.e., stations). To carry out this analysis we downloaded census tracts from the 2013 US Census Bureau's MAF/TIGER database and extracted only those tracts that had some portion of their boundary within the 47 BSS planning areas, which amounted to 8,470 study census tracts. Census tracts are small, relatively permanent statistical subdivisions of a county and generally have a population size between 1,200 and 8,000 people with an optimum size of 4,000 people. Therefore, the geographic size of census tracts varies widely depending on the density of settlement. For the present analyses, census tracts are used as proxies for neighborhoods.

Next we identified and downloaded appropriate census variables from the 2013 5-year American Community Survey (ACS) to create an economic hardship index that could be used to categorize neighborhoods (i.e., census tracts) by socioeconomic conditions. The ACS is considered the most reliable source of detailed socioeconomic data currently available, and is the only source of data available for small geographies such as census tracts. At the time of the analysis, the 2013 5-year estimates were the latest year available and census tracts are the finest resolution at which the ACS data are available.

To calculate the economic hardship index we began with six inter-related component variables from the 2013 ACS, namely: (1) *unemployment (PCTUNEMP)*, defined as the percent of the civilian population over the age of 16 who were unemployed; (2) *dependency (PCTDEPPOP)*, the percentage of the population that are under the age of 18 or over the age of 64; (3) *education (PCTLESSHS)*, the percentage of the population over the age of 25 who have less than a high school education; (4) *more than 30 percent of income (PCTMore30pct)*, calculated as gross rent or owner costs as a percentage of household income in the past 12 months; (5) *crowded housing (PCTOvercrowded)*, measured by the percent of occupied housing units with more than one person per room; and (6) *health insurance (PCTNoHealthIns)*, the percent of civilian noninstitutionalized population 18 years and over with no health insurance coverage. These six variables were selected because they each represent distinct dimensions of economic performance while collectively encompassing a broad range of socioeconomic conditions.

To develop the economic hardship index, we used a technique similar to that implemented by the Rockefeller Institute's Intercity Hardship Index which allows for the comparison of economic conditions across select US cities over time (David J. Wright and Lisa M. Montiel 2007). The formulation used to calculate the economic hardship index is as follows: X = ((Y-Ymin)/(Ymax—Ymin)) where: X = standardized value of component variable (for example, unemployment rate) for each census tract to be computed. Y = unstandardized value of component variable for each census tract. Ymin = the minimum value for Y across all census tracts. Ymax = the maximum value for Y across all census tracts. The above formula standardizes each of the component variables so that each is given equal weight in the composite index. The index represents the average of the standardized ratios of all six component variables

and thus ranges from 0 to 1 with a higher value indicating greater hardship. We then attributed each census tract into one of five economic hardship categories—highest, high, moderate, low or lowest—using both a global and local approach. The global economic hardship category was assigned based on the quintile category estimated using all 8,470 census tracts (i.e., across all BSS planning areas) whereas the local economic hardship category was assigned based on the quintile category estimated using only census tracts located within the respective BSS planning area boundary. Analyses of the above indices data at a fine-scale (such as at the census tract or neighborhood level) can help identify vulnerable populations and assess potential transportation justice concerns. Specifically, these economic hardship categories were used to calculate the sum of stations and docks by socioeconomic group; i.e., the distributional equity of bike-sharing infrastructure both across the country and within each planning area.

Part Three: Explaining variations in station placement

In part three we explored the degree to which socio-economic characteristics of communities explain variations in the siting of bicycle sharing infrastructure controlling for other factors conventionally considered in the siting process. For this we reviewed studies from academic literature, BSS websites and related documents to identify non-socioeconomic factors that may have played a role in siting bike-sharing stations. Through this exercise, we identified over twenty potential factors including, but not limited to: proximity to transit (especially rail stations with high numbers of boardings and frequencies); population density; job density; major destinations, points of interest; crime rate; traffic volumes on adjacent streets (or average annual daily traffic); sun exposure (especially important for solar-powered station kiosks); land use and land ownership characteristics; access to transit connectivity; maximum/minimum/average

distance to bike share station(s); street network density; proximity to existing non-motorized infrastructure, especially bike lanes/paths; commute mode share; site visibility; site topography.

Because this was a nationwide study, we were limited to operationalize the above factors derived from data that were fine-scale (i.e., able to be meaningfully examined at the neighborhood scale), readily available and comparable and/or relatively consistent across the US. To this end, we developed a range of BSS station siting factors using data from multiple sources including: the 2013 ACS 5-Year estimates to estimate population density and commute share (e.g. percent of workers who commute by walking, private vehicle, transit and/or bicycle); 2013 US Census Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES) for employment/job density (These census block-level data were aggregated to census tract); Open Street Map (OSM) for street network density (i.e., miles of non-highway street network divided by area of census tract), non-motorized path density and points of interest density; General Transit Feed System (GTFS) data for calculating rail and bus network densities and access to transit (i.e., spatially weighted distance to transit station and/or bus stop). Spatial weights were calculated using GeoDa (Anselin, Syabri, and Kho 2004) whereas the spatial autocorrelation analyses were evaluated and computed with R Studio (R Studio Team 2015).

Part Four: Equity analysis of Divvy's expansion

In part four we carried out an equity analysis of the city of Chicago's Divvy system, which is one of the largest so-called third-generation bike-share networks in the country. The initial roll out of Divvy in 2013 included 300 bike-sharing stations; the locations of which were determined via a multi-tiered planning process. Soon after the system was opened to the public, there were concerns that a vast majority of the stations were concentrated in Chicago's central business district and wealthier North Side neighborhoods, while relatively few located in the

city's South and West Sides. In summer 2015, Divvy expanded its system by adding 1,750 bikes to its fleet and another 176 bike-share stations, in part, to address equity concerns. We evaluated the equitable performance (i.e., distributional equity) of the Divvy system before and after its 2015 expansion by employing a variety of accessibility indices at the neighborhood scale.

Data presentation and analysis

This section briefly summarizes data collected as part of this research and associated analytical results in four parts, each responding to a research question.

Characteristics of bike-sharing systems in the US

BSS information was gathered from numerous data sources and compiled into a single spatial dataset that included system name, location, station locations and associated capacity (i.e., number of docks) information. Altogether information was collected for 42 US BSS spanning 72 places (i.e., incorporated areas, CDPs) collectively representing 2,137 docking stations and 39,394 docks. These systems were reallocated to 47 planning areas (and a corresponding number of BSS) for analytical purposes as described in the previous section. Figure 1 presents the growth of US BSS by showing system counts and cumulative dock totals by year.

In addition to the geographic characteristic of the planning areas (e.g., area, perimeter), we calculated BSS-specific summaries and distributional characteristics that were used to compare systems. Cluster analytic techniques (i.e., K-means tests) were applied to these descriptive data to detect structure, commonalities and variability across BSS. In order to allow for greater comparability only systems with greater than or equal to five stations and/or greater than or equal to 75 bicycles were retained for further analysis. These criteria dropped the number of systems considered for further study to 35. A map of the 35 study systems locations graduated by size (i.e., total docks) is presented in Figure 2.

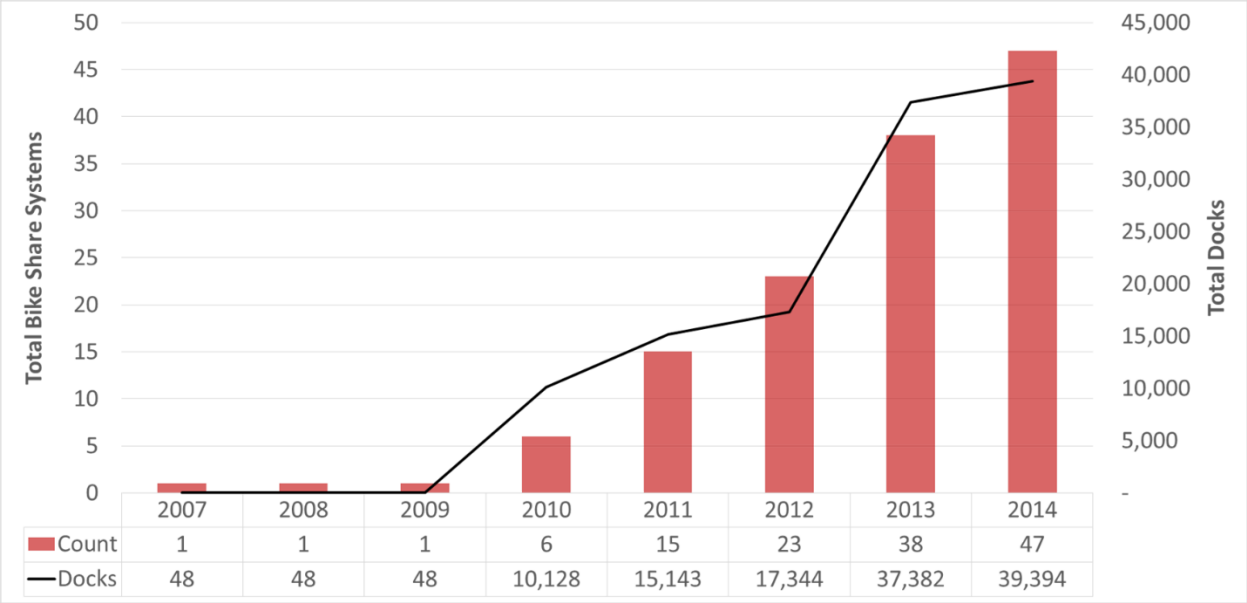


Figure 1: US Bike-Sharing Systems, 2014

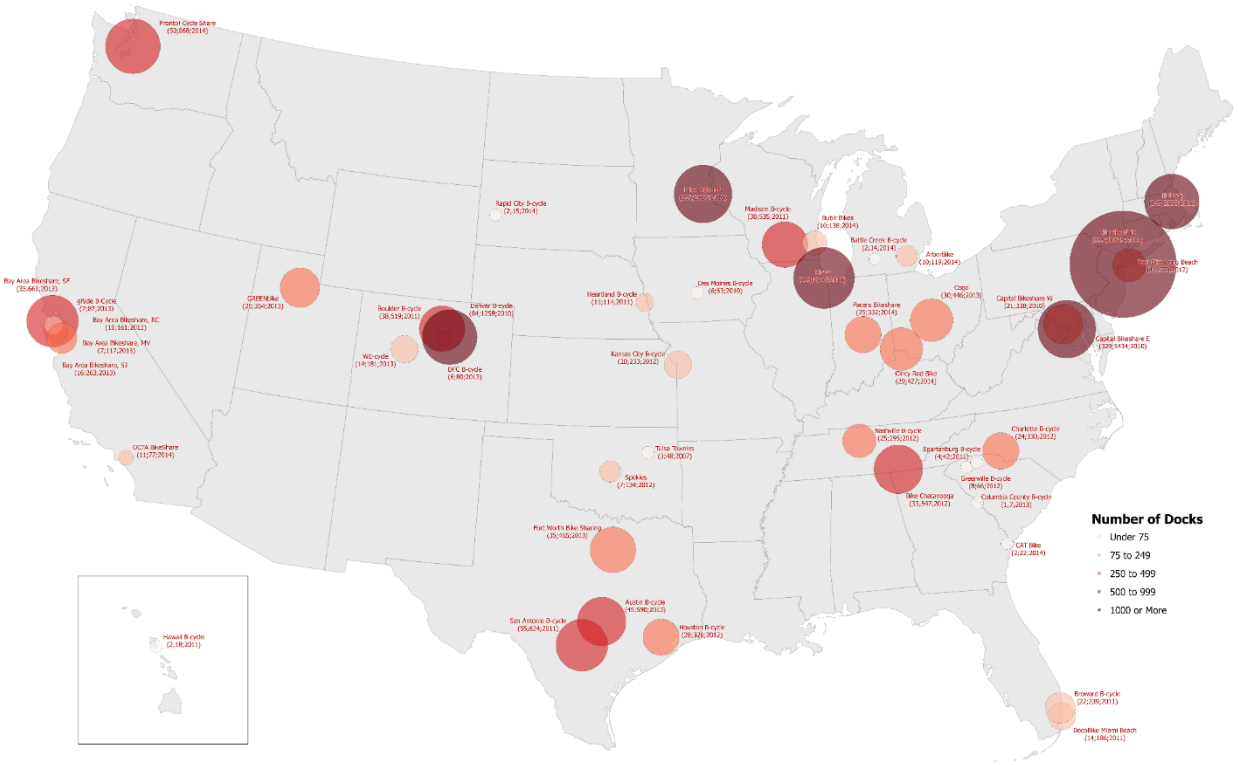


Figure 2: Map of Study US Bike-Sharing Systems, 2014

While most of the systems were established around the same time and use similar operators, the study BSS vary considerably in many respects, including size, service area, minimum distance to stations, etc. Figure 4 lists the study BSS ordered by size (i.e., number of docks) and provides a numeric and graphical display of system characteristics. These and other system-level characteristics together with BSS planning area attributes including population density, employment density, transit station density (i.e., number of train stations and bus stops normalized by BSS planning area), street network density (i.e., miles of street network normalized by BSS planning area), and other information were used to further partition the study BSS into groups via a K-means clustering process. K-means divides the observations into discrete groups based on a numeric distance metric. We used Hartigan's Rule to identify the number of potential clusters. A plot of Hartigan's Rule (Figure 3) suggests that there are approximately three distinct categories of BSS represented in the data.

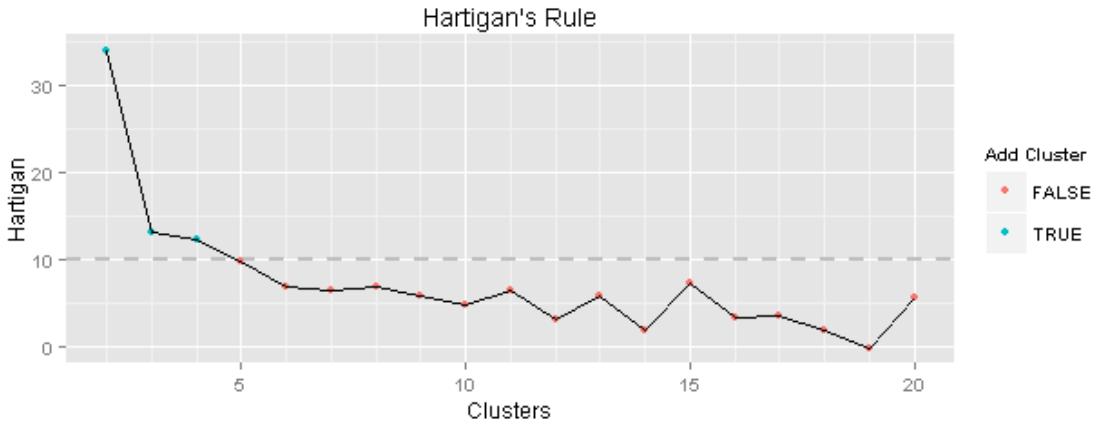


Figure 3. Characteristics of Larger US Bike-Sharing Systems, 2014

System Name	Principal City, State	Business Model	Operator	Year Est.	Number of Stations	Number of Docks	Service Area	Minimum Distance	Average Distance
Citi Bike NYC (CITI)	New York, New York	Publicly Owned	Motivate	2013	335	10,845	15.8	174.7	11,976
Divvy (DIVY)	Chicago, Illinois	Publicly Owned	Motivate	2013	328	5,706	31.4	0.5	19,290
Capital Bikeshare E (CAPE)	Arlington, Virginia	Publicly Owned	Motivate	2010	329	5,434	36.0	90.0	22,731
Nice Ride MN (NICE)	Minneapolis, Minnesota	Non-Profit	Bixi	2010	169	2,987	23.0	452.5	23,550
Hubway (HUBW)	Boston, Massachusetts	Publicly Owned	Motivate	2011	147	2,538	18.3	61.5	13,649
Denver B-cycle (DNVR)	Denver, Colorado	Non-Profit	B-Cycle	2010	84	1,258	9.6	440.8	9,938
Pronto! Cycle Share (PRNT)	Seattle, Washington	Non-Profit	Motivate	2014	50	868	5.6	561.9	9,450
San Antonio B-cycle (SANT)	San Antonio, Texas	Non-Profit	B-Cycle	2011	55	824	5.9	42.0	12,389
Bay Area Bikeshare, SF (BASF)	San Francisco, California	Publicly Owned	Motivate	2013	35	661	3.2	145.1	4,787
Austin B-cycle (AUST)	Austin, Texas	Non-Profit	B-Cycle	2013	45	590	4.6	330.7	6,177
Bike Chatanooga (CHAT)	Chattanooga, Tennessee	Publicly Owned	Motivate	2012	33	547	2.7	353.8	5,129
Madison B-cycle (MADN)	Madison, Wisconsin	Non-Profit	B-Cycle	2011	38	535	4.9	228.1	9,599
Boulder B-cycle (BOUL)	Boulder, Colorado	Non-Profit	B-Cycle	2011	38	519	4.9	532.5	6,690
Fort Worth Bike Sharing (FTWR)	Fort Worth, Texas	Non-Profit	B-Cycle	2013	35	465	3.9	564.3	8,423
Cogo (COGO)	Columbus, Ohio	Publicly Owned	Motivate	2013	30	446	3.5	519.0	5,334
Cincy Red Bike (CINC)	Cincinnati, Ohio	Privately Owned	B-Cycle	2014	29	427	3.0	586.1	6,747
GREENbike (GREN)	Salt Lake City, Utah	Non-Profit	B-Cycle	2013	20	354	1.8	607.7	3,104
Capital Bikeshare W (CAPW)	Rockville, Maryland	Publicly Owned	Motivate	2010	21	338	3.3	478.2	9,952
Pacers Bikeshare (INDY)	Indianapolis, Indiana	Non-Profit	B-Cycle	2014	25	332	2.6	516.8	4,521
Charlotte B-cycle (CHAR)	Charlotte, North Carolina	Non-Profit	B-Cycle	2012	24	330	3.0	342.7	6,104
Houston B-cycle (HOUS)	Houston, Texas	Non-Profit	B-Cycle	2012	28	326	4.1	470.3	8,070
Nashville B-cycle (NASH)	Nashville, Tennessee	Non-Profit	B-Cycle	2012	25	295	3.7	582.9	8,790
DecoBike Long Beach (DCLB)	East Atlantic Beach, New York	Publicly Owned	DecoBike	2012	14	270	1.8	49.0	7,008
Bay Area Bikeshare, SJ (BASJ)	San Jose, California	Publicly Owned	Motivate	2013	16	263	1.9	674.1	3,931
Broward B-cycle (BROW)	Fort Lauderdale, Florida	Non-Profit	B-Cycle	2011	22	239	3.8	672.0	24,743
Kansas City B-cycle (KANS)	Kansas City, Missouri	Non-Profit	B-Cycle	2012	20	233	2.7	892.1	11,247
DecoBike Miami Beach (DCMB)	Miami Beach, Florida	Privately Owned	SandVault	2011	14	186	2.3	901.2	15,319
WE-cycle (WECY)	Aspen, Colorado	Non-Profit	Bixi	2013	14	181	1.6	421.5	4,075
Bay Area Bikeshare, RC (BARC)	Redwood City, California	Publicly Owned	Motivate	2013	10	161	1.0	224.1	3,955
Bublr Bikes (BBLR)	Milwaukee, Wisconsin	Non-Profit	B-Cycle	2014	10	138	1.3	698.5	2,923
ArborBike (ARBR)	Ann Arbor, Michigan	Non-Profit	B-Cycle	2014	10	119	1.4	1062.3	4,542
Bay Area Bikeshare, MV (BAMV)	Mountain View, California	Publicly Owned	Motivate	2013	7	117	0.9	1304.4	6,716
Heartland B-cycle (HTLN)	Omaha, Nebraska	Non-Profit	B-Cycle	2011	11	114	1.6	852.5	14,219
OCTA BikeShare (OCTA)	Fullerton, California	Publicly Owned	Bike Nation	2014	11	77	1.6	880.8	7,604
Bay Area Bikeshare, PA (BAPA)	Palo Alto, California	Publicly Owned	Motivate	2013	5	75	1.1	517.5	6,246

Figure 4. Characteristics of Larger US Bike-Sharing Systems, 2014

The distributive equity of US bike-share systems

After having characterized BSS systems, the next step was to determine to what extent lower-income communities experience differential access to this bike-sharing infrastructure (i.e., stations). For this analysis we developed an economic hardship index composed of six variables (percent overcrowded; percent unemployed; percent with less than high school diploma; percent dependent population; percent spending more than 30 percent of income on housing; and percent with no health insurance). An economic hardship index value was calculated for each of the 8,470 census tracts located within BSS planning areas. These economic hardship index values were then formed into quintile categories of economic hardship—i.e., highest, high, moderate,

low or lowest—of which each tract (i.e., neighborhood) was assigned a global and local economic hardship category. The global economic hardship category represents the quintile category assigned to each neighborhood accounting for all 8,470 census tracts (i.e., across all BSS planning areas) whereas the local economic hardship category was assigned to neighborhoods based on the quintile category estimated using only census tracts located within the respective BSS planning area boundary.

Figure 5 indicates that more than three quarters (1,556 or 2,063 or 75.4 percent) of bike-sharing stations across the US are located in communities with low or lowest economic hardship whereas only 245 (11.9 percent) of stations are located in communities with high or highest economic hardship. Figure 6 presents the distribution of bike-sharing stations by localized economic hardship category for each of the study BSS. Variations are present across systems in terms of equitable performance yet, overall, stations are skewed toward locations with lower economic hardship in a large majority of the BSS planning areas. Indeed, only four of the study BSS have over 40 percent of stations located in communities categorized as having high to highest economic hardship: Greenbike in Salt Lake City, Utah (100 percent), Boulder BCycle (52.6 percent), ArborBike in Ann Arbor, Michigan (50 percent) and Bay Area Bikeshare in Mountain View, California (42.9 percent). Figure 7 maps contrasts distributions of bike-share stations for two study BSS, namely, Nice Ride in Minneapolis, Minnesota and Bike Chattanooga located in Chattanooga, Tennessee. the former has higher equitable performance compared to the latter with approximately 26.6 percent of stations located in neighborhoods with higher economic hardship compared with 15.2 percent, respectively.

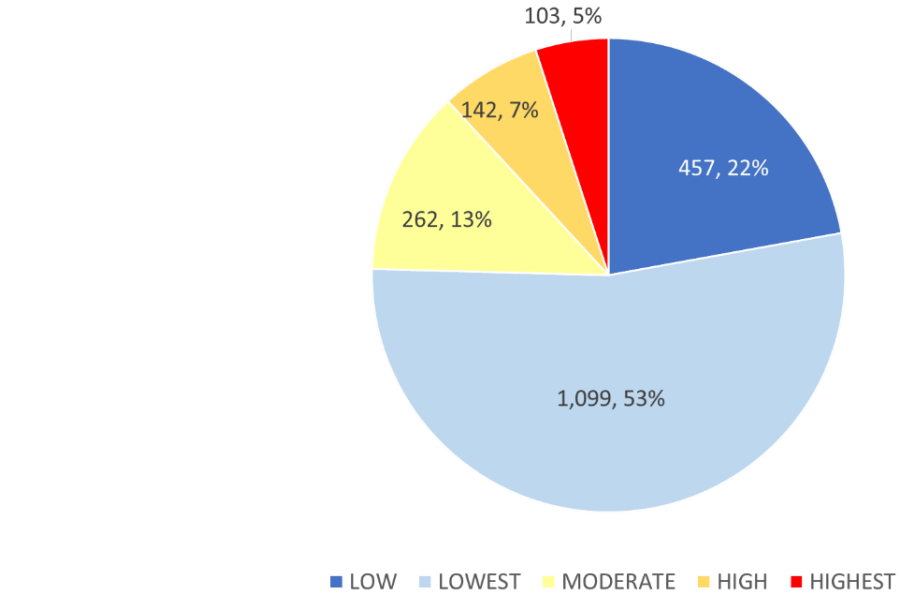


Figure 5. Distribution of Bike-Sharing Stations by Economic Hardship Category (Global Quintile Categories), 2014

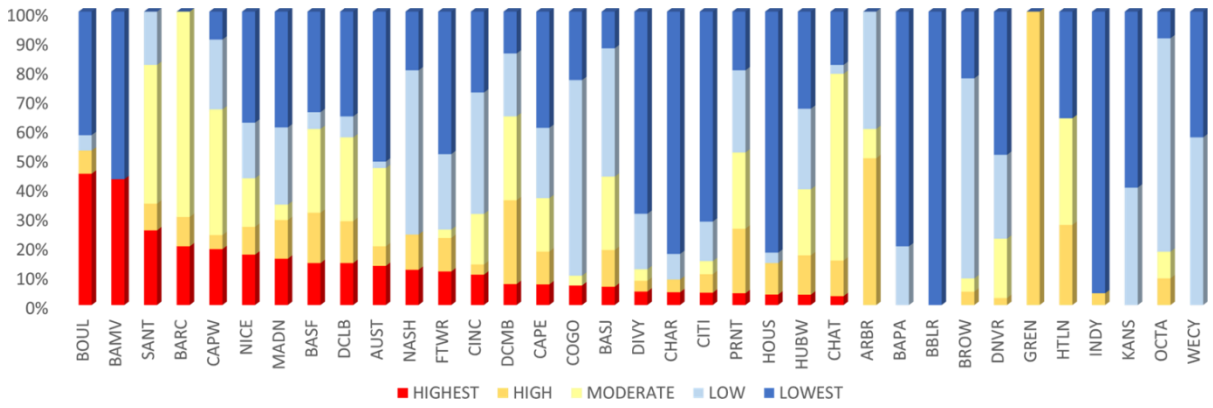


Figure 6. Distribution of Bike-Share Stations by Economic Hardship Category by Study BSS (Local Quintile Categories), 2014

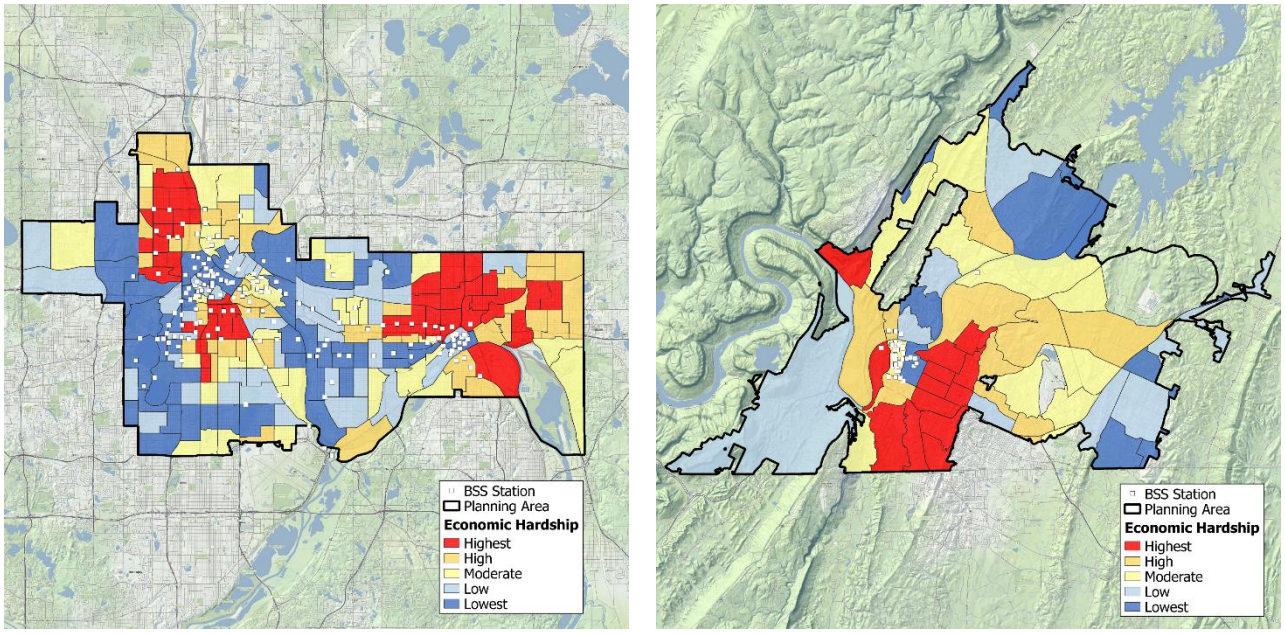


Figure 7. Distribution of Bike-Share Stations by Economic Hardship Category for Nice Ride, MN (left) and Bike Chattanooga, TN (right), 2014

Explaining variations in the geographic distribution of Divvy's bike-share infrastructure

The city of Chicago, along with Washington DC and New York City, was one of the first large US cities to adopt a so-called fourth-generation bike-share system. Chicago is also home to the second highest number of bike-share stations (328 in November 2014) and one the largest service areas (15.8 square miles). Only Montreal and New York City have more bikes than Chicago. Implemented in 2013, the Divvy system has become a key component of the city's public transit system. Shaun Jacobsen of *Transitized* performed an analysis examining the median travel time of Divvy trips taken in 2014 between every possible station pair and compared it to the same trip by public transportation. He found that, in most cases, Divvy trips were actually faster (i.e., more convenient) than walking and using Chicago Transit Authority's (CTA) bus and/or elevated rail. However, the previous analysis shows that the system performs

rather poorly in terms of equity with only 8.2 percent of stations located in higher economic hardship areas.

This present analysis aims to explain variations in the distribution of bike-share stations within the BSS planning area that comprises the Divvy system. Toward this end, we reviewed studies from academic literature, BSS websites and related documents to identify non-socioeconomic factors that may have played a role in siting bike-sharing stations. We also attended two workshops during which Divvy planners discussed the steps involved in the initial siting process. Through these activities, we identified over twenty factors that are likely to be considered when siting bike-sharing stations, namely: proximity to transit; population density; job density; major destinations, points of interest; crime rate; traffic volumes on adjacent streets; sun exposure; land use and land ownership characteristics; access to transit connectivity; maximum/minimum/average distance to bike share station(s); street network density; proximity to existing non-motorized infrastructure, especially bike lanes/paths; commute mode share; site visibility; site topography.

We developed a series of spatial models regressing the above predictor variables (together with the six component variables used for economic hardship index and race and ethnicity characteristics) on eleven dependent variables representing neighborhood accessibility to bike-sharing stations. In all models we found that economic hardship and race ethnicity were significant although not strong predictors for variations in bike-sharing infrastructure. The strength of the predictors also varied with the exogenous variables used in the model (i.e.,with different measures of accessibility).

Toward a more equitable Chicago's Divvy system

Soon after the initial outlay of over 300 stations in Chicago, criticisms arose concerning the lack of bike-sharing stations in lower income communities. For example, in December 2014, a group of local African-American cyclist organizations sent a letter to the City of Chicago's Mayor's Bicycle Advisory Council, urging it to improve bicycling conditions in predominantly African-American neighborhoods, especially on the South and West Sides. In spring 2015 Divvy added 1,750 bikes to its fleet expanding its number of stations from 300 to 476. City officials stated that the new stations would do much to improve the equitable performance of the system.

The final analysis examined the degree to which these additional stations improved accessibility to bike-sharing infrastructure among communities with higher economic hardship. Figure 8 shows that many new stations were added to the original outlay; expanding access to the north, east and south. What is not clear is how the expansion improved access across particular neighborhoods in terms of socioeconomic status. Figure 9 shows changes in accessibility across economic hardship category pre- and post-expansion using three measures of access (i.e., count, spatially weighted network access with ½ mile cutoff and spatially weighted network access with 1 mile cutoff). We see here that access was improved considerably for moderate and higher economic hardship areas.

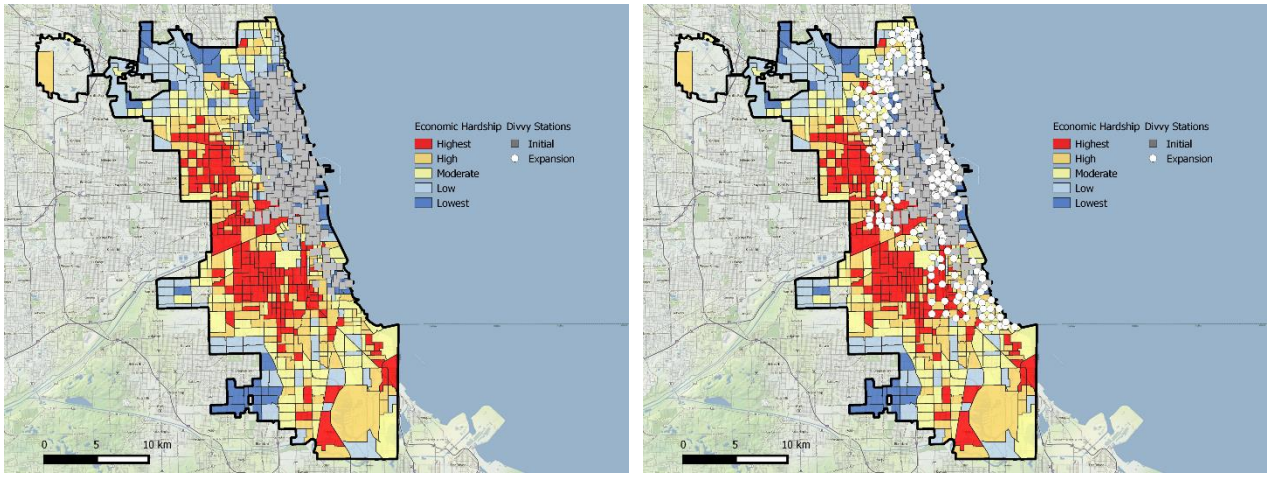


Figure 8. Distribution of Bike-Share Stations by Economic Hardship Category for Divvy, Chicago Illinois Pre-(left) and Post-(right) Expansion, 2014/5

Economic Hardship	Count (Pre)	Count (Post)	% Change
HIGHEST	15	39	160%
HIGH	12	46	283%
MODERATE	14	57	307%
LOW	60	95	58%
LOWEST	199	240	21%
Total	*300*	*477*	*59%*

Economic Hardship	1/2 mi (Pre)	1/2 mi (Post)	% Change
HIGHEST	40	135	238%
HIGH	62	215	247%
MODERATE	76	235	209%
LOW	286	439	53%
LOWEST	948	1,116	18%
Total	*1,412*	*2,144*	*52%*

Economic Hardship	1 mi (Pre)	1 mi (Post)	% Change
HIGHEST	186	569	206%
HIGH	274	801	192%
MODERATE	292	881	202%
LOW	1,036	1,605	55%
LOWEST	3,362	3,973	18%
Total	*5,157*	*7,850*	*52%*

Figure 9. Change in Accessibility to Bike-Share Stations, Pre- and Post-Expansion of Chicago's Divvy System, 2014/5

Findings, implications and next steps

The pride with which cities have taken up the call for bicycle-sharing, other forms of mobility is promising that cities and its residents are not only taking sustainable transport seriously, but are establishing protocols and arrangements to advance. The pace at which innovation is occurring, alongside other technological advancements as they are metabolized into planning. The quality of life, sheer latent demand for these facilities is evidenced not only in the infrastructure itself, but also its use and effects on property values, etc.

There are likely to be several root problems of this. However, given that, beyond these factors, there are examples where race and income are strongest predictors, modifications there need to be ways to provide incentives for greater, a concerted effort. We see this in the variety of programs. There are several strategies that are being carried out to do just that. The effectiveness of these programs need to have tangible outcomes in order to have and maintain credibility. For example, in the Divvy example, the initial roll out and planning strategy had several… Indego in Philadelphia, a bike-share program that launched this spring, is one of the first to directly focus on attracting a diverse ridership from the outset. Of the 600 bikes in its system, a third are in low-income neighborhoods. Existing bike-share programs are making changes to combat inequity too. Pronto in Seattle has plans to cover more peripheral areas, and Bublr Bikes in Milwaukee announced an initiative last week to increase its presence in low-income neighborhoods. Discounts for public housing residents in New York attempt to make the fee more realistic for the people who need it most.

References

America Walks, and Sam Schwartz Engineering. 2012. "Steps to a Walkable Community: A Guide for Citizens, Planners and Engineers." Sam Schwartz Engineering and America Walks. http://americawalks.org/walksteps/.

Anselin, Luc, Ibnu Syabri, and Youngihn Kho. 2004. "GeoDa: An Introduction to Spatial Data Analysis." Edited by Spatial Analysis Laboratory.

Barth, Matthew, and Susan Shaheen. 2002. "Shared-Use Vehicle Systems: Framework for Classifying Carsharing, Station Cars, and Combined Approaches." *Transportation Research Record: Journal of the Transportation Research Board* 1791 (January): 105–12. doi:10.3141/1791-16.

Beatley, Timothy. 1999. *Green Urbanism: Learning From European Cities*. 1st ed. Island Press.

Brulle, Robert J., and David Pellow. 2006. "Environmental Justice: Human Health And Environmental Inequalities." *Annual Review of Public Health* 27 (3): 1–22.

Bullard, Robert D. 2004. "The Anatomy of Transportation Racism." In *Highway Robbery: Transportation Racism and New Routes to Equity*, edited by Robert D. Bullard, Glenn S. Johnson, and Angel O. Torres. Cambridge: South End Press.

Bullard, Robert D., and Glenn S. Johnson. 1997. *Just Transportation : Dismantling Race and Class Barriers to Mobility*. Gabriola Island, BC: New Society Publishers.

Congress for the New Urbanism. 2000. *Charter of the New Urbanism*. New York: McGraw-Hill.

Corburn, Jason. 2009. *Toward the Healthy City: People, Places, and the Politics of Urban Planning*. 1st ed. The MIT Press.

David J. Wright, and Lisa M. Montiel. 2007. "Divided They Fall: Hardship in America's Cities and Suburbs." The Nelson A. Rockefeller Institute of Government.

Day, K. 2006. "Active Living and Social Justice: Planning for Physical Activity in Low-Income, Black, and Latino Communities." *Journal of the American Planning Association* 72 (1): 88–99.

DeMaio, Paul. 2009. "Bike-Sharing: History, Impacts, Models of Provision, and Future." *Journal of Public Transportation* 12 (4): 3.

Dill, Jennifer, and Theresa Carr. 2003. "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them." *Transportation Research Record: Journal of the Transportation Research Board* 1828 (January): 116–23. doi:10.3141/1828-14.

Ellin, Nan. 2012. *Good Urbanism: Six Steps to Creating Prosperous Places*. Washington: Island Press.

Ewing, Reid, and Robert Cervero. 2001. "Travel and the Built Environment: A Synthesis." *Transportation Research Record: Journal of the Transportation Research Board* 1780 (January): 87–114. doi:10.3141/1780-10.

Fainstein, Susan. 2005. "Cities And Diversity Should We Want It? Can We Plan For It?" *Urban Affairs Review* 41 (1): 3–19.

Fishman, Elliot. 2015. "Bikeshare: A Review of Recent Literature." *Transport Reviews* 0 (0): 1–22. doi:10.1080/01441647.2015.1033036.

Fishman, Elliot, Simon Washington, and Narelle Haworth. 2013. "Bike Share: A Synthesis of the Literature." *Transport Reviews* 33 (2): 148–65. doi:10.1080/01441647.2013.775612.

Forkenbrock, David J., and Lisa A. Schweitzer. 1999. "Environmental Justice in Transportation Planning." *Journal of the American Planning Association* 65 (1): 97–111.

Friedman, Steven Marc, Matthew Adamson, Paula Cleiman, Tamara Arenovich, Karolina Oleksak, Ishmael Michael Mohabir, Robert Ta, and Kimberley Reiter. 2015. "Helmet-Wearing Practices and Barriers in Toronto Bike-Share Users: A Case-Control Study." *Canadian Journal of Emergency Medicine* FirstView (Supplement -1): 1–9. doi:10.1017/cem.2015.22.

Goodman, Anna, and James Cheshire. 2014. "Inequalities in the London Bicycle Sharing System Revisited: Impacts of Extending the Scheme to Poorer Areas but Then Doubling Prices." *Journal of Transport Geography*. Accessed August 5. doi:10.1016/j.jtrangeo.2014.04.004.

Handy, Susan. 2005. "Smart Growth and the Transportation-Land Use Connection: What Does the Research Tell Us?" *International Regional Science Review* 28 (2): 146–67 %U http://irx.sagepub.com/cgi/content/abstract/28/2/146.

Hodge, David, and Susan Hanson. 1995. "My Fair Share: Equity Issues in Urban Transportation." In *The Geography Of Urban Transportation*. London: The Guilford Press.

Institute for Transportation and Development Policy. 2013. "The Bike-Share Planning Guide." Institute for Transportation and Development Policy. https://www.itdp.org/the-bike-share-planning-guide-2/.

Kaplan, Sigal, Carlo Giacomo Prato, and Thomas Alexander Sick Nielsen. 2015. "A35 The Relationship between Walking and Cycling of Youth and Urban Form: A Heckman Selection Model of Active Travel Mode and." *Journal of Transport & Health* 2 (2, Supplement): S23. doi:10.1016/j.jth.2015.04.523.

Kraemer, John D., Jason S. Roffenbender, and Laura Anderko. 2012. "Helmet Wearing among Users of a Public Bicycle-Sharing Program in the District of Columbia and Comparable Riders on Personal Bicycles." *American Journal of Public Health* 102 (8): e23–25.

League of American Bicyclists. 2013. "The New Majority is Pedaling Toward Equity." Text. http://bikeleague.org/content/report-new-majority-pedaling-toward-equity-0.

Litman, Todd. 2015. "Evaluating Active Transport Benefits and Costs Guide to Valuing Walking and Cycling Improvements and Encouragement Programs." Victoria Transport Policy Institute.

Liu, Zhili, Xudong Jia, and Wen Cheng. 2012. "Solving the Last Mile Problem: Ensure the Success of Public Bicycle System in Beijing." *Procedia - Social and Behavioral Sciences*, 8th International Conference on Traffic and Transportation Studies (ICTTS 2012), 43: 73–78. doi:10.1016/j.sbspro.2012.04.079.

Martin, Elliot W., and Susan A. Shaheen. 2014a. "Evaluating Public Transit Modal Shift Dynamics in Response to Bikesharing: A Tale of Two US Cities." *Journal of Transport Geography* 41: 315–24.

———. 2014b. "Evaluating Public Transit Modal Shift Dynamics in Response to Bikesharing: A Tale of Two U.S. Cities." *Journal of Transport Geography*. doi:10.1016/j.jtrangeo.2014.06.026.

McCann, Barbara. 2013. *Completing Our Streets: The Transition to Safe and Inclusive Transportation Networks*. 2 edition. Washington: Island Press.

Midgley, Peter. 2011. "Bicycle-Sharing Schemes: Enhancing Sustainable Mobility in Urban Areas." *United Nations, Department of Economic and Social Affairs*. http://www.cleanairinstitute.org/cops/bd/file/tnm/13-bicycle-sharing.pdf.

NACTO. 2015. “Walkable Station Spacing Is Key to Successful, Equitable Bike Share.” National Association of City Transportation Officials. http://nacto.org/2015/04/28/walkable-station-spacing-is-key-to-successful-equitable-bike-share/.

Parkes, Stephen D., Greg Marsden, Susan A. Shaheen, and Adam P. Cohen. 2013. “Understanding the Diffusion of Public Bikesharing Systems: Evidence from Europe and North America.” *Journal of Transport Geography* 31 (July): 94–103. doi:10.1016/j.jtrangeo.2013.06.003.

Pucher, John, and Ron N. Buehler. 2008. “Making Cycling Irresistible: Lessons from the Netherlands, Denmark and Germany.” *Transport Reviews* 28 (4): 495–528.

Pucher, John, and Ron N. Buliung. 2014. “City Cycling.” *Journal of Transport Geography* 35 (February): 160–61. doi:10.1016/j.jtrangeo.2013.12.013.

Pucher, John, Jan Garrard, and Stephen Greaves. 2011. “Cycling down under: A Comparative Analysis of Bicycling Trends and Policies in Sydney and Melbourne.” *Journal of Transport Geography* 19 (2): 332–45. doi:10.1016/j.jtrangeo.2010.02.007.

Rainer-Harbach, Marian, Petrina Papazek, Bin Hu, and Günther R. Raidl. 2013. “Balancing Bicycle Sharing Systems: A Variable Neighborhood Search Approach.” In *Evolutionary Computation in Combinatorial Optimization*, edited by Martin Middendorf and Christian Blum, 121–32. Lecture Notes in Computer Science 7832. Springer Berlin Heidelberg. http://link.springer.com/chapter/10.1007/978-3-642-37198-1_11.

R Studio Team. 2015. *R Studio: Integrated Development for R. RStudio, Inc.,*. Boston, MA.

Schwartz, Samuel I., and William Rosen. 2015. *Street Smart: The Rise of Cities and the Fall of Cars*. PublicAffairs.

Shaheen, Susan A., Stacey Guzman, and Hua Zhang. 2010. “Bikesharing in Europe, the Americas, and Asia.” *Transportation Research Record: Journal of the Transportation Research Board* 2143 (1): 159–67.

Siavash Shahsavaripour. 2015. “Different Methods of Redistributing Bike among the Station: A Mathematical Solution in Order to Find Critical Stations.” *American Journal of Environmental Engineering* 5 (1): 21–31.

Speck, Jeff. 2012. *Walkable City: How Downtown Can Save America, One Step at a Time*. Reprint edition. Farrar, Straus and Giroux.

Susan A. Shaheen, Ph.D, Elliot W. Martin, Ph.D., Nelson D. Chan, Ph.D., Adam P. Cohen, Ph.D., Mike Pogodzinski, Ph.D., and Susan A. Shaheen, Ph.D. 2014. “Public Bikesharing in North America During a Period of Rapid Expansion: Understanding Business Models, Industry Trends and User Impacts.” 12-29. Mineta Transportation Institute. http://transweb.sjsu.edu/project/1131.html.

TED Books, ed. 2013. *City 2.0: The Habitat of the Future and How to Get There*. TED Conferences.

Tolley, Rodney. 2003. *Sustainable Transport: Planning for Walking and Cycling in Urban Environments*. 1 edition. Boca Raton, FL : Cambridge, England: CRC Press.

Toole Design Group, and Pedestrian and Bicycle Information Center. 2012. “Bike Sharing in the United States: State of the Practice and Guide to Implementation.” US DOT Federal Highway Administration. http://www.pedbikeinfo.org/pdf/Programs_Promote_bikeshareintheus.pdf.

Townsend, Anthony M. 2013. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. 1 edition. W. W. Norton & Company.

U.S. Department of Health and Human Services. 2015. "Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities." Washington, DC: U.S. Dept of Health and Human Services, Office of the Surgeon General. http://www.surgeongeneral.gov/library/calls/walking-and-walkable-communities/.

Wikipedia. 2014. "List of Bicycle-Sharing Systems." *Wikipedia, the Free Encyclopedia*. Wikipedia. https://en.wikipedia.org/w/index.php?title=List_of_bicycle-sharing_systems&oldid=683335517.

Wojan, Timothy R., and Karen S. Hamrick. 2015. "Can Walking or Biking to Work Really Make a Difference? Compact Development, Observed Commuter Choice and Body Mass Index." *PLoS ONE* 10 (7): e0130903. doi:10.1371/journal.pone.0130903.

Wolfe, Charles R. 2013. *Urbanism Without Effort*. Island Press.