Equity in Bike Share: A Geo-Spatial Analysis of Los Angeles' Metro Bike Share

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Abstract:

Bike share is a growing phenomenon across the United States with many potential positive impacts, especially for low-income populations and communities of color. However, studies on bike share systems have demonstrated inequity in where bike share stations are placed in that they tend to be located in areas with populations that are more white, higher-income, and better educated (Smith, Oh, & Lei, 2015; Ursaki & Aultman-Hall, 2015). This research paper conducts a geo-spatial analysis of L.A.'s Metro Bike Share program in order to answer the questions: What factors are relevant in the locations of Metro Bike Share's docked bike share stations? Do the factors of race, education level, and income impact station location in a way that creates inequity? It takes a quantitative approach, using ArcGIS to map Metro Bike Share's station locations against census tract data on race, educational attainment, median household income, job density, population density, and journey to work for L.A. County and L.A. City. It then uses logistic and Poisson regressions in STATA to analyze which factors are more likely to influence station placement and if there are any equity issues. This research revealed potential equity concerns in terms of Metro Bike Share stations being located in higher-educated areas. However, it also revealed that Metro Bike Share serves a diverse ethnic population and a range of incomes. This study calls on L.A. Metro to over-place new docked bike share stations in lower-income areas to address equity concerns and ensure equitable access to opportunities through improved mobility.

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Introduction:

Bike sharing systems are a growing phenomenon in the United States, as the National Association of City Transportation Officials (NACTO) (2019) found that bike share trips were up 25 percent in 2017 at 35 million compared to 2016. These bike share systems "consist of electronic bicycle docking stations, where users can check out a bicycle for short periods of time" (Ursaki & Aultman-Hall, 2015, p. 3). Although the concept of bike sharing originally began in Amsterdam in 1965, it did not begin to grow and spread until the city of Lyon in France established a program with 1,500 bikes in 2005 and Paris followed in 2007 (DeMaio, 2009). Since then, cities in countries across the world from China, Brazil, New Zealand, and the United States have begun to implement their own programs. Technological improvements in the 1990s and on have allowed for modern-day systems where bikes can be tracked, electronically locked in stations, and accessed through smartphones (DeMaio, 2009).

The potential positive impacts of bike sharing programs are many: helping bridge the first mile last mile gap to public transportation, reducing greenhouse gas emissions by getting people out of their cars, health benefits from increased exercise, and more mobility options, to name a few (DeMaio, 2009). They hold particular potential for low-income populations of color, who have historically been disadvantaged by transportation policies and investments and therefore have had less access to opportunities and employment. However, studies on bike share systems have demonstrated inequity in where bike share stations are placed in that they tend to be located in areas with populations that are more white, higher-income, and better educated (Smith, Oh, & Lei, 2015; Ursaki & Aultman-Hall, 2015). While transportation equity can be defined in a number of ways, this study will consider equity in terms of access to bike share stations based on race, median household income, and education level. Therefore, while bike share systems hold a lot of potential for disadvantaged populations, stations must be placed in their communities so that they have fair access to the program and the same opportunities to use the bikes as others.

Following other major cities such as Washington D.C. and Chicago, a bike share system was created in Los Angeles in 2016. Called Metro Bike Share, the system is a partnership between the Los Angeles County Metropolitan Transportation Authority (L.A. Metro), the City of L.A., and the Port of L.A ("About," 2018). At the time of this study, it operated 24/7 in Downtown L.A., Central L.A., North Hollywood, the Port of L.A., and the Westside ("About," 2018). Depending on the station, users can find a Classic Metro Bike, an Electric Metro Bike, or a Smart Metro Bike ("About," 2018). Before implementation, L.A. Metro was sensitive to where their bike stations would be located. They included relevant research in their system plan as well as solicited feedback from the community on station sitting. However, the chosen locations of the bike share stations have not been thoroughly studied since implementation. This research paper conducts a geo-spatial analysis of L.A.'s Metro Bike Share program in order to answer the questions: What factors are relevant in the locations of Metro Bike Share's docked bike share stations? Do the factors of race, education level, and income impact station location in a way that creates inequity?

It takes a quantitative approach, using ArcGIS Online (ArcGIS) to map Metro Bike Share's station locations against census tract data on race, educational attainment, income, job density, population density, and journey to work for L.A. County and L.A. City. It then uses STATA to analyze which factors are more likely to influence where a station is placed and if there are any equity issues. Based on previous studies in other cities, this paper hypothesizes that race, educational attainment, and income level are factors that impact Metro Bike Share's station placements, resulting in stations placed more often in whiter, more educated, and higher-income areas. With the vast socioeconomic diversity in Los Angeles County and the documented inequity in placement of bike share stations in other cities, a geo-spatial analysis of Metro Bike Share's station locations will help create an understanding of which factors impact station sitting and if there is any inequity in the process.

Background:

History and Purpose of Bike Share

Although scaling-up and growing in popularity only in more recent years in the United States, bike sharing has a longer history across the world. Bike share systems can be looked at generationally, and it is now argued that they are in an emerging fourth generation (DeMaio, 2009; Martin & Shaheen, 2014). The first generation began with the first bike share program in Amsterdam on July 28, 1965. Called "White Bikes," a number of bicycles painted white were put out for free public use. However, without the technology to keep track of these bikes, they were stolen and vandalized and the program was very short-lived (DeMaio, 2009). Program failure was also the case in a similar program in the UK in 1993, though a free bike share system, started in 1974, continues to operate successfully today in La Rochelle, France (Shaheen, Guzman, & Zhang, 2010).

The second generation began in Denmark in the 1990s. In this system the bicycles were built intentionally for intense long-term use, were operated by a non-profit organization, had specific pick-up and drop off locations, and required a coin deposit (DeMaio, 2009). Although the second generation showed improvements in the system, the programs again had issues of theft because of the lack of accountability of the rider. Nevertheless, it spread throughout a number of European cities (Shaheen, Guzman, & Zhang, 2010).

The third generation of bike sharing saw a rise in the use of technology to improve the systems. It started in England in 1996, where magnetic stripe cards could be used to rent a bike. Other technological advances "including electronically-locking racks or bike locks, telecommunication systems, smartcards and fobs, mobile phone access, and on-board computers" further enhanced systems in this generation and made it much more difficult to steal bikes (DeMaio, 2009, p. 42). There has been a large growth of these third generation bike share programs with a diversity of business models and service providers outside of Europe and across the world (DeMaio, 2009, p. 43; Shaheen, Guzman, & Zhang, 2010, p. 10).

Finally, Shaheen et al. (2010) propose a fourth generation of bike share called 'Demand Responsive, Multi-Modal Systems' (p. 15). These systems improve on the third generation and "emphasize flexible, clean docking stations; bicycle redistribution innovations; smartcard integration with other transportation modes, such as public transit and carsharing; and technological advances including GPS tracking, touchscreen kiosks, and electric bikes" (Shaheen et al., 2010, p. 15). The United States comes into bike sharing largely in the third and fourth generation, with Los Angeles' Metro Bike Share system fitting into the description of the fourth generation. So, while originating in European cities, bike share systems are now becoming common on an international scale and have been rapidly expanding in North America at a frequency of about two dozen public systems created per year (McNeil, Dill, MacArthur, Broach, & Howland, 2017).

There are many reasons why people use bike share programs, such as a way to get to and from work, school, or transit, for social purposes, exercise, or to run errands. The predominant reasons vary among cities and member profiles, considering differences between the size of cities, car and bicycle ownership among individuals, and type of membership (annual vs. daily pass). The National Association of City Transportation Officials found that among station-based bike share riders, those with annual or monthly passes were more likely to use bike share during traditional rush-hours and those with day passes or single-trip rides were more likely to ride for longer periods of time in the middle of the day and on weekends (NACTO, 2018). Thus, it is likely that annual and monthly pass holders use bike share to commute while others use it for more social and recreational purposes (NACTO, 2018). In addition, convenience is consistently found to be a key motivator for choosing bike share, among other reasons such as speed and access (Fishman et al., 2013). In fact, a study of a bike share program in China found that a majority of respondents found bike share more convenient than using a private bicycle (Fishman et al., 2013). Clearly, bike share systems are taking hold in cities around the world in many forms and are serving many purposes.

Los Angeles Metro Bike Share

L.A. Metro serves L.A. County, an area made up of over 9.6 million people, with their transportation work (“about Metro,” n.d.). Their vision includes three parts: “increased prosperity for all by removing mobility barriers; swift and easy mobility throughout L.A. County, anytime; and accommodating more trips through a variety of high-quality mobility options” (“About Metro,” n.d.). It is evident that bike share fits into this vision, and L.A. Metro has many active transportation projects and programs that focus specifically on biking. These include Metro Bike Week, Guided Community Bicycle Rides, and Bicycle Traffic Safety Classes. In addition, L.A.’s 2019 Sustainable City pLAn, called the Green New Deal, sets a goal of expanding Metro Bike Share to new neighborhoods and increasing “the percentage of all trips made by walking, biking, micro-mobility / matched rides or transit to at least 35% by 2025; 50%

by 2035; and maintain at least 50% by 2050" (pp. 72-74). With this goal in mind, L.A. Metro is partnering with a number of organizations such as East Yard Communities for Environmental Justice and People for Mobility Justice who work on promoting active transportation and transportation equity with specific programs on cycling ("L.A.'s Green New Deal," 2019). Because cycling is a key part of L.A. Metro's vision and the city's transportation future, Metro Bike Share is uniquely situated for growth and expansion.

L.A. Metro rolled out Metro Bike Share on July 7, 2016, and it operates 24/7 in Downtown L.A., Central L.A., North Hollywood, the Port of L.A., and the Westside ("About," 2018). From the beginning, L.A. Metro has stated their commitment to making the bike share program accessible. This is seen in the Regional Bike Share Implementation Plan for Los Angeles County, prepared for L.A. Metro by Fehr Peers in 2015, which states accessibility of the system as a goal in L.A. Metro's mission. The plan promotes equity through affordability and "by making stations available in a variety of neighborhoods" (p. 9). In addition, it includes an analysis of the minority population and the share of the population living in poverty surrounding proposed bike share stations located in Downtown Los Angeles, concluding that these groups did not face a disproportionate burden from the locations (Fehr Peers, 2015). While the plan is a promising commitment to equity, McNeil, Broach, and Dill (2018) found that it was more likely for pre-launch systems to consider equity. In addition, while objectives in active transportation planning regularly include equity, they are often not effectively implemented (Lee, Sener, & Jones, 2017).

Nonetheless, L.A. Metro went beyond the pre-launch plan when considering station location by reaching out to communities about where they would like the stations to be located. Through a Better Bike Share Partnership Grant, they worked with an array of organizations including Los Angeles County Bicycle Coalition and People for Mobility Justice, conducting outreach and getting feedback on the bikeshare program in both English and Spanish (McNeil et al., 2019). They posted informational flyers at proposed station locations and provided a phone number for people without internet access to call. According to the McNeil et al. (2019) study on bike share equity programs, about 1,200 people voted on the potential station locations. Again, this is promising for the Metro Bike Share program as it shows community members were engaged in the process. However, L.A. Metro did not collect the demographics of the people who voted on station locations. This could result in bias of who voted, especially considering what populations have access to phones and internet and what populations do not.

Another important aspect of the Metro Bike Share system is that it has integrated the transit fare card (TAP card) into the bike share payment system. Metro Bike Share is one of the first bike share programs in the U.S. to combine these two systems, allowing for L.A. Metro to extend reduced-fare options for those who qualify in the transit program to the bike share program. However, a credit card is required to add a bike share account to the card, which is not needed for the transit function of the card (McNeil et al., 2019). It has been found that the credit card requirement is a deterrent for low income people because they often lack access to a credit card or fear getting charged more than expected when using a credit card (McNeil, Broach, & Dill, 2018). So, while the incorporation of bike share on the TAP card is a good start, L.A. Metro has yet to address this problem. Nevertheless, it is clear that L.A. Metro made a demonstrated effort to provide equity in their bike share placement and programming. With the documented commitment to equity in L.A. Metro's bike share plan, a geo-spatial analysis of the station locations will help understand how successful the rollout of the bike share program has been in terms of serving disadvantaged communities with bike share stations.

Literature Review:

Shared Mobility

New mobility options have exploded in recent years, from rideshare services and autonomous vehicles to bike share systems and electric scooters. These mobility options have emerged alongside a larger phenomenon of a sharing economy made up of collaborative consumption and often aided by smartphones and technology, where companies like Uber and Airbnb have quickly become huge players (Cohen & Kietzmann, 2014). The growth of the sharing economy has potential sustainability benefits, especially as urbanization is occurring on a global scale and cities are becoming more crowded (Cohen & Kietzmann, 2014). One subset of this sharing economy is shared mobility, where users can access a mode of transportation as-needed for relatively short amounts of time (American Planning Association, 2016). Services can be roundtrip, one-way and station-based, or one-way and dockless (American Planning Association, 2016). Within shared mobility, a trend of micromobility options has emerged, made up of "all shared-use fleets of small, fully or partially human-powered vehicles such as bikes, e-bikes, and e-scooters" (NACTO, 2018). In 2018, shared micromobility accounted for 84 million trips in the U.S., more than double the number of those trips taken in 2017 (NACTO, 2018). Bike share systems are a large part of emerging micromobility, and business models can range from station-based to dockless to a combination of both. While some bike share services and systems have gone dockless, docked bike share programs are an important piece of shared mobility that present unique questions because they are place-based.

Benefits of Bike Share

The rise of bike share systems has numerous potential benefits for urban regions and individuals. Bike sharing has been found to decrease driving and taxi use "almost universally" and can either reduce or increase the use of public transit depending on the circumstances (Martin & Shaheen, 2014, p. 2). For example, a study done on annual members of Washington D.C.'s Capital Bikeshare program found a shift in transportation use from rail to biking, especially in the downtown area of the city where the rail system is more congested and bike share potentially offers a faster alternative mode of transportation (Martin & Shaheen, 2014). While the larger shift was away from rail, a portion of the sample increased their use of rail with the use of bike share. These riders were more likely to live away from the urban core and thus bike share potentially acted as a connector to established public transportation systems (Martin & Shaheen, 2014).

In addition to either facilitating more public transit use or decreasing congestion on public transit in an urban core, bike share has the potential to reduce greenhouse gasses from automobile emissions (Shaheen, Guzman, & Zhang, 2010). The extent of this is dependent on how often bike share users are replacing car rides rather than other forms of transportation such as public transit or walking. Nevertheless, the possibilities for reduced car traffic congestion and greenhouse gas emissions are promising as over 60 percent of all trips in the U.S. are five miles or less, and trips in cars less than three miles long cause 46 percent of car traffic in the U.S. (Ajao, 2019; "Micromobility Revolution," n.d.). Los Angeles in particular is a city dominated by freeways and automobiles, so bike share holds a lot of potential for moving away from a car-centered culture. This is a move that L.A. residents and government officials have increasingly pushed for in recent years through funding initiatives and policy plans geared towards the development of more public and active transportation infrastructure (Los Angeles County Department of Public Health, 2014).

For individuals, bike share provides an increase in mobility options and has health benefits such as increasing exercise and improving mental wellbeing (Ogilvie & Goodman, 2012). Physical activity such as biking can help reduce risk of chronic diseases and aid people in managing their weight (Los Angeles County Department of Public Health, 2014). This is particularly relevant for Los Angeles County, as a study in 2014 found that almost two-thirds of adults and around 23 percent of children are overweight or obese (Los Angeles County Department of Public Health, 2014). Although biking can also have negative health effects by potentially increasing exposure to air pollution or risk of a traffic accident, a study done in the Netherlands found that "on average, the estimated health benefits of cycling were substantially larger than the risks relative to car driving for individuals shifting their mode of transport" (Hartog, Boogaard, Nijland, & Hoek, 2010, p. 1109). In addition, bike share can be a solution to the first mile last mile problem—the gap between a transit station and a transit rider's original location or destination—and help people living in "transit deserts" who do not have adequate access to transportation to meet their demand (Cohen & Kietzmann, 2014; Jiao & Bischak, 2018).

Location of Docking Stations

Despite their potential, bike share systems have already faced criticism in the U.S. as studies have found that bike share stations are often inequitably placed. A study of bike share systems in U.S. cities done in 2015 found that "more than three quarters (1,556 or 2,063 or 75.4 percent) of bike sharing stations across the U.S. 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" (Smith, Oh, & Lei, 2015, p. 18). Economic hardship was quantified in terms of unemployment, dependency, education, percent of household income spent on housing, crowded housing, and health insurance (Smith, Oh, & Lei, 2015). Another study looked at the population of people within the service areas of bike share programs in Boston, Chicago, Denver, Seattle, New York City, Washington D.C., and Arlington compared to populations outside of the service area in each city. It found that the percentage of people living in the service area with college degrees was greater than those without in every city (Ursaki & Aultman-Hall, 2015). In addition, white people had more access to bike share stations than African Americans in every city but D.C., and there were more households in the service areas earning over $100,000 per year than those earning less than $20,000 in every city but Seattle (Ursaki & Aultman-Hall, 2015). Thus, these studies reveal a trend of bike share stations located in more advantaged communities. This is important because the "proximity of residential addresses to docking stations appears to have a powerful influence over propensity to use a bike share program" (Fishman, Washington, & Haworth, 2013, p. 156). Bike share has the potential to help lower-income communities of color by giving them access to opportunities through improved mobility, but it is critical that these communities have fair access to stations in order for this to occur.

Some cities have taken note of these trends and are implementing equity into their programs as a result. In a study of bike share equity programs across the U.S., McNeil et al. (2019) found that 74 percent of systems had equity efforts, and among them, "51 percent had programs with a primary focus on service area determination, station siting, and/or bicycle placement and balancing" (p. 24). Tactics included finding underserved communities, putting stations next to lower-income housing, and including the targeted communities in deciding where stations should be located through outreach efforts (McNeil et al., 2019). One potential problem of placing stations in lower-income communities is generating enough revenue to sustain the stations, thus external funding is often sought in addition to these equity efforts (McNeil et al., 2019).

The city of Chicago's Divvy bike share program had experience with this, as it was launched in 2013 and received criticism for locating stations in predominantly white and affluent neighborhoods (Wisniewski & Pratt, 2017). Going back to the Smith, Oh, and Lei (2015) study that considered economic hardship in relation to bike share locations, the original Divvy system had only 8.2 percent of their stations in higher economic hardship areas. In 2015, Divvy grew their bike share program to address equity concerns, adding 1,750 bikes and 176 bike share stations, and expanding more into the predominantly black and Latino South and West sides of Chicago (Smith, Oh, and Lei, 2015; Wisniewski & Pratt, 2017). While this growth was shown to improve access for moderate and higher economic hardship areas, the city's annual income dropped by almost $1 million following the expansion (Smith, Oh, and Lei, 2015; Wisniewski & Pratt, 2017). Beyond the expenses of servicing more bikes, challenges arose in the South and West sides with use of the bike share program such as cost and communities' greater impediments to biking such as less infrastructure and fear of violence (Wisniewski & Pratt, 2017). Clearly, there are many factors and trade-offs that cities must take into account when placing bike share stations.

Transportation Equity

If managed in a way that ensures access and equity, bike share systems have a lot of potential for specifically helping low-income populations and communities of color. Bike share can help overcome mobility limitations for those without a driver's license, access to a car, or a working bicycle (McNeil, Broach & Dill, 2018). In addition, McNeil, Dill, MacArthur, Broach, and Howland (2017) conducted a survey study in Philadelphia, Chicago, and Brooklyn and found:

> Some of the most common barriers to bicycling cited by lower-income people of color included not having a bike or related gear (47%), not having a safe place to leave a bike where they need to go (36%), the expense of buying a bike or related gear (41%), not having a safe place to store a bike at home (32%), not knowing a place to get a bike fixed (23%), and worries about something going wrong with a bike, such as a flat tire (20%). (p. 1)

Thus, bike share can reduce barriers to access and motivate lower-income people of color to bike because it addresses a number of the reasons these populations might avoid biking. In regards to the positive health impacts of biking, the McNeil et al. (2017) survey study found that lower-income people of color responded at a much higher rate (71 percent) than other respondent groups that a reason they would use bike share would be to get exercise. The possibilities of bike share have huge opportunity implications for low-income populations, as studies have shown a link between transit access and upward mobility (Jiao & Bischak, 2018). While bike share has the potential to improve transportation access for all, history reveals a common theme of inequity when it comes to transportation benefits.

Transportation benefits are not equitably distributed, as wealthier and more educated sections of a population generally benefit more, whereas less wealthy sections are more burdened (Bullard, 2003). In this sense, equity "refers to the distribution of impacts (benefits and costs) and whether that distribution is considered fair and appropriate" (Litman, 2019, p. 3). Equity can be measured in many different ways and consider many different categories of people, so it is important to note that each study reviewed might consider equity differently, which has important policy implications. Because there is not a set definition or measurement of transportation equity, it is important to consider multiple points of view and outcomes (Litman, 2019). With bike share programs, equity can be measured by looking at community outreach and education, cost, access, or other factors. It can also consider different populations such as communities of color, lower-income communities, older populations, and disabled people. There is no one way or best practice for determining transportation equity, as all are important for different reasons.

The history of inequity in transportation benefits can be seen by looking at how and where transportation funding is spent and the impact it has. For example, 80 percent of surface transportation money is allotted to highways and only 20 percent to public transportation (Bullard, 2003). Not only does this disadvantage lower-income populations without access to cars, but also the African Americans and Latinos who make up over 54 percent of transit riders in urban areas (Bullard, 2003). In addition, transportation policies that have aided suburban sprawl, such as freeways and car-centered roads, have created harmful social and economic impacts for marginalized segments of the population. Among these are residential segregation and "exacerbating the inability of minorities to gain access to entry-level employment that is increasingly found in suburban areas" (Sanchez, Brenman, Ma, & Stolz, 2007, p. 2). Thus, persistent transportation inequity creates a cycle where "poor Americans are likely to have lower-than-average access to transit, but often are unable to move out of poverty because of this lack of transit" (Jiao & Bischak, 2018). Finally, lower-income communities of color are disproportionately burdened by pollution exposure caused by transportation inequity (Ursaki &

Aultman-Hall, 2015). Under a wider umbrella of "environmental exposures" which can include things like air pollution and burdensome traffic routes, a number of studies have found that African Americans and communities of color are more likely to face a disproportionate burden than white communities (Freudenberg, Pastor, & Israel, 2011). Lower-income status also led to a higher burden of environmental exposures (Freudenberg, Pastor, & Israel, 2011).

Transportation inequity holds true for biking, as infrastructure for active transportation tends to favor already advantaged populations in the U.S., such as middle-class residents in suburban neighborhoods (Lee, Sener, & Jones, 2017). This is important in terms of biking infrastructure as a study found "a statistically significant relationship between bike share activity and the presence of bike lanes — even when controlling for population and retail opportunities around docking stations" (Fishman et al., 2013, p. 160). Thus, a deterrent to bike share among disadvantaged groups of people such as lower-income communities of color may simply be the lack of infrastructure and not a lack of interest. Ridership reflects inequality, as shown by Shaheen et al. (2012 & 2013) who conducted surveys of public bike share members in Montreal, Minneapolis and Saint Paul, Toronto, and Washington D.C., finding that "relative to the population within the four cities, bike sharing members has slightly higher incomes, were younger, more educated, and had a higher percentage of Caucasians than the general population." (Martin & Shaheen, 2014, p. 3). Men also made up a majority of bike share members in every city (Martin & Shaheen, 2014).

This is not a result of a lack of interest among low-income people and people of color. A survey study in Philadelphia, Chicago, and Brooklyn found that lower-income people and people of color were using bike share less than higher-income white people, however they had the same level of interest for using it in the future (McNeil, Broach & Dill, 2018). In addition, a survey study of residents in Berkeley, California found similar levels of interest in using Berkeley bike share among low- and high-income respondents, with station location being the most important factor in the likelihood of using bike share in the future (Savickas & Sohn, 2015). Finally, McNeil, Broach and Dill (2018) found that once lower-income people and people of color utilized “equity-focused discounts or related programs” and became members of bike share programs, they used it as often as other members, including higher-income white members, and were twice as likely to report that “bike share was saving them $21 or more per week on travel costs” (p. 34). Thus, bike share offers the potential to fill a persistent inequality gap and improve the lives and economic possibilities of low-income people and people of color as an independent mobility option or as a link to public transit.

Methodology:

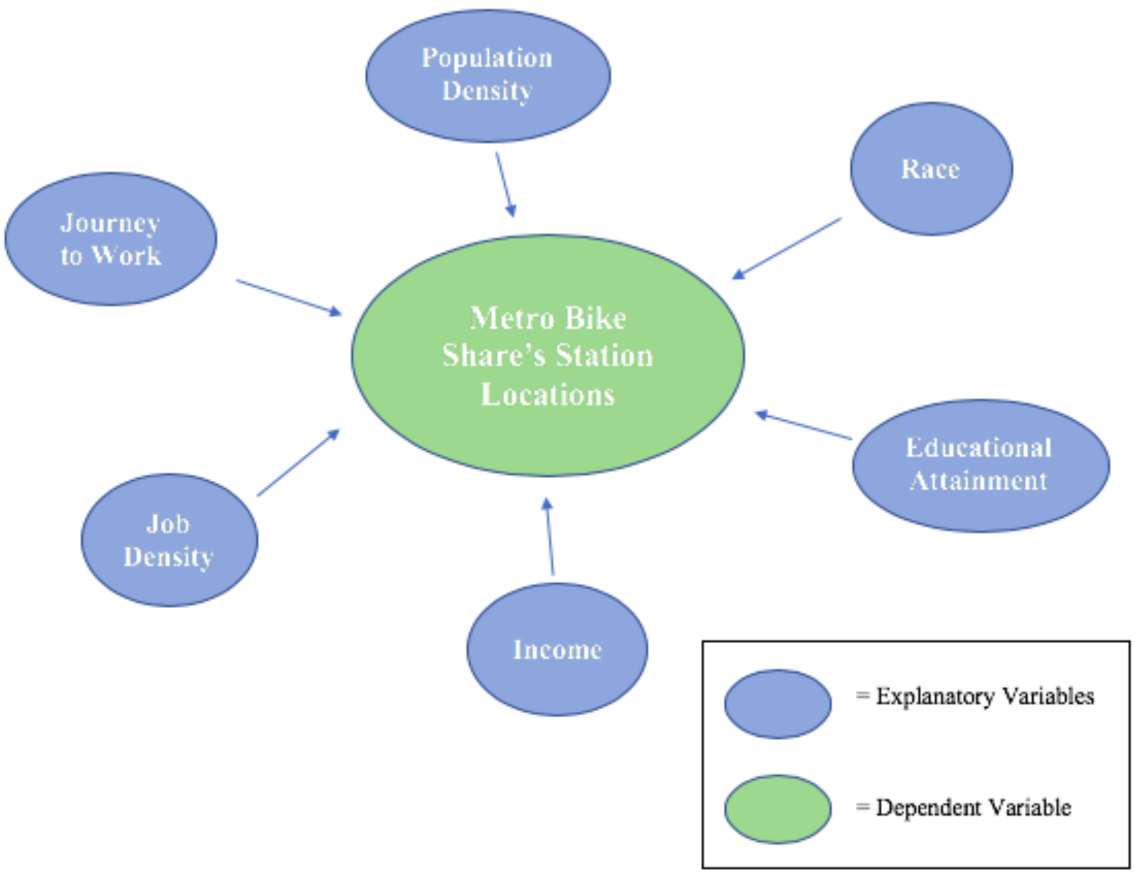
This research paper uses quantitative methods to conduct a geo-spatial analysis of which factors are most prevalent in and around the locations of Metro Bike Share’s docked bike share stations. Further, it analyzes if the factors of race, education level, and income impact station location in a way that causes inequity. Data for the study was obtained primarily from IPUMS, a free online database of census microdata. Using the IPUMS NHGIS Data Finder, five-year data from 2013 to 2017 was taken from the American Community Survey (ACS) at the census tract level. The ACS was chosen as the dataset because the last U.S. census was conducted in 2010, and the ACS provides more recent, publicly available data available at census tract level. Data on jobs totaled by work Census Block was retrieved from the U.S. Census Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES). All of this data was manipulated in Excel and then imported into ArcGIS Online and mapped against Los

Angeles County census tracts. In addition, Metro Bike Share's docked station locations were downloaded from their website and mapped on ArcGIS ("Data," 2018). The explanatory variables measured were analyzed in relation to Metro Bike Share's docked station locations using the statistical software STATA.

The Model

The dependent variable in this study is Metro Bike Share's docked station locations, operationalized as number of stations per census tract. The explanatory variables are race, educational attainment, income, job density, population density, and journey to work. Beyond the socio-economic characteristics (race, educational attainment, and income) included to examine equity, Smith, Oh, and Lei (2015) found that population density, job density, and journey to work are among other factors that may play a role in placing bike share stations, therefore they are included in this study as control variables. A number of other variables were also found to impact station placement, however they were not included in this study due to a lack of available data and limited time and resources. This is important to note because it hinders the model's explanatory power. A model of the variables included in this study is shown visually in **Figure 1**.

Figure 1: Model of Study Variables



Operationalizing the Dependent Variable

The dependent variable, Metro Bike Share's docked station locations, was operationalized as number of stations per census tract. In order to get this information, L.A. Metro's publicly available GeoJSON file of live station locations and status information was downloaded on October 3, 2019. This data was imported into ArcGIS, and the station locations were mapped as points. The total number of docked stations per neighborhood is shown in **Table 1** below. Next, census tract boundaries for L.A. County were downloaded from IPUMS NHGIS and mapped in ArcGIS. Using this information, counts of the number of bike share stations within each census tract were calculated using ArcGIS. The frequency of the number of docked stations in each census tract for L.A. City and L.A. County can be seen in **Table 2** below. Based on this information, a second dummy dependent variable was created for the statistical analysis. This variable consisted of 0, meaning no bike share stations in a census tract, and 1, meaning one or more bike share stations in a census tract.

Table 1: Total Number of Docking Stations by Neighborhood

Neighborhood	Number of Stations
Downtown L.A. and Central L.A.	108
North Hollywood	17
The Westside	46
The Port of L.A.	12

Table 2: Frequency of Number of Docking Stations per Census Tract

Number of Stations per Tract	L.A. City Frequency	L.A. City Percent	L.A. County Frequency	L.A. County Percent
0	910	90.28	2,237	95.68
1	66	6.55	69	2.95
2	16	1.59	16	0.68
3	6	0.60	6	0.26
4	2	0.20	2	0.09
5	2	0.20	2	0.09
6	1	0.10	1	0.04
7	2	0.20	2	0.09
8	1	0.10	1	0.04
9	2	0.20	2	0.09
Total	1,008	100.00	2,338	100.00

Operationalizing the Explanatory Variables

To measure educational attainment, data on educational attainment for the population 25 years and over was downloaded from NHGIS, and a scale was created in Excel. The scale consisted of **less than high school**, made up of no schooling completed, nursery school, kindergarten, 1st grade through 11th grade, and 12th grade but no diploma, **high school or**

equivalent, made up of regular high school diploma and GED or alternative credential, **some college**, made up of less than 1 year of college, 1 or more years but no degree, and an associate's degree, **bachelors,** made up of a bachelor's degree, and **above bachelors**, made up of a master's degree, professional school degree, and doctorate degree. To measure race, data on Hispanic or Latino origin by race was downloaded from NHGIS and put into the categories of **Hispanic or Latino**, **non-Hispanic White**, **non-Hispanic Black or African American**, **non-Hispanic Asian**, and **non-Hispanic Other**. Non-Hispanic Other consisted of non-Hispanic American Indian and Alaska Natives, non-Hispanic Native Hawaiian and other Pacific Islanders, non-Hispanic some other race alone, and non-Hispanic two or more races. Income was also obtained from NHGIS and measured by **median household income** in the past 12 months in 2017 inflation-adjusted dollars. A scale on median household income was created for the statistical analysis relative to the U.S. Department of Housing and Urban Development's (HUD) rounded median family income (MFI) for L.A. County in fiscal year 2017. The scale was developed based on a number of sources and consisted of: very low income- 0% to 50% of MFI, so $0 to $32,150, lower income- 50% to 80% of MFI, so $32,151 to $51,440, middle income- 80% to 150% of MFI, so $51,441to $96,450, and higher income- 150% of MFI and above, so $96,450 and up (Amadeo, 2019; HUD "Income Limits," n.d.). To measure journey to work, means of transportation to work for workers 16 years and over was downloaded from NHGIS and put into the following categories: **drove**, made up of drove alone, carpooled, taxicab, motorcycled, **public transportation,** made up of public transportation (excluding taxicab) by bus or trolley bus, streetcar or trolley car, subway or elevated, railroad, and ferryboat, **bicycle**, made up of bicycled, **walked**, made up of walked, and **other means**, made up of other means and worked at home. All of the categories for educational attainment, race, and journey to work were turned into percentages to aid in the analysis. Population density was created by dividing the total population in each census tract, obtained from NHGIS, by the area of the census tract in square miles. Job density was created by downloading Workplace Area Characteristic (WAC) data on total number of jobs per work Census Block from U.S. Census LEHD Origin-Destination Employment Statistics. This data was aggregated into census tracts using Excel, and job density was created by dividing the number of jobs per census tract by the area of the census tract in square miles. All of this information was imported into ArcGIS. **Table 3** compares the mean of each of these variables for tracts without bike share stations and tracts with one or more bike share stations within L.A. City. **Table 4** does the same for all of L.A. County.

Table 3: Descriptive Statistics, L.A. City

Variable		**Mean for Tracts Without Bike Share Stations**	**Mean for Tracts With Bike Share Stations**
Education Level	Less than High School	.2519597	.2024354
	High School or Equivalent	.2011801	.1515428
	Some College	.2372049	.2203486
	Bachelor's Degree	.2043017	.2791924
	Above Bachelors	.1053536	.1464808
Race	Hispanic or Latino	.4914895	.3610064
	Non-Hispanic White	.2876057	.3421727
	Non-Hispanic Black or African American	.0836776	.0724857
	Non-Hispanic Asian	.1096697	.1869924
	Non-Hispanic Other	.0275575	.0373427

Median Household Income		61,940.75472	55,403.04082
Journey to Work	Drove	.7901871	.6634862
	Public Transportation	.0963858	.1481545
	Walked	.0322253	.0778844
	Bicycle	.01032586	.02627516
	Other Means	.070876	.0841997
Population Density		11,497.88	14,658.35
Job Density		3,158.992	14,010.8

Table 4: Descriptive Statistics, L.A. County

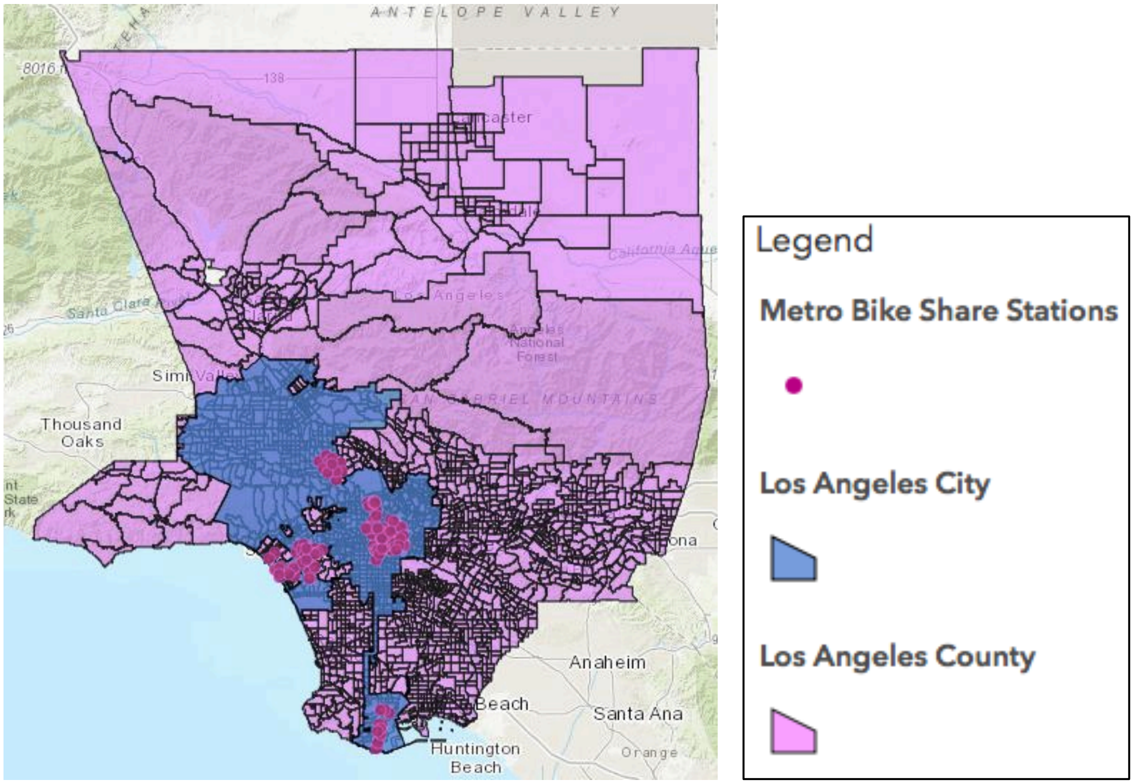
Variable		Mean for Tracts Without Bike Share Stations	Mean for Tracts With Bike Share Stations
Education Level	Less than High School	.2325938	.1993019
	High School or Equivalent	.2119678	.1505936
	Some College	.260839	.2203529
	Bachelor’s Degree	.1925278	.1925278
	Above Bachelors	.1020716	.1489875
Race	Hispanic or Latino	.4843229	.3575005
	Non-Hispanic White	.2682953	.3468763
	Non-Hispanic Black or African American	.0778115	.0731041
	Non-Hispanic Asian	.1398124	.1845833
	Non-Hispanic Other	.0297578	.0379359
Median Household Income		66,667.7619	55,913.50495

Journey to Work	Drove	.8377043	.6652887
	Public Transportation	.0638905	.1453165
	Walked	.0267135	.0781828
	Bicycle	.00820433	.02656294
	Other Means	.0634873	.0846491
Population Density		8,980.543	14,369.83
Job Density		2,626.348	1,3985.9

The Map of L.A. Metro Bike Share Stations

A visual of each cluster of bike share stations (Downtown L.A. and Central L.A., North Hollywood, the Port of L.A., and the Westside) can be seen on the completed map in **Figure 2.** Once the map was finalized with all of the necessary data, the information was downloaded and put into STATA.

Figure 2: Metro Bike Share Stations in the Context of L.A. County and L.A. City



Statistical Analysis

The statistical software STATA was used to analyze the data from the map. First, variables for job density and population density in thousands were created in order for the model to reflect the effect of a more meaningful change in density than one person. In addition, the education level variables were combined into those with **less than a bachelor's degree**—made up of the education levels less than high school, high school or equivalent, and some college—and those with **a bachelor's degree or above**—made up of those with a bachelor's degree, a master's degree, a professional school degree, and/or a doctorate degree. This was done in order to make the results and analysis more clear. The above variables, along with the median household income scale, journey to work categories, and race categories made up the explanatory variables in the statistical models. A logistic (logit) regression and a Poisson regression were then run on both the city and county level to find which explanatory variables are more likely to determine if a tract gets a bike station. The logit regression was used to consider the binary dependent variable discussed above (no bike share station versus one or more bike share stations). The Poisson regression considered the dependent variable count of stations, meaning the specific number of stations within each census tract, ranging from zero to nine. The regressions showed which variables are statistically significant in determining if a census tract gets a bike share station, and produced interesting results in terms of equity of who is being served by the bike share stations, to be discussed below. It is important to note that the findings from this study are correlational and not causal.

Findings:

The findings section looks at the regression results directly. The binary case (one or more stations versus no station) is presented first at the city level and then differences at the county level are considered. The count of stations case is presented after this, again on the city level first and then the county level. Finally, the analysis section interprets the results more deeply across all four regressions.

Logistic Regression

The first regression that was performed on the data was at city level with all explanatory variables and the binary dependent variable of no station or one or more stations. A logistic regression—the appropriate regression when the dependent variable is dichotomous—was run, which computes the probability of an event occurrence (Chauhan, 2019). The results of the regression are shown in Appendix A. The pseudo R-squared value is .2315, showing that the explanatory variables in this regression can explain 23% of why bike share stations are placed where they are. While this number is not super high, it is reasonable for urban research. In the urban setting, any location decisions are likely to have many correlates, and bike share stations are no different. Still, the variables in this analysis explain nearly one quarter of location variation at the census tract level and can provide an interesting view into bike share location decisions. Moreover, the prob>chi2 shows that the results are jointly significant because the probability is below .0000, meaning that together, these variables do a reasonable job of explaining the dependent variable.

The logit regression revealed a number of things about the explanatory variables. The explanatory variables job density, population density, public transportation, biking, Asian race, and an education level of a bachelor's degree or above all came out as statistically significant factors in determining bike share station location. Holding all other variables constant, an increase in job density by 1,000 people per square mile increases the odds of getting a bike share station in a census tract by almost 2%, while an increase in population density of 1,000 people per square mile decreases the odds of getting a bike share station in a census tract by 4%. Both job density and population density have odds ratios that are very close to one, however, they are still meaningful because population density in Los Angeles varies super widely. Job density is statistically significant at the 1% level, with a p value of .007, and population density is statistically significant at the 5% level, with a p value of .014. Relative to driving, both journey to work by public transit and biking are statistically significant for greatly increasing the odds of getting a bike share station in a census tract at the 1% level, with p values of less than .000. However, it is important to note that both have large standard errors, particularly biking. This is likely due to the fact that many census tracts have zero percent of people biking to work, and a number have very low percentages of people using public transportation to get to work. For example, just under half of L.A. City census tracts and one third of L.A. County census tracts have 0% of people who bike to work. Nevertheless, even when these census tracts were removed from the analysis, there is still a very strong relationship between bike share stations and areas where more people walk and bike to work. Given the large standard errors, future research is needed to better understand the role of walking and biking to work and bike share station placement.

Looking at the equity-focused variables, the results of the Asian race category show that holding all else constant, being 1% more Asian increases a census tract's likelihood of getting a bike station almost 13 times more than if a census tract was 1% more white. This is statistically significant at the 5% level, with a p value of .019. The results of education level show that having an education of a bachelor's degree or higher is statistically significant for greatly increasing the odds of getting a bike share station in a census tract at the 1% level, with a p value of .009. Finally, the results indicate that there is no statistically significant relationship between income level and odds of having one or more bike share stations in a census tract. In addition, the explanatory variables of walking, other transportation, black, Hispanic or Latino, and other race were not statistically significant.

A logit regression was then run at the county level, which produced similar findings. They are shown in Appendix B. At the county level, the pseudo R-squared value is .2949, showing that this regression has more explanatory power as the variables can explain 29% of why bike share stations are placed where they are. Again, the results were jointly significant with a prob>chi2 below .0000. The county data has a higher number of observations than the city, with 2,318 census tracts compared to 1,003 at the city level. With this larger sample size, the variable higher income became statistically significant at the 5% level, with a p value of .0014. The results show that holding all other variables constant, as the percentage of those with higher income increase in a census tract, the odds of having a bike share station placed in the census tract decrease. Beyond this, the only other difference at county level is that Asian race became insignificant.

Poisson Regression

A second regression was performed on the same variables at the city level but with the count of stations per tract as the dependent variable. The dependent variable count of points indicates the number of bike share stations in a census tract ranging from zero (no bike share station) to nine (nine bike share stations in one census tract). A poisson regression showing incidence rate ratio (IRR) for each variable was chosen to analyze this data because it is the appropriate regression for a count dependent variable. The incidence rate ratio was obtained by exponentiating the Poisson regression coefficient ("Poisson Regression," n.d.). The results of the regression are shown in Appendix C. The pseudo R-squared value is .3041, showing that the explanatory variables in this regression can explain 30% of why bike share stations are placed where they are. The results of the Poisson regression were jointly significant, as the prob>chi2 is below .0000.

In the Poisson regression, all of the variables except for lower income and higher income came out as statistically significant factors at some level in determining if a census tract will receive an additional bike share station. As with the logit regression, both job density and population density have incidence rate ratios that are very close to one. Holding all other variables constant, an increase in job density by 1,000 people per square mile only increases the incidence rate of receiving an additional bike share station by 1%, while an increase in population density of 1,000 people per square mile decreases the incidence rate of getting an additional bike share station by 6%. Job density and population density are statistically significant at the 1% level, with p values of less than .000. Looking at the journey to work variables, public transportation, walking, and biking all positively increase the incidence rate of an additional bike share station placed in a census tract at a 1% significance level with p values of less than .000. Other transportation also has a positive relationship with the dependent variable and is statistically significant at the 10% level with a p value of .051. This means that additional bike share stations are more likely to be placed in census tracts where more people use means other than driving, such as public transportation, walking, and biking to get to work. It also means that journey to work is an important factor impacting the location placement of Metro Bike Share's docked bike share stations.

Looking at the equity-focused variables, the output indicates that relative to the white population, the percentage of black, Asian, Hispanic or Latino, and other race positively increase the incidence rate of an additional bike share station placed in a census tract. Black is statistically significant at the 10% level with a p value of .052, Hispanic or Latino is statistically significant at the 5% level with a p value of .026, and Asian and other race are statistically significant at the 1% level with p values of less than .000. Therefore, as the percentage of these populations increases in a census tract relative to the white population, so does the likelihood of an additional bike share station. Looking at education level, having a higher education level (bachelor's degree or above) is statistically significant for increasing the incidence rate of an additional bike share station placed in a census tract. This is statistically significant at the 1% level with a p value of less than .000. Finally, the results show that relative to the very low income category, as the percentage of people in the middle income category increases in a census tract, the incidence rate of an additional bike share station placed in that census tract increases, holding all other variables constant. This is statistically significant at the 5% level with a p value of .011.

On the county level, the Poisson regression produced similar results with a few small differences, shown in Appendix D. The pseudo R-squared value is .3439, showing that the explanatory variables can explain 34% of why bike share stations are placed where they are. Given this number, the Poisson model at county level has the most explanatory power out of the regressions examined in this paper. The results were jointly significant with a prob>chi2 below .0000. On the county level, use of other transit to get to work relative to driving became statistically significant at the 1% level with a p value of .001. Looking at the race variables, black became statistically significant at the 5% level with a p value of .029 and Asian became no longer statistically significant. Middle income also became no longer statistically significant, while higher income actually became statically significant for decreasing the incidence rate of an additional bike share station in a census tract at the 5% level with a p value of .044.

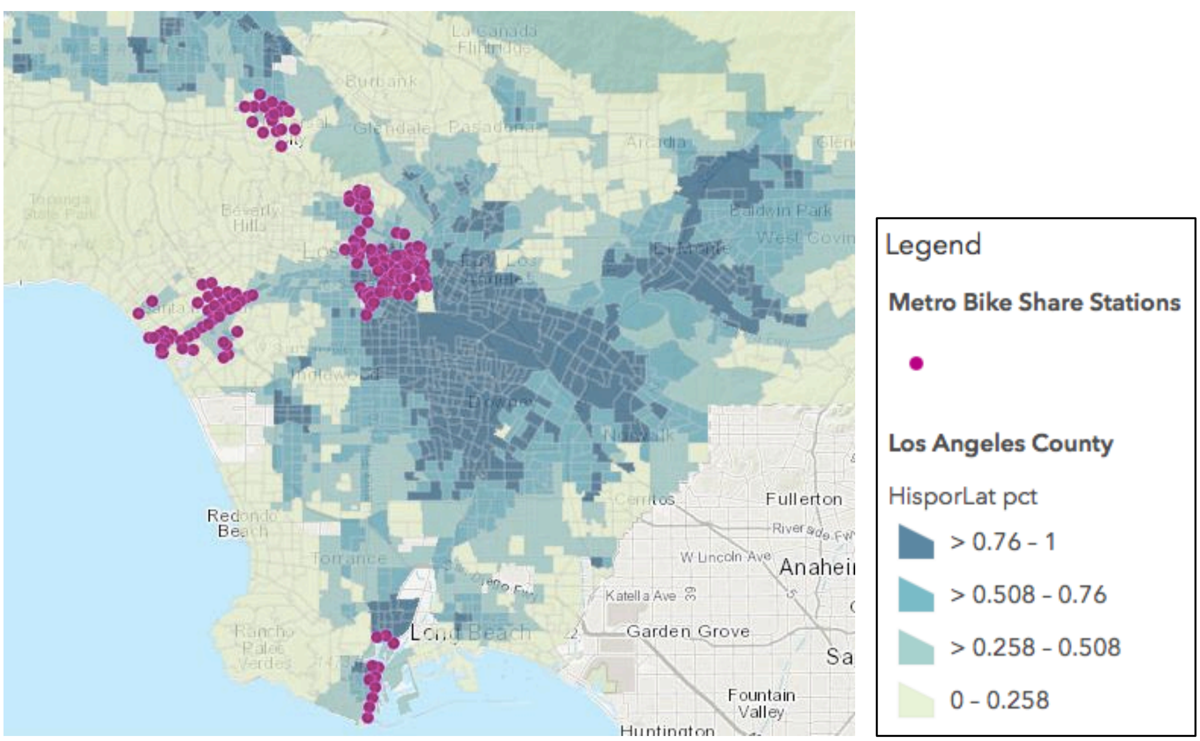
Analysis:

Logistic Regression

Overall, the results from the logit regression on both the city and county level show that the control variables job density, population density, and journey to work are consistently statistically significant factors in placement of Metro Bike Share's docked bike share stations. The fact that increased job and population density do not have much of an impact on the odds of getting one or more bike share stations is a surprising finding, as it is often cited as a factor that cities and systems consider when deciding where to place stations (Smith, Oh, & Lei, 2015, p. 18; Ursaki & Aultman-Hall, 2015). It is especially surprising that an increase in population density seems to result in a decrease in the odds of receiving a bike share station. However, it is important to remember that the decrease in odds is not very large, as well as to note that population density is much higher in L.A. City than in L.A. County. So, looking at L.A. City as a rough proxy for Metro Bike Share's service area (as all but three stations are located within L.A. City), population density is higher inside of the service area of the bikeshare stations than outside of the service area. While population density in each census tract varies, the stations are still placed mostly in L.A. City and thus in a very population dense area. In terms of journey to work, the odds of receiving one or more bike share stations go up for census tracts where people more often use public transportation and biking relative to cars to get to and from work. This is a very strong relationship, and it makes sense as commuters who walk or bike to work may be better served by bike share than people who rely on driving. This variable was meant to act as a control variable, and the results were as expected.

Looking at the equity variables in question—race, education level, and income level—with the logit reveals interesting findings and equity issues that must be looked at more closely. The results for the race variable seem to indicate that bike share stations are more likely to be placed in areas with high concentrations of Asian people. However, this relationship does not hold at county level. This may be explained by considering the spatial distribution of Asian people by census tract in L.A. City compared to L.A. County. Downtown L.A. and Central L.A., where clusters of Metro Bike Share stations are located, include the communities of Chinatown, Little Tokyo, and Koreatown, which have high densities of Asian people. Therefore, it makes sense that a relationship exists at this level and not at the county level. Another interesting finding, given that there are so many Hispanic and Latino people in Los Angeles, is that Hispanic or Latino race does not significantly impact station location. **Figure 3** shows the spatial distribution of the Hispanic and Latino population for all of L.A. County, zoomed in to the clusters of bike share stations in order to show a more clear picture of the distribution in relation to where the bike share stations were located at the time of this study. It reveals that bike share stations are largely missing in densely Hispanic or Latino areas, with an exception of some of the Downtown L.A. and Central L.A. placements, indicating a potential equity issue in terms of who is being served. These findings are important because L.A. Metro may want to target certain populations, such as Hispanics and Latinos, with station placement in order to improve equity, as will be discussed in the recommendations section. In terms of race, the hypothesis that Metro Bike Share's docked stations are located in more white areas is not supported by these findings.

Figure 3: Hispanic or Latino Percentage per Census Tract Relative to Metro Bike Share Stations



The logit regression flags an equity issue when it comes to education level. At both the city and county level, more educated census tracts—with a bachelor's degree or higher—are much more likely to have bike share stations. Thus, education level is an important factor in the location of Metro Bike Share's docked stations, and the hypothesis that stations are more often placed in higher educated areas is supported. Finally, while there was no statistically significant relationship at city level—and only a minor one at county level—between median household income and bike share stations, this does not mean stations are equally spread. The finding of no significance is important, as stations should potentially be targeted towards low-income areas for equity purposes, as will be discussed in the recommendations section. The fact that income level and bike share station placement does not have a statistically significant relationship indicates that median household income is not a factor that impacts Metro Bike Share's docked bike station placements. In addition, the hypothesis that Metro Bike Share's docked stations are more often placed in higher-income areas is not supported.

Poisson Regression

A more nuanced analysis with the count of stations as the dependent variable, the poisson regression produced more statistically significant variables than the logit regression. The control variables in the model impacted station count in a similar way as with the logit regression, with job and population density having surprisingly small, although statistically significant, impacts on bike share station locations. In terms of journey to work, increasing all modes of getting to work relative to driving were statistically significant at both the city and county level. As discussed above, this finding makes sense as bike share serves those populations better than people who rely on driving.

Considering the variables used to measure equity, the Poisson regression output shows a more comprehensive picture of how race impacts bike share station placement. On the city level, there is a positive, statistically significant relationship between all non-white races and incidence rate of receiving an additional bike share station. Although Asian race loses statistical significance at county level, these results show that race is an important factor in terms of additional docked Metro Bike Share stations. It refutes the hypothesis that stations are placed in whiter areas and instead shows that L.A. Metro is doing a good job in serving communities of color. However, it is still important to consider the logit regression and the fact that the Hispanic or Latino population could use more access to bike share stations. As with the logit regression, the Poisson regression showed a strong relationship between likelihood of additional bike share stations and census tracts where more people have a bachelor's degree or higher, indicating an equity concern. The Poisson regression did not provide enough evidence to make a statement about the effect of median household income on count of stations in a census tract, therefore future research is needed to better understand this variable.

Limitations:

During the time of this study, the bike share stations at the Port of L.A. were removed and additional bike share stations were placed in Downtown L.A and the Westside. These changes limit the findings of this study because the results were influenced by the demographics of the census tracts with bike share stations near the Port of L.A. and do not take into consideration new station locations. Metro Bike Share is a continuously growing and changing program, thus there was no way to avoid this limitation. The study had to analyze station locations during a specific moment in time. That said, there are important findings that can be taken away from that moment and policy recommendations that apply to Metro Bike Share as well as other bike share systems more generally.

An additional limitation of this study stems from the variation between docked and dockless bike share systems within Metro Bike Share. The neighborhoods of the Westside and North Hollywood both operate with the Smart Metro Bike system, where bikes can be locked at any Smart Metro Bike Share station or at any public bike rack for a convenience fee ("Smart Metro Bike," 2018). Thus, the smart bikes are not as strictly place-based as the Downtown L.A., Central L.A., and the Port of L.A. bike systems. This limits the findings of the study because they are based on the premise that the bikes must be parked at the docked station locations. In addition, three Metro Bike Share stations were located outside of L.A. City at the time of the study and therefore were not included in the regressions run at city level, further limiting those findings.

Another limitation of this study is omitted variable bias. Smith, Oh, and Lei's (2015) study reviewed relevant literature and identified over 20 potential non-socioeconomic factors that might be considered in the placement of bike share stations. Among these were

> 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. (pp. 12-13)

For the purposes of this study, population density, job density, and commute mode share (journey to work) were seen as particularly important factors that could be operationalized and thus were included. Many factors were omitted due to a lack of time, resources, and readily available data at census tract level. Because of this, the effects of the measured variables may be greater than they would be if more factors were included in the study.

This study only analyzes the Metro Bike Share system. Bike Share Connect—made up of Beverly Hills Bike Share, Santa Monica's Breeze Bike Share, and UCLA's Bruin Bike Share—also operates in L.A. County, with 830 bikes at 135 different stations ("Bike Share," n.d.). Due to the inability to secure a CSV file of the hub details for this system, as well as the fact that they are a "dock-optional" system that allows users to lock the bikes at any public bike rack, Bike Share Connect was not included in this study. Similarly, Long Beach Bike Share—with 472 bikes and 82 stations—was not included in the study ("Choose a Plan," n.d.). However, not taking these programs into consideration limits the findings of the study because it does not give a clear picture of the full coverage of bike share stations in Los Angeles County and how residents are being served. These other stations may be serving wider segments of the population, or they may be creating additional equity issues. Because they could not be included in this study, additional research is needed to understand who they serve and if they are equitable. Finally, this study is limited by the fact that publicly available data on dockless mobility is very sparse, thus various forms of new mobility such as dockless electric scooters and bikes that serve similar purposes as docked bike share systems have to be excluded.

Recommendations:

Target Lower-Income Areas with New Station Placement

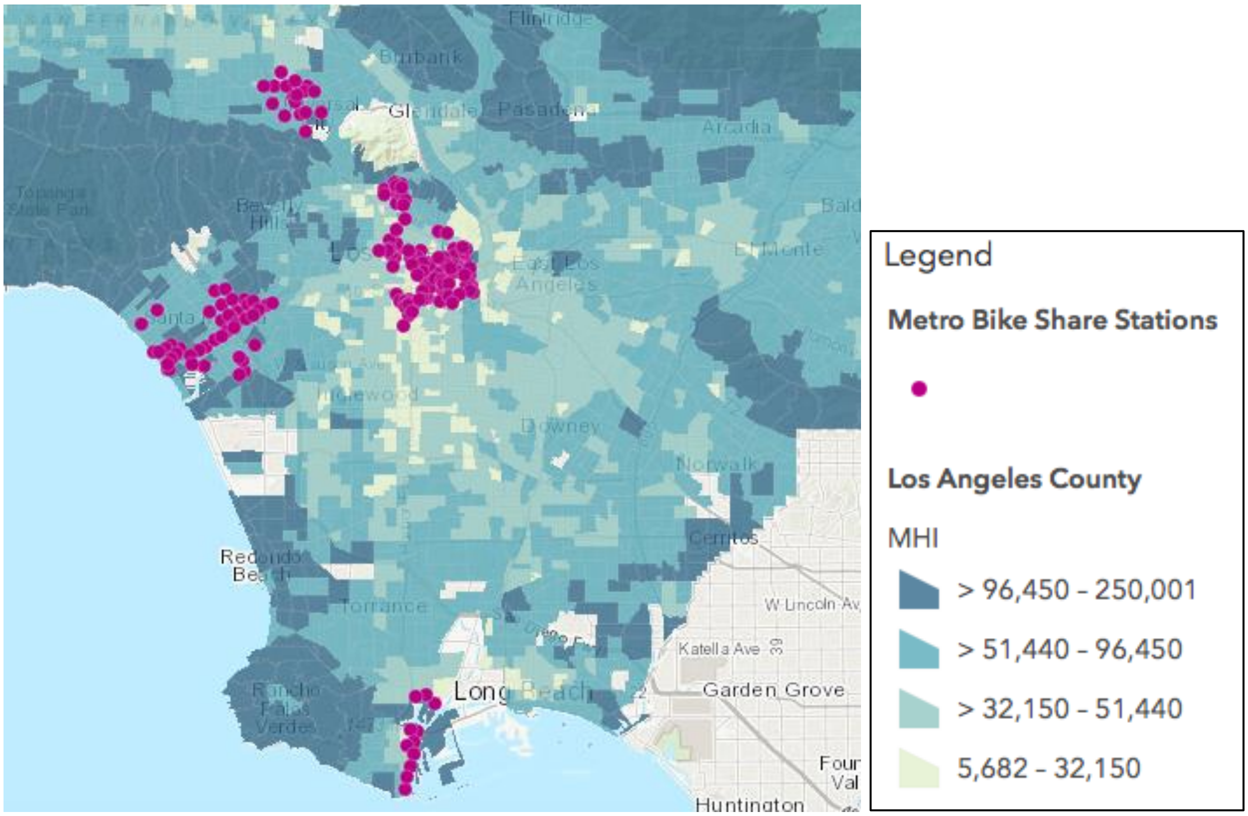
This study found no statistically significant relationship between income and Metro Bike Share stations. While this does not point to any specific equity issues, it does not mean stations are equitably placed. Looking at **Figure 4**, which shows median household income per census tract as well as Metro Bike Share's docked stations, it appears that the Downtown and Central L.A. cluster of stations serve a lower-income population, while the other clusters serve more high-income areas. Given the definition of equity in this research paper, which is in terms of access to bike share stations based on race, education level, and median household income, Metro Bike Share should over-place new stations in low-income areas. Not only will this benefit low-income populations, but it will likely improve access among communities of color as well as less educated populations, who are also underserved. This is likely to occur because race and wealth have a relationship within the Los Angeles population. A report called *The Color of Wealth in Los Angeles* (2016) found that in L.A., white households have a median net worth of $355,000 whereas "Mexicans and U.S. blacks have a median wealth of $3,500 and $4,000, respectively," African blacks had a median net worth of $72,000, other Latinos of $42,500, Koreans of $23,400, Vietnamese of $61,500, and Filipinos $243,000 (De La Cruz-Viesca, Chen, Ong, Hamilton & Darity Jr, p. 5). While wealth is different than income, this relationship shows that placing stations in low-income areas will likely increase access among non-white populations. In addition, income and education level tend to track each other, as those with higher-incomes can invest more in education (De La Cruz-Viesca et al., 2016). So, stations placed in lower-income areas would also likely improve access for people with less educational attainment.

L.A.'s 2019 Sustainable City pLAn sets a goal of expanding Metro Bike Share to new neighborhoods, thus they should consider targeting a lower-income neighborhood in this expansion. L.A. Metro should look to Bublr, a station-based bike share system located in Milwaukee, Wisconsin, on how they implemented effective stations in lower-income areas. Bublr partnered with the Housing Authority of the City of Milwaukee, working with staff to place bike share stations at two public housing complexes and actively engage residents and encourage them to use the program (McNeil et al., 2019). L.A. Metro should partner with the Housing Authority of the City of Los Angeles in order to identify suitable locations for bike share stations near public housing where more low-income people can be served. In order to make sure these stations are successful, Housing Authority staff should be used to educate residents of the public housing on the bike share program and assist them in taking advantage of the reduced fare passes. For extra funding to make this happen, L.A. Metro should look to organizations such as Better Bike Share Partnership and ClimateWorks Foundation for grant opportunities. In addition, in order to ensure effective use of resources and allow for a larger network of stations in an expansion, Metro Bike Share should consider installing smaller stations at new locations. Healthy Ride, a bike share program in Pittsburgh, Pennsylvania, did this in their expansion, allowing for more stations and flexibility surrounding the needs of the community and city (McNeil et al., 2019). Finally, Metro Bike Share should incorporate the "dockless" feature Healthy Ride used, where bikes can be parked next to a small dock without a fee if the dock is full (McNeil et al., 2019).

A map showing median household income (MHI) per census tract, broken up in the categories used in the statistical analysis—$0 to $32,150 for very low income, $32,151 to $51,440 for lower income, $51,441 to $96,450 for middle income, and $96,450 and up for higher income—shows that Southeast Los Angeles is an area that could benefit from Metro Bike Share (**Figure 4**). L.A. Metro should consider putting a group of stations in Southeast L.A., as the map shows it has a high concentration of very low and low-income people. In addition, this area has a high density of Hispanic or Latino population (seen in **Figure 3**) and a high density of people with less than a bachelor's degree, which were equity concerns flagged in the statistical analysis

(De La Cruz-Viesca et al., 2016). Thus, additional bike share stations in Southeast L.A. would greatly expand access to populations who would benefit greatly from it.

Figure 4: Median Household Income per Census Tract Relative to Metro Bike Share Stations



Additionally, L.A. Metro should incorporate a “dock optional” system like Bike Share Connect, which allows users to lock bikes at any public bike rack for no additional fee, into an expansion into lower-income neighborhoods. In contrast, both the Westside and North Hollywood Metro Bike Share stations currently operate with the Smart Metro Bike system, which allows bikes to be locked at any Smart Metro Bike Share station or any public bike rack for a convenience fee. If locked at a public bike rack within the Smart Metro Bike service area, the fee is $2. If locked outside of the service area, there is a $20 convenience fee (“Smart Metro

Bike," 2018). This system creates an equity concern for two reasons. First, the use of a fee makes Metro Bike Share much more convenient for people who can afford to pay to leave a bike wherever they want. In addition, the Smart Metro Bike system is only available in certain neighborhoods- the Westside and North Hollywood. As **Figure 2** shows, these neighborhoods are generally higher income than Central L.A., Downtown L.A., and the Port of L.A. Thus, higher-income neighborhoods tend to have a more convenient bike share system, creating inequalities between neighborhoods. Opting for a dock optional system in lower-income areas would ensure this same convenience without the fees and help to mitigate this equity issue. Given the resources, Metro Bike Share should also work to retrofit their other bikes to be dock optional and remove extra fees.

Establish a Definition of Equity

Moving forward, it is critical for established and emerging bike share programs that express a commitment to equity have a set, public definition of what equity means to them as well as standard evaluation methods. It is important to determine a definition and evaluation methods so that equity can be measured and studied in a meaningful way, benchmarks can be set, and systems can monitor their progress toward their goals. Without these things, equity impacts can be and often are ignored or dismissed (Litman, 2019). Metro Bike Share expressed a public commitment to equity with their system, however, they are lacking an explicit and measurable definition. Thus, Metro Bike Share must create a definition of what equity means in their program moving forward, along with standard evaluation methods, and make sure it is publicly known. This must be done with all bike share systems that vow to incorporate equity into their programs in order to ensure that equity targets are being achieved and systems are holding true to their missions. This should make it easier for the public and the bike share systems themselves to make sure programs are meeting equity goals.

Continue Strategic Partnerships and Community Engagement

As detailed in the background section of this paper, L.A. Metro explicitly took equity into consideration when planning their bike share system and deciding on station location. They engaged in community outreach in both English and Spanish, partnering with local organizations in order to get this done (McNeil et al., 2019). As the results show, the only major equity concern flagged in terms of where stations are placed showed up with education level. Every regression performed showed a strong relationship between having a bachelor's degree or above and access to bike share stations. This is similar to bike share systems in other U.S. cities, as the Ursaki & Aultman-Hall (2015) study of six major cities found that the percentage of people with college degrees living within bike share service areas was greater than those without in every city. While this is something that Metro Bike Share must address, they did outperform many other cities in terms of making sure most bike share stations were not placed in predominantly white and high-income neighborhoods. The regressions show that census tracts that were more ethnically diverse often had a positive relationship with station placement, which was a positive result in terms of equity considerations. In addition, income level did not significantly impact station location. Thus, while more can and should be done, the commitment to equity and the work done before the roll out of the program was clearly beneficial in terms of considering the needs of the underserved and making sure the station placements served a broad population. Other cities and communities looking to implement bike share should take these practices into consideration, specifically partnering with local community organizations and utilizing languages beyond

English to gain community feedback. In addition, Metro Bike Share must continue these partnerships and community engagement in future expansions, with a critical look at how station placement relates to education level.

Time-Sensitive Recommendations: COVID-19 and Metro Bike Share

During the writing of the findings and recommendations for this research study, a new coronavirus called COVID-19 became a global pandemic. COVID-19 is a respiratory illness that transmits easily from person-to-person, thus keeping at least six feet of distance from others is recommended. At the time this paper was written, there were over two million confirmed cases of COVID-19 and over 128,000 deaths worldwide ("Coronavirus," 2020). In addition, there are country and state shutdowns as people are told to quarantine inside and social distance from one another. Given the nature of bike share as a widely-used transportation option that allows riders to stay a safe distance from others, it is important to analyze bike share's role in this pandemic and offer recommendations.

In early March, as the pandemic was spreading in the United States, bike share ridership seemed to spike for many systems. For example, Divvy bike share in Chicago saw a 100% increase in the number of rentals from March 1st to March 11th 2020, compared to the same time in 2019 (Greenfield, 2020). This is likely due to people finding that bike share was a better option compared to riding on confined, potentially crowded public transportation where they could be exposed to the virus. After this initial spike, bike share usage decreased as non-essential businesses and workplaces were shut down and people were encouraged to stay home (Greenfield, 2020). Nevertheless, bike share remains a good transportation option during this time—although washing hands before and after use, wearing gloves, and wiping off the handle bars with disinfectant is recommended—and many systems are doing relatively well (Linton, 2020).

Bike share systems in the United States have had varied responses to COVID-19. Some, such as those run by Lyft in New York City, Boston, and Chicago are offering free rides for healthcare workers, transportation workers, and first responders and others are partnering with restaurants to assist with food delivery (Linton, 2020). Additionally, some systems are currently offering unlimited free rides to all users while others have shut down altogether (Linton, 2020). Metro Bike Share has had a lackluster response- continuing to operate as usual with bikes available 24/7 at normal ride costs.

Metro Bike Share has a unique opportunity to help people while encouraging bicycle usage during this pandemic, but they must take a number of steps. First, Metro Bike Share should make all rides free for the duration of this crisis to aid Angelenos and essential workers in safe mobility. They can apply for a Better Bike Share Partnership Emergency Response Grant of up to $10,000 to help cover costs during the COVID-19 pandemic in order to make this happen ("Better Bike Share," 2020). In addition, L.A. Metro should work with the city to add temporary bike lanes as a number of other cities have done in the midst of decreased car traffic to support and encourage biking. No one knows what society will look like post-pandemic. However, it is reasonable to believe that biking and bike share systems will play an important role as a mobility option as "shared enclosed spaces—like ride-hail and transit—may see ridership declines continue [and] expensive modes—like driving and ride-hail—may be depressed during a recession triggered by COVID-19" (Linton, 2020). L.A. Metro should capitalize on this now, assisting people in safe bicycle use and making the city more bike-friendly in order to gain support for biking and permanent bike infrastructure in the future.

Conclusion:

The field of urban mobility is going through an exciting and transformative time, as new technologies rapidly enter the market and work to solve pervasive transportation problems. Bike share is an example of this, as it began to grow and spread only about a decade ago and is now quickly advancing in technology and taking hold in cities all over the world. While there are many opportunities with new mobility technology, there are also many ways that those who have been historically disadvantaged by transportation policy, specifically low-income communities of color, could continue to be marginalized.

This study looks specifically at the Metro Bike Share program in Los Angeles, considering why stations are placed where they are and if the equity dimensions of race, educational attainment, and income level played a role in station placement. It highlights potential equity issues in terms of stations being placed in more educated areas, however it also shows that Metro Bike Share has some success in terms of serving an ethnically diverse population. As Metro Bike Share continues to grow, a measurable definition of what equity means when it comes to their system and station sitting must be created. In addition, Metro Bike Share must continue to work with the community to determine docked station placements, and should prioritize lower-income communities with new stations in order to reach more lower-income, non-white, and less educated populations. Looking forward to future bike share programs and new mobility options—especially with a potentially large spike in bike share programs post-pandemic—equity must be prioritized at every step of the way in order to ensure that transportation is serving the needs of all people and providing the opportunity for all to succeed and thrive.

While this research paper has provided insight into Metro Bike Share at a moment in time, additional research can build on this study by conducting an updated analysis of bike share stations and utilizing mixed methods. For the quantitative analysis, future research should utilize 2020 census data for Los Angeles County and include additional explanatory variables such as proximity to transit, sun exposure, and existing bike infrastructure for a more full picture of which factors impact the locations of Metro Bike Share's docked stations. In addition to quantitative methods, qualitative methods such as interviews or surveys could be used to understand the perspectives of community members, Metro staff, and policy makers on station placement and bike share usage.

Additionally, further research could build on the equity dimensions used in this paper by taking a more nuanced look at education level or breaking up the income categories in a different way. It could also consider other dimensions of equity, such as the impact of price on bike share use or having Smart Metro Bikes versus Classic Metro Bikes. As discussed in the limitations section, future research should take a broader look at bike share in Los Angeles and analyze all of the bike share programs that operate in L.A. County, instead of just focusing on Metro Bike Share. Finally, there is an emerging field of research on even newer forms of micromobility, including dockless bikes and scooters. As more data becomes publicly available on these new mobility options, academic research is critical to determine how they are being used and by who to ensure that they are serving all populations.

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Appendix A:

Logit Regression Output, L.A. City

Number of Observations	1,003
LR chi2(14)	148.62
Prob > chi2	0.0000
Pseudo R2	0.2315
Log Likelihood	-246.66361

Variable	Odds Ratio	Standard Error	Z	P>|z|	95% Confidence Interval	
Job Density per 1,000 People	1.019725	0.0073401	2.71	0.007**	1.00544	1.034213
Population Density per 1,000 People	0.9629911	0.0147857	-2.46	0.014*	0.9344433	0.992411
Public Transportation	15020.16	25533.33	5.66	0.000**	536.6423	420401.3
Walked	5.450216	8.971084	1.03	0.303	0.2164371	137.2448
Bicycle	1.78E+10	1.01E+11	4.17	0.000**	268361	1.18E+15
Other Means of Transportation	3.634573	11.78461	0.40	0.691	0.0063175	2091.027
Non-Hispanic Black	1.650961	2.451473	0.34	0.736	0.08991	30.31556
Non-Hispanic Asian	12.96051	14.13003	2.35	0.019*	1.529712	109.808
Hispanic or Latino	0.5181726	0.6513562	-0.52	0.601	0.0441055	6.087746
Non-Hispanic Other Race	175.4597	996.1394	0.91	0.363	0.0025801	1.19E+07
Bachelor's Degree or Above	36.09963	49.20321	2.63	0.009**	2.496485	522.0073
MHI Lower Income	1.310104	0.5550818	0.64	0.524	0.5710285	3.005757
MHI Middle Income	0.9999539	0.5500252	-0.00	1.000	0.3402327	2.938894
MHI Higher Income	0.5134544	0.3569474	-0.96	0.338	0.1314488	2.005613
Constant	0.005444	0.0069729	-4.07	0.000	0.0004422	0.0670154

The reference categories are driving, white race, less than a bachelor's degree education level, and very low income, therefore they are excluded from the regression. Note: ^ indicates statistical significance at the 10% level; * at the 5% level; ** at the 1% level.

Appendix B:

Logit Regression Output, L.A. County

Number of Observations	2,318
LR chi2(14)	244.89
Prob > chi2	0.0000
Pseudo R2	0.2949
Log Likelihood	-292.79138

Variable	Odds Ratio	Standard Error	Z	P>|z|	95% Confidence Interval	
Job Density per 1,000 People	1.022751	0.0070339	3.27	0.001**	1.009057	1.03663
Population Density per 1,000 People	0.970963	0.0142616	-2.01	0.045*	0.9434093	0.9993214
Public Transportation	82861.02	129298.5	7.26	0.000**	3891.461	1764363
Walked	8.445584	13.09725	1.38	0.169	0.404206	176.4642
Bicycle	3.36E+10	1.70E+11	4.81	0.000**	1724587	6.56E+14
Other Means of Transportation	13.47842	35.35731	0.99	0.321	0.0788356	2304.39
Non-Hispanic Black	1.898204	2.499034	0.49	0.626	0.1437852	25.05945
Non-Hispanic Asian	2.570866	2.297666	1.06	0.291	0.4459984	14.81923
Hispanic or Latino	0.8163018	0.9321532	-0.18	0.859	0.0870652	7.653441
Non-Hispanic Other Race	104.3694	431.7931	1.12	0.261	0.031406	3.47E+05
Bachelor's Degree or Above	277.1561	334.642	4.66	0.000**	25.99994	2954.449
MHI Lower Income	1.342335	0.5642398	0.7	0.484	0.5889316	3.059544
MHI Middle Income	0.6126326	0.3241378	-0.93	0.354	0.217189	1.728074
MHI Higher Income	0.1985527	0.1312613	-2.45	0.014*	0.0543444	0.7254323
Constant	0.001321	0.0015181	-5.77	0.000	0.0001389	0.0125636
The reference categories are driving, white race, less than a bachelor's degree education level, and very low income, therefore they are excluded from the regression. Note: ^ indicates statistical significance at the 10% level; * at the 5% level; ** at the 1% level.						

Appendix C:

Poisson Regression Output, L.A. City

Number of Observations	1,003
LR chi2(14)	356.89
Prob > chi2	0.0000
Pseudo R2	0.3041
Log Likelihood	-408.36613

Variable	Incidence Rate Ratio	Standard Error	Z	P>|z|	95% Confidence Interval	
Job Density per 1,000 People	1.012258	0.0016894	7.30	0.000**	1.008953	1.015575
Population Density per 1,000 People	0.9462156	0.0108657	-4.81	0.000**	0.9251571	0.9677534
Public Transportation	4679.255	4101.69	9.64	0.000**	839.5369	26080.36
Walked	83.21593	58.13942	6.33	0.000**	21.15964	327.2688
Bicycle	149150.2	266515.4	6.67	0.000**	4493.846	4950277
Other Means of Transportation	41.2412	78.44106	1.96	0.051^	0.9916077	1715.231
Non-Hispanic Black	6.380174	6.082372	1.94	0.052^	0.9848314	41.3336
Non-Hispanic Asian	12.55904	8.652725	3.67	0.000**	3.25469	48.46224
Hispanic or Latino	6.029018	4.866039	2.23	0.026*	1.239479	29.32607
Non-Hispanic Other Race	911190.4	3021342	4.14	0.000**	1371.446	6.05E+08
Bachelor's Degree or Above	38.53473	29.59563	4.75	0.000**	8.552801	173.6186
MHI Lower Income	1.482231	0.4061822	1.44	0.151	0.866278	2.536146
MHI Middle Income	2.140366	0.6413459	2.54	0.011*	1.189683	3.850744
MHI Higher Income	1.257133	0.488719	0.59	0.556	0.5867744	2.693343
Constant	0.0013368	0.0011343	-7.80	0.000	0.0002534	0.0070523
The reference categories are driving, white race, less than a bachelor's degree education level, and very low income, therefore they are excluded from the regression. Note: ^ indicates statistical significance at the 10% level; * at the 5% level; ** at the 1% level.						

Appendix D:

Poisson Regression Output, L.A. County

Number of Observations	2,318
LR chi2(14)	512.65
Prob > chi2	0.0000
Pseudo R2	0.3439
Log Likelihood	-488.91683

Variable	Incidence Rate Ratio	Standard Error	Z	P>|z|	95% Confidence Interval	
Job Density per 1,000 People	1.015168	0.0016564	9.23	0.000**	1.011927	1.01842
Population Density per 1,000 People	0.9539308	0.0108985	-4.13	0.000**	0.9328075	0.9755324
Public Transportation	14358.16	11366.1	12.09	0.000**	3042.825	67751.77
Walked	97.54406	68.55005	6.52	0.000**	24.60428	386.715
Bicycle	3.37E+05	5.79E+05	7.4	0.000**	11579.56	9.78E+06
Other Means of Transportation	113.7724	163.5832	3.29	0.001**	6.794701	1905.037
Non-Hispanic Black	6.252752	5.263296	2.18	0.029*	1.201065	32.55186
Non-Hispanic Asian	2.748508	1.708472	1.63	0.104	0.8128123	9.294025
Hispanic or Latino	6.298882	4.747884	2.44	0.015*	1.437661	27.59754
Non-Hispanic Other Race	1831.591	2736.004	5.03	0.000**	98.02035	3.42E+04
Bachelor's Degree or Above	214.0204	160.9857	7.13	0.000**	48.99853	934.8186
MHI Lower Income	1.309344	0.3561281	0.99	0.322	0.7683089	2.231371
MHI Middle Income	1.322935	0.402114	0.92	0.357	0.7291395	2.400304
MHI Higher Income	0.4463046	0.1791501	-2.01	0.044*	0.2032135	0.9801899
Constant	0.000631	0.0004988	-9.32	0.000	0.000134	0.0029706
The reference categories are driving, white race, less than a bachelor's degree education level, and very low income, therefore they are excluded from the regression. Note: ^ indicates statistical significance at the 10% level; * at the 5% level; ** at the 1% level.						