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A Report from the University of Vermont Transportation Research Center

QUANTIFYING THE EQUITY OF BIKESHARE ACCESS IN US CITIES

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QUANTIFYING THE EQUITY OF BIKESHARE ACCESS IN US CITIES

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ABSTRACT

Bikesharing programs are an increasingly popular potential solution to many of the transportation sustainability challenges that cities face. The environmental and economic aspects of sustainability for bikesharing has been discussed extensively. While critical to overall success, the social equity aspect of bikeshare sustainability has been considered but not quantitatively assessed. This study finds that there is an inequitable distribution of bikeshare access among the population groups in US cities. This spatial analysis compares social and economic characteristics of US Census Bureau block groups based on the American Community Survey for areas within and outside of bikeshare service areas in seven cities. The locations of bikeshare stations were used to define the bikeshare service areas by creating a 500 meter buffer around each station in ArcGIS. Using a Student's t-test to compare the means of socioeconomic characteristics inside and outside of the bikeshare service areas, significant differences in access based on race and income variables were found in Boston, Chicago, Denver, Seattle, and New York City. Moreover, in Chicago, New York City, Denver, and Seattle, there was also a difference in the education level variables. The inequity in bikeshare access should be addressed by planning agencies and local governments. Corrective actions include public subsidies for stations in low income neighborhoods and educational resources.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Over the past several years, bikesharing systems have been introduced to many cities in the United States of America (USA). These systems consist of electronic bicycle docking stations, where users can check out a bicycle for short periods of time. In the US, the size and scale of bikeshare can range from just twenty-five bikes and three stations in Des Moines, Iowa to six thousand bikes at more than three hundred stations in New York City (*1*). Internationally, bikesharing systems have far surpassed this scale, with the largest bikeshare in Hangzhou, China, comprised of 60,600 bicycles (*2*). As cities throughout the world face transportation system challenges such as congestion, greenhouse gas emissions, and public health issues like obesity and heart disease, bikeshare programs offer a unique solution by promoting active travel while bypassing the need for external energy sources and space required by other modes of transportation.

Bikeshare programs have been implemented in more than seventy cities and college campuses in the USA since 2008, and it is expected that more will be introduced in the coming years (*3*). The first major system in the USA began in 2010 with Capital Bikeshare in the Washington, D.C. area, and now includes more than 3,000 bicycles (*4*). An even larger program, Citi Bike in New York City (NYC), opened in May 2013 with 6,000 bicycles but not without much controversy regarding safety. For example, two articles published in the New York Post read "Citi Bike is putting your head at risk" (*5*) and "Citi Bike rack remains a 'death trap' in the West Village" (*6*). However, there have yet to be any fatalities or significant safety incidents (*7*). In Boston, following the city's Boston Bikes program founded in 2007, Hubway was launched in July 2011 and now hosts 1,300 bicycles (*8*). Chicago's bikesharing program, Divvy, was launched in June 2013 and now has almost 5,000 bicycles (*9*). Two smaller bikesharing programs in Denver and Seattle both operate with less than 1000 bicycles.

Bikesharing is rapidly growing in popularity and becoming established in all types of cities throughout the USA. Therefore, it is important that consideration is given to ensure equitable access for all types of users, including those in traditionally disadvantaged groups whose circumstances often limit access to other modes of transportation, particularly automobile ownership. Access to public transit, including bikeshare, for all people of a city is imperative in measuring the success of a public transportation system. Although many groups have expressed concern over equitable access to the bikeshare systems of the US, such as the League of American Bicyclists, People for Bikes, and media including CityLab, few quantitative analyses of differences in access have been conducted.

This paper uses a spatial analysis that compares the social and economic characteristics of census block groups within and outside of the bikeshare service areas of the following bikeshare programs:

Citi Bike in NYC, New York,
Hubway in Boston, Massachusetts,
Capital Bikeshare in the Washington DC and Arlington VA,
Divvy in Chicago, Illinois,
B-Cycle in Denver, Colorado, and
Pronto in Seattle, Washington.

This is a varied group of USA cities and bikeshare programs in terms of size, geographical location, and urban form that allows bikesharing programs to be examined in many different contexts. The location in the USA and population of each city is shown in Figure 1. This

research aims to consider the socioeconomic characteristics of the population with and without proximate access to bikeshare stations and to address whether bikeshare docking stations in the cities are allocated equitably. Other barriers to accessing bikeshare, such as owning a credit card or the ability to read or understand necessary instructions for using bikeshare, are not directly addressed here but are also important elements of equitable access.

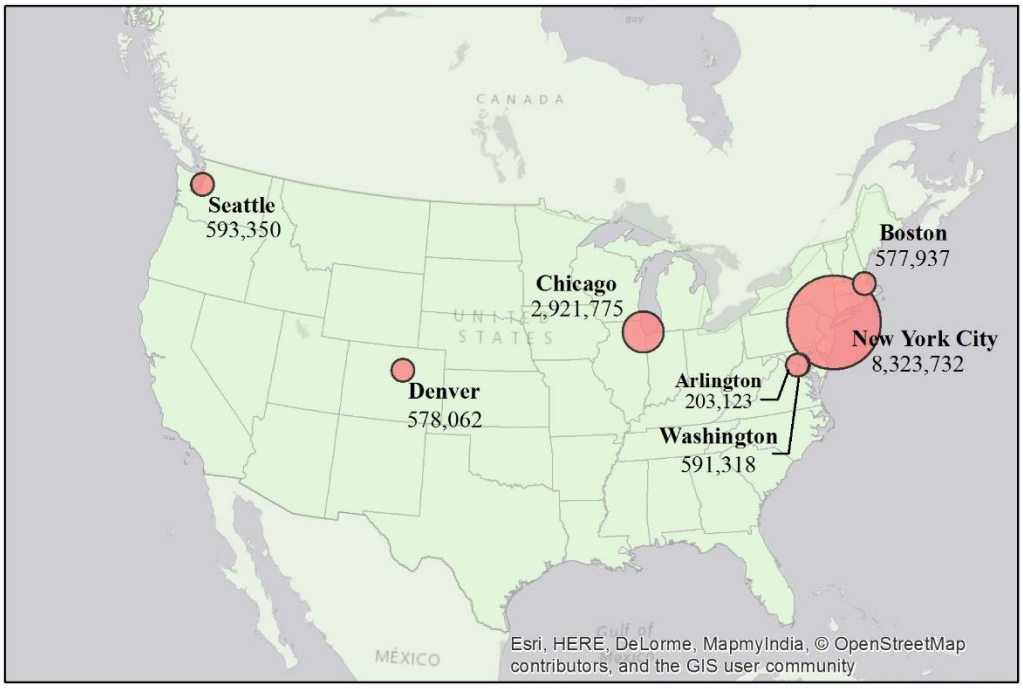

Figure 1. Location of seven cities with bikeshare and their population

LITERATURE REVIEW

Factors Influencing Bicycle Use in Cities

Existing research assessing factors that determine how and why people use bicycles in cities provides background that can also help understand factors that influence the use of bikeshare programs. Recent studies have shown that the presence and type of bicycle infrastructure play a significant role in bicycle use (*10, 11*). In general, facilities that minimize exposure to motor vehicles, like separated bike paths and bike boxes placed at intersections, are associated with more bicycling and make cyclists feel safer (*12, 13*). Another factor associated with bicycle use is the size and population density of a city. In their study of cities throughout the Netherlands, Rietveld et al. (*14*) found that cities with the largest populations have lower bicycle use, perhaps because of already existing facilities for other types of public transit. In terms of bicycle facility use within cities, Salon et al. (*15*) saw trends indicating that pedestrians and cyclists were most likely to use the roads, bike paths, and sidewalks in the most densely populated areas of California. This research tells us that more bicycle infrastructure in densely populated areas encourages cycling, which will most likely also be true with bikeshare use. No literature was found that linked the level of bicycle infrastructure to neighborhood socioeconomic variables, although some have suggested that dedicated infrastructure is more likely to be developed in more affluent neighborhoods.

Socio-Demographic Attributes of Existing Bikeshare Users

Previous studies have found that a majority of bikeshare users are white, male, and affluent (*16, 17*) suggesting that bikeshare program users do not necessarily reflect the diversity of a city's population. Ogilvie et al. (*18*) analyzed users of London's Barclays Cycle Hire (BCH, London's bicycle sharing program) to identify the socio-demographic characteristics of its users. They used the centroid of postcodes to determine the number of docking stations within 250 meters and compared this with characteristics of the surrounding population. Their results indicate that there is an association between the geographical positioning of each docking station and the socioeconomic explanatory variables that they examined. For example, only 18.4% of BCH bicycle trips were made by females, and only 15.9% of users were from the most-deprived income areas. A survey-based study in Australia revealed that those aged "18-34 had 3.3-fold greater odds of being a bikeshare member," and that compared to the general population, members of bike share had completed more schooling (*19*).

Additionally, an exploratory study for bikeshare in NYC found that men made up 65% of bicycle users in the fall 2007 Department of City Planning bicycle count (*20*). Despite equity concerns raised by the NYC bikeshare user studies, Fuller et al. (*21*) found that the number of men and women using Montreal's bikesharing program BIXI was about equal. These contradicting results may be due to differences in methodology – Fuller et al. sent out surveys and had a response rate of 34.6%, while Olgivie et al. used data directly from BCH registrants. It is also possible that contextual differences between the studies, such as the differences in the culture and infrastructure of these cities, play a role in determining who uses bikeshare.

Bikeshare System Design and Equity Considerations

Literature pertaining to methods of bikeshare system design provides an understanding of why the distribution of docking stations exists as it does. Krykewycz et al. (*22*) evaluated the viability of a bikeshare scheme in Philadelphia PA by locating areas with the most potential for bicycle usage. Areas of the city were identified as "primary markets" using variables such as

population density, job density, location of tourist attractions, proximity to rail stations, and proximity to streets with bicycle lanes for 10-meter cells in Philadelphia and its surrounding regions. The primary market defined in this study fell within the boundaries of the urban core. Downing (*23*) combined data about the geographical distribution of the presence of health conditions from the Southeastern Pennsylvania Household Health Survey with a map of the service area proposed by Krykewycz et al. and socio-demographic characteristics of these areas. From this, she found those who have the highest risk of developing chronic health conditions, whom she called "target health groups," include women, blacks, Latinos, and those living below 200% of the Federal Poverty Level. Furthermore, her results identified West Philadelphia as an important area for this bikeshare program to target due to both the low rates of exercise and high rates of health conditions. Her research suggested that the inequitable distribution of heath conditions should be considered in order to achieve the public health benefits of bikesharing.

With a more economic perspective on equity, Buck (*24*) surveyed managers of bikeshare programs in the USA to measure their efforts for equity of users in the design of their bikeshare systems. The seven strategies he outlined in the survey that promote the equity of bikeshare programs included ensuring there are stations located in low-income neighborhoods, providing financial assistance to low-income users, installing bicycle infrastructure in low-income neighborhoods, incorporating other accounts (i.e. transit fare cards) with bikeshare payment, exposing groups who are underrepresented as cyclists to bikeshare through marketing and outreach, providing resources, such as helmets and simple bicycle use instructions, and making a contribution to the economic well-being on low-income communities by partnering with local organizations. Many respondents indicated that placing bikeshare stations in low-income communities was the most essential strategy for equity, and that their bikeshare systems either had done this or had plans to do this. Several of the bikeshare systems that were surveyed indicated that they were also using strategies to encourage equity, but the most frequent reason for not pursuing these strategies was a lack of funding.

Equity concerns do not only apply to bikesharing, and other promising sustainable modes of transportation are considering how to reach traditionally disadvantaged groups as well. For example, Espino and Truong (*25*) provide numerous recommendations to "help ensure a successful carsharing program in underserved communities." Among their suggestions is the operation of storefront locations with multilingual, in-person resources like orientations, people to organize reservations and payments that do not necessitate a credit card, and other educational materials for those who are unfamiliar with how the program works or how to operate the vehicle. It is reasonable to assume that a resource like this would also be beneficial for bikeshare programs.

Another important consideration in bikeshare infrastructure is the private sector sponsorship of many programs throughout the USA. Banks, airlines, health care providers, and sport retail companies have all sponsored bikeshare programs throughout the country. For example, Citi has contributed $41 million to Citi Bike in New York City (*26*); Alaska Air sponsors Pronto in Seattle (*27*); Frontier Airlines sponsors B-Cycle in Denver (*28*); and New Balance sponsors Hubway in Boston (*8*). It is understandable that companies want to see positive advertising from these bikesharing systems and the location of docking stations impacts the success of the marketing strategy and number of targets within a specific demographic group that may or may not fall within certain customer bases.

The existing research indicates that equity outreach should be a primary focus of bikesharing systems. It also suggests that the amount of diversity seen in some cities is not

reflected in the users of their bikesharing programs. One possible explanation of this pattern could be that bikeshare program infrastructure has not been allocated in a spatially equitable pattern. This question requires further assessment, as it has not been adequately addressed by previous studies.

DATA AND METHODS

This study compares social and economic characteristics of Census block groups within the service area of bikeshare programs to those characteristics outside of the service area in seven cities. Data describing bikeshare docking locations and the number of docks at each station for Hubway, Citi Bike, Capital Bikeshare, and Pronto was provided by Alta Bicycle Share (which has since changed its name to Motivate). The data for Divvy and B-Cycle comes from the City of Chicago Data Portal and the Denver Open Data Catalog respectively, which are both open source websites. All six datasets in seven cities consist of the latitude and longitude of each bikeshare station and the number of docks at each station. It was entered into ArcGIS using the WGS 1984 coordinate system.

The service area for a bikeshare docking station is defined here as the area within 500 meters of the station. The boundary for the study area in each city was defined by political boundaries. Areas within 500 meters of a bikeshare station and within the study area are considered within the service areas. Areas within the political boundaries and outside a bike station service area are considered outside the service area. These studies are displayed in Figure 2 on two different scales.

New York City is a special case because of its large size and population. For an analysis of this city, the boundary for being outside of the service area is considered in two ways: within Brooklyn and Manhattan alone (the two boroughs that currently have bikeshare stations and are shown in darker color in Figure 2), and within all five boroughs. Another special case is Capital Bikeshare, whose service area spans three different cities. Washington, DC and Arlington, Virginia were considered as they are the largest of the three cities that Capital Bikeshare serves and have the most docking stations. By using the cities as two separate study areas we remain consistent with our definition of areas outside of the service area boundary, which is the political border of each city.

Table 1 below shows the differences in the sizes of each city, in terms of population, area, and scope of the existing bikeshare system. NYC is the most populous and spans the largest amount of area, while its service area is the densest, covering the fewest square kilometers and having the most bikeshare stations. Chicago has the second largest population and land area and has almost as many bikeshare stations as NYC, but stations are spread out in a service area more than twice the size of Citi Bike's. DC also has a large population, and Capital Bikeshare's service area spans almost half of the area in the city limits of DC but with notably fewer bicycles than Citi Bike. Boston and Denver have relatively smaller populations, land areas, and number of bikeshare stations, but their service areas are spread over areas larger than the Citi Bike service area. Arlington's population is the smallest, but it is important to note that its surrounding areas are very heavily populated. Note that proportion of the city population within the bike share services areas varies considerably from 10 to 50%.

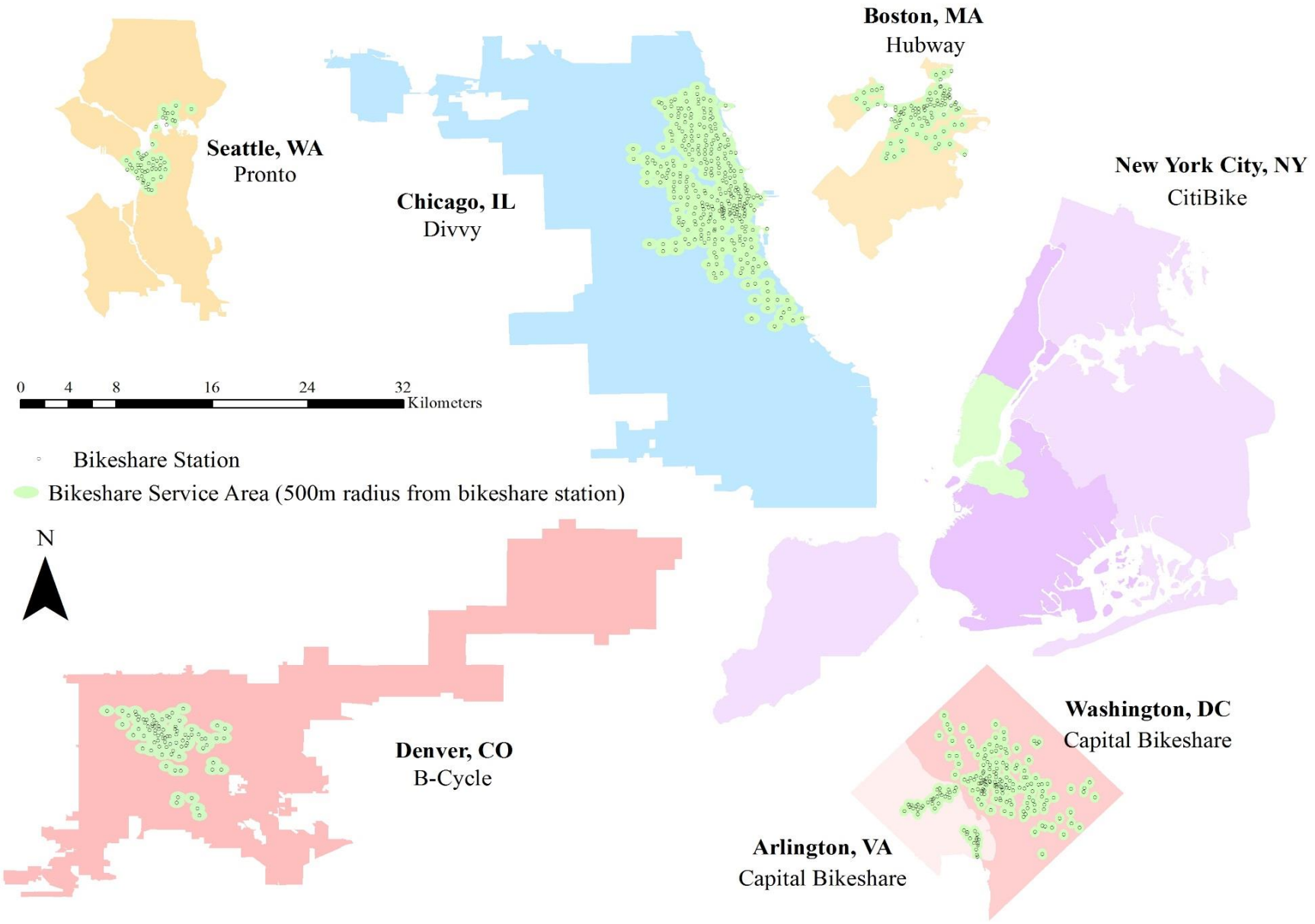

Figure 2. Bikeshare service areas and study area boundaries

Table 1. Selected Characteristics of Boston, Chicago, DC, Arlington, Denver, and Seattle

	Study Area	Bike Share Stations	# of Docks	Population (% of total)	Area (km^2) (% of total)	# of Census Block Groups	Mean Population per Block Group
In Service Area	Boston	131	767	412,454 (50.5)	54.4 (33.6)	439	1166
	Chicago	300	5,192	684,527 (24.9)	91.5 (15.5)	626	1293
	Brooklyn-Manhattan	331	11,574	855,768 (20.5)	37.5 (15.6)	744	1237
	NYC (5 boroughs)	331	11,574	855,768 (10.4)	37.5 (4.8)	744	1237
	DC	191	3459	479,955 (79.2)	136.5 (47.1)	352	1364
	Arlington	67	874	155,630 (51.6)	4.3 (6.7)	132	1179
	Denver	84	1263	165,299 (22.9)	63.4 (13.9)	140	1181
	Seattle	50	--	140,867 (19.5)	35.6 (10.8)	106	2658
Outside Service Area	Boston			404,257 (49.5)	107.4 (66.4)	557	1139
	Chicago			2,064,974 (75.1)	500.3 (84.5)	1821	1232
	Brooklyn-Manhattan			3,310,128 (79.5)	202.5 (84.4)	2547	1300
	NYC (5 boroughs)			7,343,456 (89.6)	737.2 (95.2)	5811	1274
	DC			125,804 (20.8)	153.2 (52.9)	303	1322
	Arlington			145,911 (48.4)	60 (93.3)	129	1131
	Denver			556,265 (77.1)	391.5 (86.1)	441	1261
	Seattle			581,154 (80.5)	295 (89.2)	456	1274
Total	Boston			816,711	161.7	996	1289
	Chicago			2,749,501	591.8	2447	1244
	Brooklyn-Manhattan			4,165,896	240	3291	1269
	NYC (5 boroughs)			8,199,224	774.7	6555	1271
	DC			605,759	289.7	378	1357
	Arlington			301,541	64.3	261	1155
	Denver			721,564	454.9	581	1242
	Seattle			722,021	330.6	561	1287

The variables that were selected as measures of socioeconomic factors are shown in Table 2. This data comes from the US Census American Community Survey's 2012 5-year estimates at the block group level.

Table 2. Social and Economic Variables

Category	Variable
Population	Population Density
Race	% White % African American USA Today Diversity Index (described below)
Age	% aged over 60 years
Education Level	% Completed High School % With College Degree (including Associate's, Bachelor's, Master's, and Doctorate)
Income	% Households making under $20,000 / year % Households making over $100,000 / year % Households making over $200,000 / year

The USA Today Diversity Index was chosen as a way to use Census data to measure how varied the different racial groups are in a given area. It uses probability to measure diversity by squaring the percentages of people in each Census racial category (per block group, in this case) and adding the squares together. This number is a way to indicate the likelihood that two people randomly chosen from a block group will be of the same race. The Diversity Index is on a scale from 0 to 100, with a 100 indicating the highest level of diversity where every person is from a unique race and 0 indicates all people are of the same race (*29*). Figure 3 illustrates that within block group diversity varies between cities with NYC having the most and Washington DC and Arlington having the least.

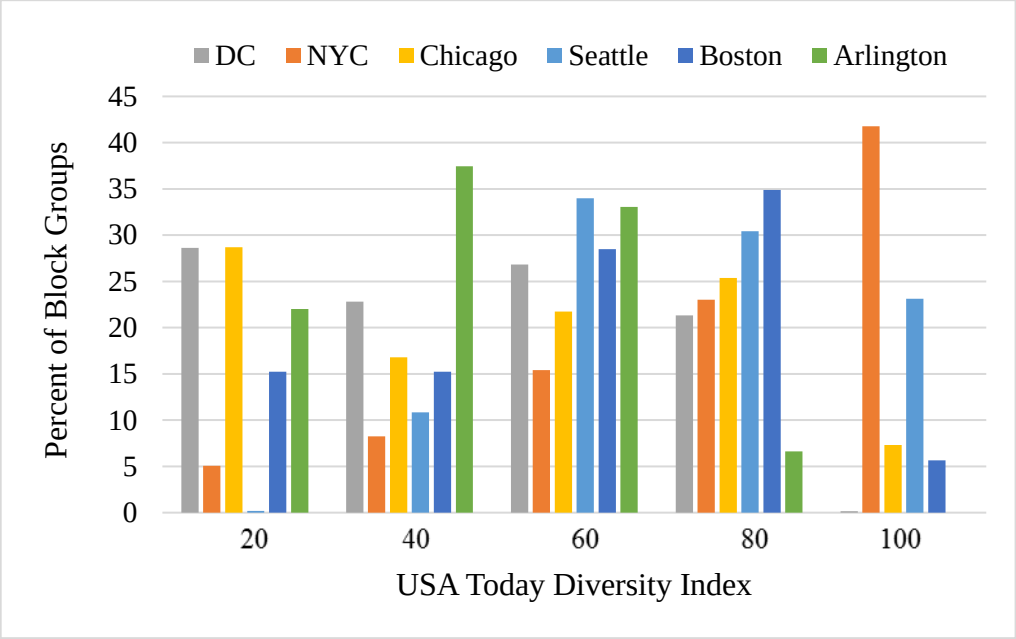

Figure 3. Summary of USA Today Diversity Index for Seven Study Cities

RESULTS

Table 3 shows one way to consider equitable access of bikeshare by city. In this case population is summed by category for block groups within and outside bikeshare service areas. With the exception of Washington, DC, the percent of white people with access to bikeshare is notably higher than the percent of African American people. Additionally, for all seven cities the percent of people in the bikeshare service area is greater for those with college degrees than without. The percent of households earning more than $100,000 per year is also greater than the percent earning less than $20,000, with the exception of Seattle. The percent of people over the age of sixty years in the service areas is considerably low, with the highest percentage in Washington, D.C. of just under 15%.

Table 3. Comparing the total population with access to bikeshare of each city by social and economic characteristics

	% White	% African American	% with Degree	% without Degree	% HH earning >$100,000	% HH earning <$20,000	% Over 60 years
Arlington	35.4	5.2	38.0	13.6	24.6	4.0	5.9
Boston	42.6	7.1	40.3	22.3	18.6	14.8	6.7
Chicago	18.7	5.2	18.1	11.4	8.7	6.1	4.0
Washington DC	41.5	42.6	52.1	41.5	31.7	17.0	14.3
Denver	19.0	1.6	14.4	8.5	5.8	5.2	3.4
New York City	7.1	1.4	7.2	4.1	4.3	2.2	1.9
Seattle	14.0	1.3	13.3	6.2	4.7	4.8	2.7

In order to assess statistical significance, the variables were summarized in an alternative way based on means by block group and Student t-tests were performed. As seen in Table 4 below, in Boston, NYC, Chicago, Denver, and Seattle, the mean percent of African Americans living inside the bike share service areas per block group is significantly lower than outside of the service area. Additionally, the percent of white people is larger inside of the service area in these five cities.

Every city in this study showed a difference in at least one income variable, whether it be the percent of people with access at the higher end (making over $100,000 or $200,000 per year) or lower end (making less than $20,000) of the income spectrum. Among all eight study areas, the percent of households making more than $200,000 per year was the most common significant income measurement variable. Only one city showed a difference in all three income variables (Washington, DC).

In Chicago, there was a difference in all of the variables tested except percent of households making less than $20,000 per year and the USA Today diversity index. The large difference in the mean of the percent of the population that is African American in Chicago is notable, although these variables also have very large standard deviations. In New York City, the variables that show a difference are the same when looking at the Citi Bike service area versus just Brooklyn and Manhattan and also versus all five boroughs. Both study areas showed a

difference in all variables but percent of households making less than $20,000 per year and the diversity variable.

Denver, Seattle, and Chicago all show differences in measures of race and education level. The significance of the diversity index varies among the cities but is smaller inside the service area with the exception of Washington, DC. In all seven cities and all eight study areas, the population density was higher inside the bikeshare service areas than outside.

Table 4. Comparison of the Means of Socioeconomic Variables Inside and Outside of the Service Areas

			Chicago (N in = 626, N out = 1821)	**Boston** (N in = 439, N out = 557)	**NYC** (5 Boroughs) (N in = 744, N out = 5811)	**NYC** (Brooklyn & Manhattan) (N in = 744, N out = 2547)	**Arlington** (N in = 132, N out = 129)	**Washington DC** (N in = 352, N out = 303)	**Denver** (N in = 140, N out = 441)	**Seattle** (N in = 105, N out = 456)
Category	**Measurement Variable**	**Service Area?**	**Mean** (**bold** indicates significance at the 0.05 level based on a two-tailed t-test)							
Population	Population Density (people/km^2)	In	**0.012**	**0.011**	**0.032**	**0.032**	**0.008**	**0.008**	**0.004**	**0.009**
		Out	**0.012**	**0.007**	**0.023**	**0.028**	**0.004**	**0.005**	**0.003**	**0.004**
Race	Diversity Index	In	43.70	49.77	**44.34**	**44.34**	33.39	**40.75**	**38.34**	46.02
		Out	41.22	49.07	**53.64**	**47.71**	34.94	**34.72**	**50.07**	43.50
	% White	In	**63.1**	**67.8**	**60.3**	**60.3**	69.7	42.6	**83.7**	**71.6**
		Out	**39.6**	**55.6**	**42.1**	**47.1**	72.5	30.2	**74.3**	**70.8**
	% African Am	In	**18.7**	**11.5**	**12.5**	**12.5**	8.96	47.2	**6.22**	**6.53**
		Out	**41.9**	**25.1**	**25.7**	**29.7**	7.09	61.5	**9.55**	**7.86**
Age	% Over 60	In	**14.3**	14.3	**16.9**	**16.9**	11.6	**17.2**	15.6	14.3
		Out	**16.4**	16.5	**17.3**	**17.7**	15.3	**20**	17	17.3
Education Level	% with Degree	In	**60.6**	62.9	**60.9**	**60.9**	73.8	55.1	**63.2**	**68.6**
		Out	**29.3**	49.2	**34.9**	**39.5**	71.7	45.1	**44.8**	**62.2**
	% High School only	In	**73.9**	78.2	**72.6**	**72.6**	8.5	**18.3**	**10.4**	**8.87**
		Out	**56.4**	71.2	**60.6**	**64.2**	10	**24.1**	**17.7**	**12.5**
Household Income	% >$100,000/yr	In	**28.4**	29.9	**35.9**	**35.9**	48.7	**34.2**	26.4	**24.5**
		Out	**15.3**	29.1	**21.3**	**22.2**	55.7	**29.9**	21.9	**32.9**
	% >$200,000/yr	In	**9.3**	9.3	**15.6**	**15.6**	**14.8**	**11.4**	**8.37**	8.34
		Out	**2.5**	7.5	**4.6**	**6.2**	**23.1**	**11.1**	**5.55**	9.05
	% <$20,000/yr	In	21	**22.4**	17.8	17.8	**6.89**	**17.8**	22	**24**
		Out	24.8	**20.7**	21.7	23.4	**6.68**	**20.4**	19.5	**13.2**

CONCLUSIONS

This study provides quantitative measures that backup many recent suggestions and concerns that there are equity and access issues relation to bikeshare system design and station location. A statistically significant difference in the race, education level, and income was found Chicago, Denver, Seattle and New York City. Boston did not show differences in the means of age or education, but it did show race and income disparities. Washington DC and Arlington were the most equitable among the variables and cities in this study, but did show differences in household income variables. In all cases, the traditionally more disadvantaged groups had less access to bikeshare.

Although bikeshare systems are often considered a solution to major transportation system challenges, bikesharing systems in the USA may be targeting a specific demographic through bikeshare station placement. This is not necessarily intentional or deliberate, and the higher population densities insides each bikeshare service area represent an explanation for why bikeshare stations are placed where they are. Placing stations in only the most densely populated areas of the city makes sense to attract a maximum number of users. However, this method of allocating stations has resulted in unintended consequences including limiting access to bikeshare for traditionally disadvantaged groups, as shown in this analysis.

Several strategies may be used to combat the inequity of bikeshare access and are being tried in several locations. Public subsidies aimed specifically at encouraging disadvantaged groups to use bikeshare would allow bikeshare stations to be placed in lower income neighborhoods. Opening information centers with in-person customer service and creating outreach programs that educate all people about bicycle use and safety would also increase bicycle accessibility and bikeshare ridership.

Further quantitative spatial research building on this study could prove useful. For example, this study was based on home location but moving on to examining bikeshare in the context of business activity, academic communities, and social gathering places would provide an understanding of accessibility in terms of origins and destinations. This approach would result in a more in-depth understanding of the accessibility provided by bikeshare.

ACKNOWLEDGMENTS

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