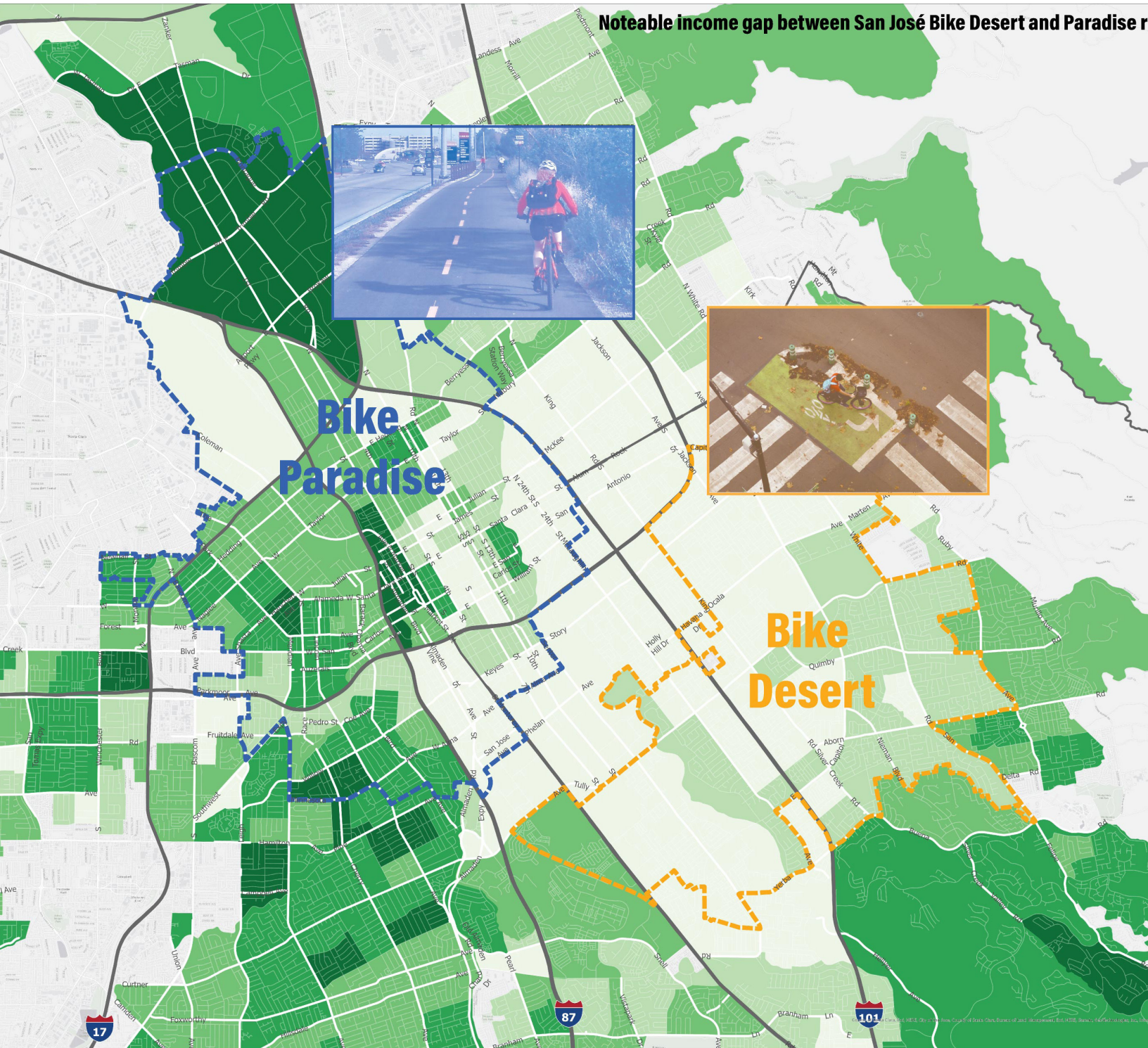


A Bike System for All in Silicon Valley: Equity Assessment of Bike Infrastructure in San José, CA

Ahoura Zandiatashbar, PhD Jochen Albrecht, PhD Hilary Nixon, PhD



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16. Abstract <p>Investing in sustainable, multimodal infrastructure is of increasing importance throughout the United States and worldwide. Cities are increasingly making strategic capital investment decisions about bicycle infrastructure—decisions that need planning efforts that accurately assess the equity aspects of developments, achieve equitable distribution of infrastructures, and draw upon accurate assessment methods. Toward these efforts, this project uses a granular bike network dataset with statistical and geospatial analyses to quantify a bike infrastructure availability score (i.e., bike score) that accounts for the safety and comfort differences in bike path classes in San José, California. San José is the 10th largest U.S. city and a growing tech hub with a booming economy, factors that correlate with increased traffic congestion if adequate multimodal and active transportation infrastructure are not in place. Therefore, San José has been keen on becoming “one of the most bike-friendly communities in North America.” The City’s new plan, which builds on its first bike plan adopted in 2009, envisions a 557-mile network of all-ages-and-abilities bikeways to support a 20% bicycle mode split (i.e., 20% of all trips to be made by bike) by 2050. Hence, San José makes a perfect study area for piloting this project’s methodology for accurately assessing the equity of urban bike plans and infrastructures. The project uses the above-mentioned bike score (representing the bike infrastructure supply status) and San José residents’ bike travel patterns (to show bike trip demand status) utilizing StreetLight data to answer the following questions: (1) Where are San José’s best (bike paradise) and worst (bike desert) regions for cycling? (2) How different are the socioeconomic attributes of San José’s bike desert and paradise residents? (3) Has San José succeeded in achieving an equitable infrastructure distribution and, if so, to what extent? And, (4) has the availability of infrastructure attracted riders from underserved communities and, if so, to what extent? Using the bike infrastructure availability score, this research measures and maps the City of San José’s best and worst regions for cycling through geospatial analyses to answer Question 1 above. Further spatial and statistical analyses including t-tests, Pairwise Pearson correlation analysis, descriptive analysis, spatial visualization, principal component analysis (PCA), and multiple regression models to answer Questions 2, 3, and 4. In addition to this report, the findings are used to develop an open access web-tool, the San José Bike Equity Web Map (SJ-BE iMap). This research contributes to the critical assessment and planning efforts of sustainable, multimodal infrastructure in California and beyond.</p>			
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1. Introduction

1.1 Background

Cities across the world are eager to develop and expand their bicycle networks through extensive investment in Bicycle Master Plans (Buehler & Pucher, 2012). These plans are mostly composed of improvement projects, including bicycle boulevards, bike boxes, buffered bike lanes, and cycle tracks (National Association of City Transportation, 2014). While American cities are not as bike-savvy as their European peers, which often have expansive bike infrastructures, there have been changes to U.S. federal policy since 2010 that aim to improve the status quo.

In 2010, the United States Department of Transportation (USDOT) Secretary Ray LaHood's policy declared that "[t]he establishment of well-connected walking and bicycling networks is an important component for livable communities, and their design should be part of Federal-aid project development" (Newhall, 2013). This interest continued with Secretary Anthony Foxx, who increased federal funding for bicycle improvement projects through "the most innovative, forward-leaning, biking-walking safety initiative ever" in 2014 (Kent & Karner, 2019) and the recent launch of a \$1 billion pilot program in 2022 that aims to help reconnect racially segregated cities and neighborhoods through rapid bus transit lines, bike lanes, and pedestrian walkways to allow for safe crossings over roadways (The Associated Press, 2022).

As the federal government, state departments of transportation, local governments, and non-profit organizations direct more funding toward bicycle infrastructure, American cities over the next few decades will need to make strategic capital investment decisions for developing and expanding their bike systems. These decisions need planning efforts to accurately assess the equity aspects of developments and to achieve an equitable distribution of infrastructures. To do so, planning efforts must draw upon accurate assessment methods that do not overestimate the availability of facilities, which could lead to false assessments of the bike plan's equity.

San José, California is the 10th largest U.S. city and one of the most diverse. According to Brookings (2017), the San José region is among the top five U.S. metro areas in terms of 2010–2015 high-tech job growth, and the Bay Area holds more than 56% of the State's Information and Communication Technology (ICT) employees (Muro & Liu, 2017). These numbers suggest the increasing potential for economic vitality that usually leads to increased traffic congestion if adequate multimodal and active transportation infrastructure is not in place (Zandiatashbar, Hamidi, & Foster, 2019). While San José has the potential to be a cyclist's paradise with a bike-friendly climate and topography, the average resident wastes 81 hours annually commuting by car, representing a \$2.7B loss in productivity for the region, according to the 2019 Silicon Valley Index (Joint Venture Silicon Valley, 2019).

In 2020, San José launched the Better Bike Plan 2025 with the goal of becoming "one of the most bike-friendly communities in North America." This new plan, which builds on the City's first bike

plan adopted in 2009, envisions a 557-mile network of all-ages-and-abilities bikeways to support a 20% bicycle mode split by 2050 (i.e., 20% of all trips to be made by bike). Decades of low-density, sprawled development in San José has perpetuated racial segregation and fostered growing income inequities. The sprawled development in San José enforced the historical pattern of segregation between East and South San José, both with large proportions of low socioeconomic status residents and a majority of the City’s Latinx residents, and West San José, which consists of the Santa Cruz Mountains and Silicon Valley, with residents that are primarily White and of higher socioeconomic status (Jumamoy et al., 2020). The City’s Better Bike Plan 2025 is designed to be a “Plan for Everyone,” but research is needed to help turn the vision into reality.

Although a glance at the Better Bike Plan 2025 suggests that the entire city seems to be well covered by the bike network, an equity analysis of bike infrastructure should address disparities between different bike lane classes in terms of the safety and comfort they provide cyclists. As a result of increased interest in active mobility infrastructures, San José, like many other American cities, is working to expand its bike infrastructure, and thus planners and decision makers must ensure that the benefits and burdens of transportation investments are equitably distributed across potential users (Kent & Karner, 2019). Several studies illustrated the spatial disparities in San José both in terms of race and economic prosperities (Alaban, 2021), hence it is important to combat such disparities in any bike planning efforts. This mission requires an accurate understanding of the existing facilities and infrastructure.

Multiple studies have evaluated the accessibility, bikeability, and equity of bicycle networks. However, most studies are limited in scope, neglecting differences in bike path classes that provide different safety and comfort levels for cyclists (Kent & Karner, 2019; Prelog, 2015). In contrast, this research fills this gap using a granular bike network dataset with statistical and geospatial analyses to quantify a bike infrastructure availability score that accounts for the safety and comfort differences in bike path classes. This score, representing the quality and availability of bike infrastructure (i.e., supply), will be combined with San José residents’ bike travel patterns to show bike trip demand status using StreetLight data¹ to answer the following research questions:

- 1) Where are San José’s best (i.e., bike paradise) and worst (i.e., bike desert) regions for cycling?
- 2) How different are the socioeconomic attributes of San José’s bike desert and paradise residents?
- 3) Has San José succeeded in achieving an equitable infrastructure distribution and, if so, to what extent?

¹ The StreetLight data contains the locations and attributes of trips collected from personal devices and internet of things (IoT), and transforms and normalizes this data to travel behavior (Yang et al., 2020).

- 4) Has the availability of infrastructure alone attracted riders from underserved communities and, if so, to what extent?

Using the bike infrastructure availability score, this study measures and maps San José's best (i.e., bike paradise) and worst (i.e., bike desert) regions for cycling by using geospatial analyses to answer the first research question. Further spatial and statistical analyses—including t-tests, pairwise Pearson correlation analysis, descriptive analysis, spatial visualization, principal component analysis (PCA), and multiple regression models—answer research questions 2, 3, and 4.

This report answers these research questions in three sections. The first section, *Introduction*, introduces the study area—San José, California—through its socioeconomic attributes, historical track record of spatial segregation, and a review of past and current status of San José's bike network development plans and implementation. The second section, *Assessment of San José's Bike Desert and Paradise*, introduces a new bike infrastructure availability score (i.e., Bike Index) for mapping San José's best (i.e., bike paradise) and worst (i.e., bike desert) regions for cycling. The third section, *Assessing Bike Use Patterns and Motivators*, using San José residents' bike travel pattern data (i.e., StreetLight data), the Bike Index, principal component analysis (PCA), and multiple regression models, investigates whether the availability of infrastructure alone attracted riders from underserved communities. This project's findings demonstrated that the conventional way of measuring bike infrastructure access (i.e., bike lane length per capita) could potentially overestimate the availability of bike infrastructure, which could lead to false assessments of bike plans' equity. The bike availability score developed in this project, which accounts for safety and comfort differences between different bike lane classes, shows a significantly different picture. Using this score shows major disparities and equity challenges across the City in the availability of safe and comfortable bike infrastructure. The analysis of resident bike travel patterns in San José also shows that an unanswered demand exists in bike desert areas; in other words, San José's bike desert areas do have notable bike trips despite the inadequate infrastructure. Furthermore, San José residents' inadequate access to bike lanes means using sidewalks, which can increase the risk of bicyclist–pedestrian collisions. These findings provide a key takeaway for the City of San José; the expansion of a safe and comfortable bike network strongly supports the City's Vision Zero goals (City of San José Department of Transportation, 2020).

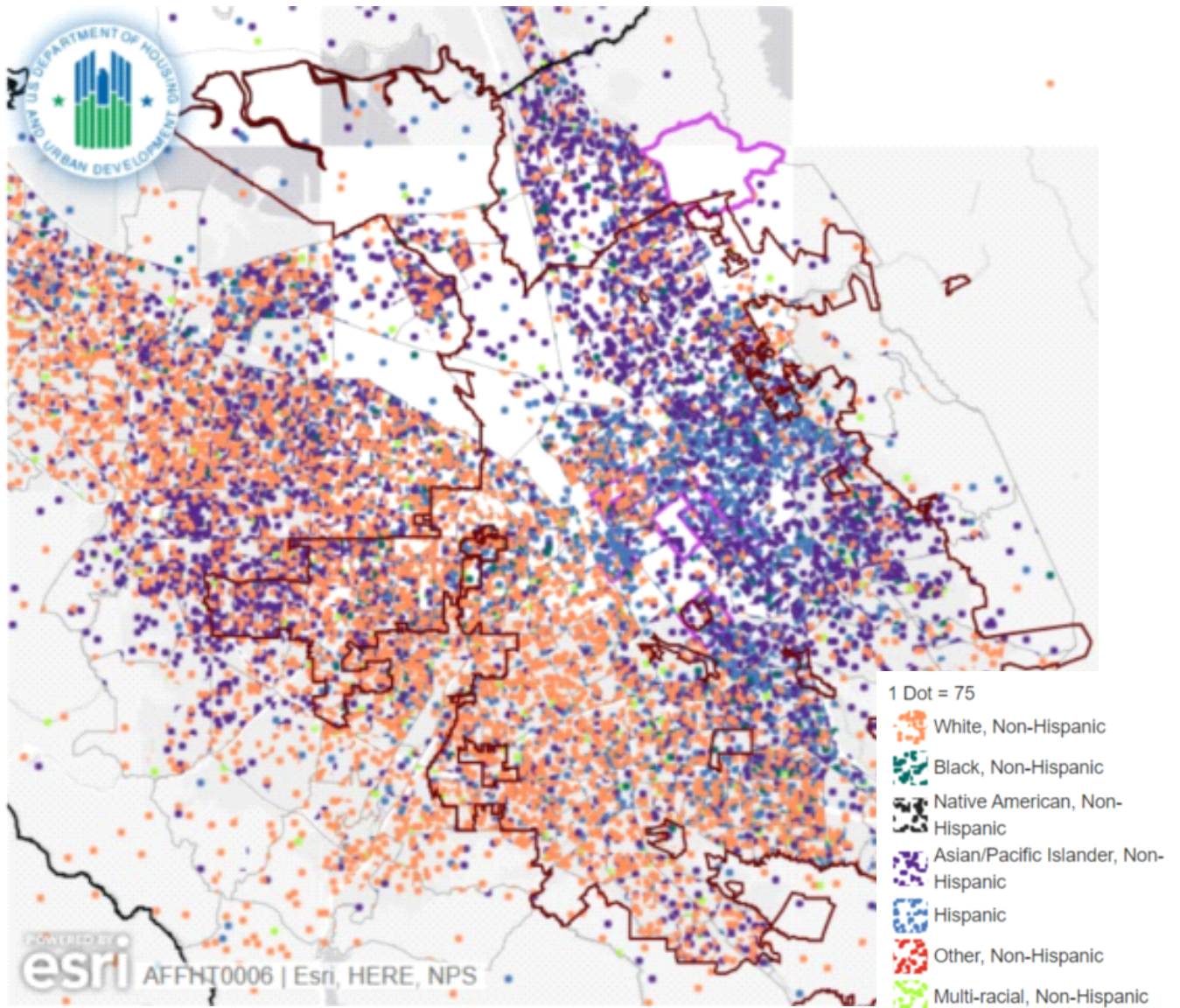
1.2 Study Area

The focus of this study is San José, California, which has the potential to be one of the top cyclist cities in the U.S. The City had a plan of completing 392 miles of on-street bikeways and 62 miles of multi-use paths (also known as trails) by 2020. The City's median household income is \$117,324 USD, and its poverty rate is 8.72%. The median monthly rent is \$2,107, while the median property value is \$864,000. This makes San José one of the most unaffordable cities in the country. However, San José is the capital of a booming knowledge economy and home to major high-tech headquarters which have spurred economic vitality and population growth (Zandiatashbar & Hamidi, 2021). Though San José is a major job hub due its strong high-tech economy, housing unaffordability pushes employees to reside in distant, more affordable areas. This situation

exacerbates traffic congestion for daily commutes, which a multimodal system that supports bike and transit would help alleviate. The City also stands among the youngest, with a median age of 36.7 years (Shrider et al., 2021). San José is the third-largest city in the state of California, the tenth largest in the U.S., and the largest in Northern California (World Population Review, 2022). The presence of a younger population, which is generally more interested in, and physically prepared for, an active lifestyle (Klein & Smart, 2017), could indicate a strong potential demand for a bike system.

Despite this growth, exacerbating issues have affected residents' quality of life, such as traffic and congestion. Such issues call for focusing on the equity aspects of urban development and the allocation of resources and infrastructure for non-automotive commute options. The observation of inequality in several spheres of Silicon Valley residents' lives suggests exploring the same equity issue when it comes to the allocation of bike network resources. For instance, the recent Assessment of Fair Housing (AFH) shows that large patterns of housing spatial segregation continue (see Figure 2) and that the City is spatially segregated/divided by Highway 101, with strong disparities in race and income (Alaban, 2021). Figure 1 visualizes these spatial disparities in the City of San José both in terms of race and economic prosperity and is in line with the AFH findings (Alaban, 2021) that the neighborhoods to the west of Highway 101 have higher concentrations of White residents with some concentrations of Asian residents. To the east of Highway 101, on the other hand, is a concentration of Latino and Asian neighborhoods, with the strongest concentrations in Alum Rock, as shown in Figure 2. The 2021 five-year American Community Survey estimates show that the City could be split in two halves: West San José, containing the wealthier neighborhoods with mostly White residents, and East San José, which is less wealthy and mainly occupied by Hispanic and/or non-White residents. To minimize this spatial disparity, the City is cautious not only to provide equitable allocation of infrastructure, but also to add extra support to the residents of East San José (City of San José Department of Transportation, 2020).

Figure 2. Racial makeup of San José residents and where they live (Alaban, 2021)



The racial composition of San José reveals disparities across the City, which make racial disparate composition a key reference for assessing the location of bike deserts. The next section explains the details of measuring and mapping bike deserts.

2. Assessment of San José’s Bike Desert and Paradise

2.1 Background

San José has a long-standing commitment to expanding its on-street bike network through supportive programs and policies (City of San José Department of Transportation, 2020). These efforts formally began with the San José Bike Plan in 2009 and continued through the Envision San José 2040 General Plan (the City’s long-term comprehensive plan), which set an ambitious blueprint for the Better Bike Plan. In terms of development, the City launched the Better Bikeways Project for the rapid implementation of all-ages-and-abilities design² in 2017 to improve the City’s bike network by installing a network of separated bike lanes and protected intersections throughout its downtown in the summers of 2018 and 2019. The first on-street bike lanes were installed in the 1970s, and the 2009 plan led to an unprecedented amount of bikeway construction, which brought the City’s total bikeway system to 392 miles of on-street bikeways and 62 miles of multi-use paths by 2020. In 2016, the Department of Parks, Recreation and Neighborhood Services published the Trail Program Strategic Plan, with the goal to complete San José’s 100-mile trail network (Table 1).

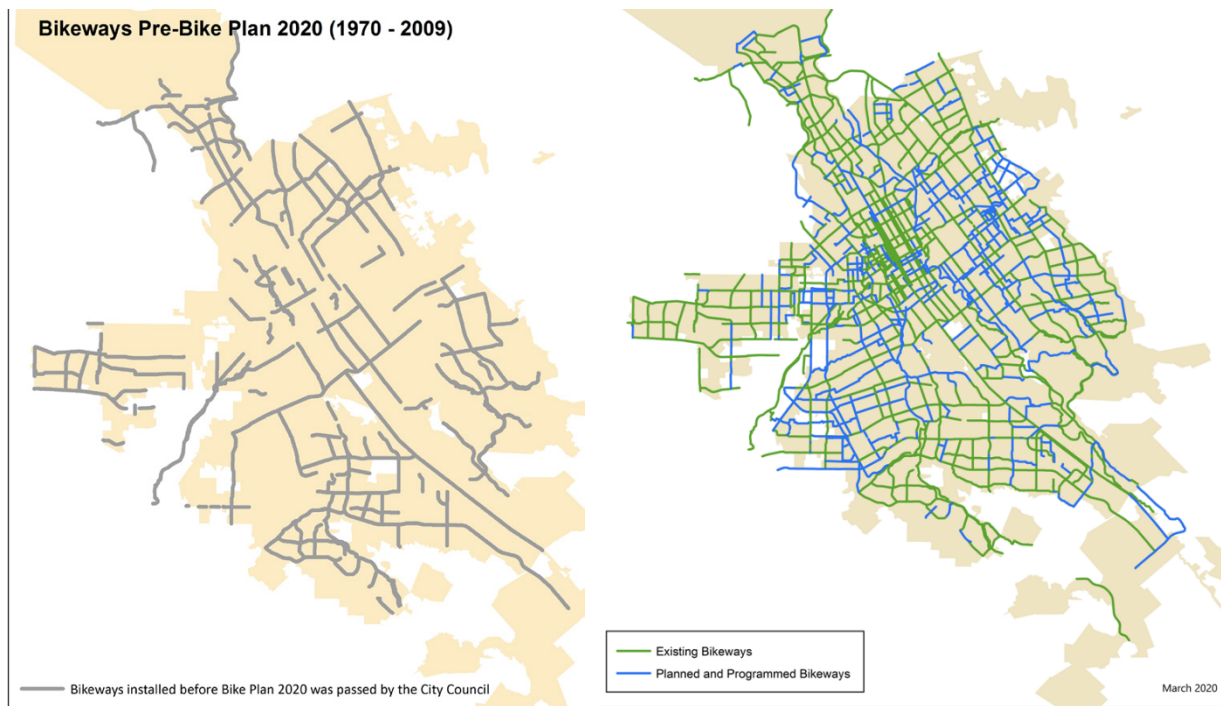
Table 1. Summary of the Status and Progress of San José’s Bike Network

	2009 Bike Plan Goals	2020 Status	Better Bike Plan 2025
Miles of Bikeways	400 miles of on-street bikeways and 100 miles of multi-use paths	392 miles of on-street bikeways (including 6 miles of protected lanes), 62 miles of trails	100-mile low-stress,* connected network
* Low-stress bikeways greatly reduce the chance of a collision with an automobile by prioritizing bicycle traffic on streets with low volumes and speeds or by providing separation from faster-moving car traffic.			

Figure 3 illustrates the growth of the city-wide bike network. To increase bike commutes and a focus on equity, the City needs to identify bike deserts to ensure an equitable distribution of bike infrastructure across different communities. This is not only about having bike lanes, but also about accounting for the different qualities of such lanes.

² A bike network that is truly safe and inviting for bicyclists of all ages and abilities and attracts wide ridership (National Association of City Transportation Officials, 2017).

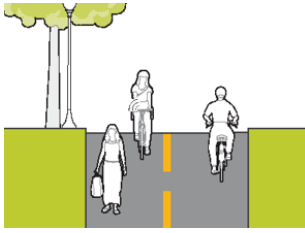
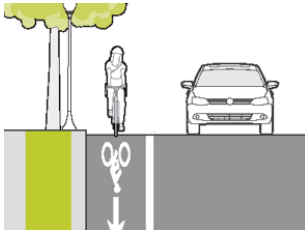
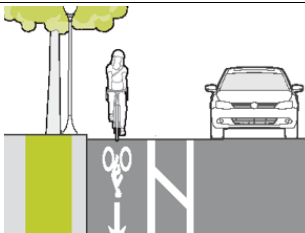
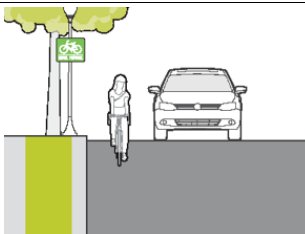

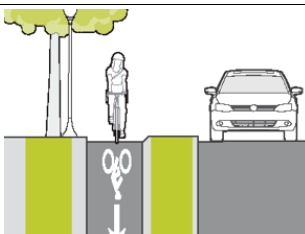
Figure 3. San José’s Bike Network Growth 2009–2019
(City of San José Department of Transportation 2020)



Existing bikeways in 2009 and existing and planned bikeways in 2019

The City’s bike network is composed of different bike lane classes, each of which provides different levels of safety and comfort for bicyclists. Although a glance at Figure 3 suggests that the entire city is well covered by the bike network, an equity analysis of the bike infrastructure will identify differences between bike lane classes available to different groups of residents across the City. These differences stem from different levels of safety and comfort that each class provides bicyclists. The attributes of these classes are presented in Table 2.

Table 2. Attributes of Different Bike Lane Classes
(National Association of City Transportation Officials, 2014)

Bikeway class attribute	Graphic illustration
<p>Bikeway Class I is also known as bike paths or shared-use paths, which are facilities with exclusive right of way for bicyclists and pedestrians. This class of bikeways is physically located away from the roadway in order to minimize cross-flows by motor traffic. In some cases, they have separate pedestrian facilities. Bikeway Class I supports both recreational and commuting opportunities. Common locations for this class are along rivers, shorelines, canals, utility rights-of-way, railroad rights-of-way, within school campuses, or within and between parks.</p>	
<p>Non-buffered Class II bikeways consist of one-way bike lanes along streets, and are typically adjacent to motor traffic traveling in the same direction. Bike lane Class II is distinguished by pavement striping and signage to allocate a portion of a roadway for bicycle travel.</p>	
<p>Buffered Class II bikeways have a greater separation from an adjacent traffic lane and/or between the bike lane and on-street parking by using chevron or diagonal markings. Greater separation can be especially useful on streets with higher motor traffic speeds or volumes.</p>	
<p>Bike Route Class III (sharrows) are established by placing bike route signs and optional shared roadway markings (sharrows) along roadways. Sharrows have designated routes for bicyclists on streets shared with motor traffic. Sharrow bike routes are not served by dedicated bikeways to support the continuity of the bikeway network and are generally not appropriate for roadways with higher motor traffic speeds or volumes. This is also the lane without any bicycle signage, where cyclists are expected to travel along the curb, often to the right of vehicles sharing the lane.</p>	
<p>Bike Route Class III, specifically a Bicycle Boulevard, is a shared roadway intended to prioritize bicycle travel for people of all ages and abilities, and which is typically sited on streets without large truck or transit vehicles, and where traffic volumes and speeds are already low, or can be further reduced through traffic calming.</p>	
<p>Bikeway Class IV is a separated bikeway/cycle often referred to as a cycle track or protected bike lane, which is for the exclusive use of bicycles. Bikeway Class IV is physically separated from motor traffic by some vertical features. The facilities for separation could be, but are not limited to, grade separation, flexible posts, inflexible barriers, or on-street parking. Class IV bikeways can be one-way or two-way. In sum, by physically separating a bikeway from motor traffic, Class IV bikeways can reduce the level of stress, improve</p>	

Bikeway class attribute	Graphic illustration
comfort for more types of bicyclists, and contribute to an increase in bicycle volumes and mode share. Ultimately, Bike Class IV provides the highest level of comfort and stress reduction for cyclists comparing to all other lanes explained above.	

Figure 4 provides examples of each bike lane class as implemented in San José. The safety and comfort for bicyclists stem from different road features, including traffic control devices such as signage, roadway markings and signals, or geometric design features that can minimize ambiguity for all roadway users in tandem with drawing attention to the presence of bicyclists. Each class uses different approaches; however, there is not a similar level of comfort and safety across all four classes.

Figure 4. Examples of Different Bike Lane Classes from San José, CA
(City of San José Department of Transportation, 2020)



2.2 Methods

In order to identify the bike desert areas in San José, we used bike network data, a street network dataset, and census blocks. We delineated the blocks that are connected to a bike lane via local roads within an acceptable distance of 0.25 miles (Zandiatashbar, Hamidi, Foster, et al., 2019) and weighted the covered blocks by the bike class type to identify bike desert areas. We provide detailed explanations for our weighting system as well as the network analysis for identifying the served census blocks by bike lanes below. In addition to detailing our analytical method, in this section we introduce our sample data and the variables used for identifying and assessing San José bike deserts.

Data and Variables

The main dataset for our analysis is the bike network GIS dataset provided by the City of San José. The dataset includes the exact location of each bike lane throughout the City as well as the bike lane classification, as detailed in Table 2. After developing a Bike Index (to be explained in the Analytical Methods section below) that accounts for bike infrastructure for the different classes (explained in Table 2), our analysis assesses the connection between the distribution of bike infrastructure and spatial disparities in terms of racial composition in the City under the Analytical Methods section. Table 3 below provides an overview of the variables that we included in the Analytical Methods section. The source for all variables in Table 3 is the American Community Survey (ACS) 5-year Estimate for 2021.

Table 3. Variables' Description and Data Sources

Variable	Description	Mean	StDev
<i>Racial attribute</i>			
<i>PctWhite</i>	% White residents	39.58	19.05
<i>PctHisp</i>	% Hispanic residents	30.05	20.55
<i>PctBlack</i>	% African American residents	3.05	2.23
<i>PctAsian</i>	% Asian residents	36.73	21.86
<i>PctAmcIndian</i>	% American Indian residents	0.78	0.55
<i>Income level</i>			
<i>Income</i>	Income per capita 2021	\$51,120	\$24,855

Analytical Methods

Our Analytical Methods is composed of two sections: measuring the Bike Index (i.e., weighted bike infrastructure availability) and an equity assessment of bike infrastructure availability.

Measuring Weighted Bike Infrastructure Availability

Different bike accommodations/classes have different roles in separating traffic for bicyclists' stress reduction, which is important to improve convenience for bicyclists, and, therefore, it is critical to account for their stress reduction level. Accordingly, we used the stress reduction percentages provided by Lowry et al. (2016) to account for the different roles that each bike class can have in providing comfort to bicyclists. Lowry et al. (2016) classified "bicycling stress" using Marginal Rates of Substitution (MRS) through empirical behavioral research on bicyclist route choice. MRS values represent bicycling stress associated with street's number of lanes and speed limit. This study defines the percentage of stress reduction for five levels of bike accommodation as:

- a signed bike route with no further accommodation (5% reduction)
- sharrows (10%)
- conventional bike lanes (50%)
- buffered bike lanes (65%)
- protected bike lanes (75%)

We assigned these values to San José’s current bike lane classes in Table 4. Our process of identifying bike deserts includes two major steps. The first step is to identify census blocks that are served by bike lanes and to assign weights to the bike classes of a census block. To identify a served block, we used a block’s center to develop a 0.25-mile network buffer using local roads. This threshold was for including the bike lanes for a block. Since the quality of road for access is not guaranteed to be bike friendly, we selected the most common buffer distance for both walking and biking access. If at least one bike lane is within the block’s network buffer, we consider that block served. We then used the percentages presented above to weight each served block by the class of its bike lane (Table 4). If a block has more than one bike lane, we summed the weights for all the bike lanes serving the census block.

Table 4. San José’s Bike Lane Classes and Weights

Bike class type		Definition	Weights
Multi-use path*	Class I	Multi-use off street like trails in park	50%
Bike lane	Class II-Basic	A signed bike route with no further accommodation	5%
Bike lane	Class II-Buffered	Buffered bike lanes	65%
Bike route	Class III-Bike Blvd/Sharrow	Route/Boulevard/Sharrow, shared	10%
Bike lane	Class IV	Protected/separated by physical object on street, separated from both sidewalk & street.	75%
Trails (i.e., multi-use path/class I) are planned/built for recreational biking/physical activities, rather than others that are meant to facilitate access to destinations. The project’s focus is on on-street bike network which is meant for access to destinations.			

In the second step, we used these weights to adjust the total length of the bike lanes serving a neighborhood (i.e., census block groups) accordingly. Census block groups are the most granular unit for which we could then collect socio-demographic variables for the equity assessment in the next section. We aggregated (summed) the census blocks' weights of a block group level and used this value to calculate the weighted bike length per capita for a block group and estimate a 0–100 normalized score, which will be our Bike Index moving forward. Ultimately, we used the weighted bike length per capita block group to identify San José's bike deserts and paradises through hotspot analysis via local Getis Ord G^* (Zandiatashbar, 2019).

Equation 1 for calculating the *Bike Index* is as follows:

$$Bike\ Index = 100 * ((X - \min(X)) / (\max(X) - \min(X))) \quad (1)$$

where X is a single raw data value (i.e., the weighted bike length per capita for a block group).

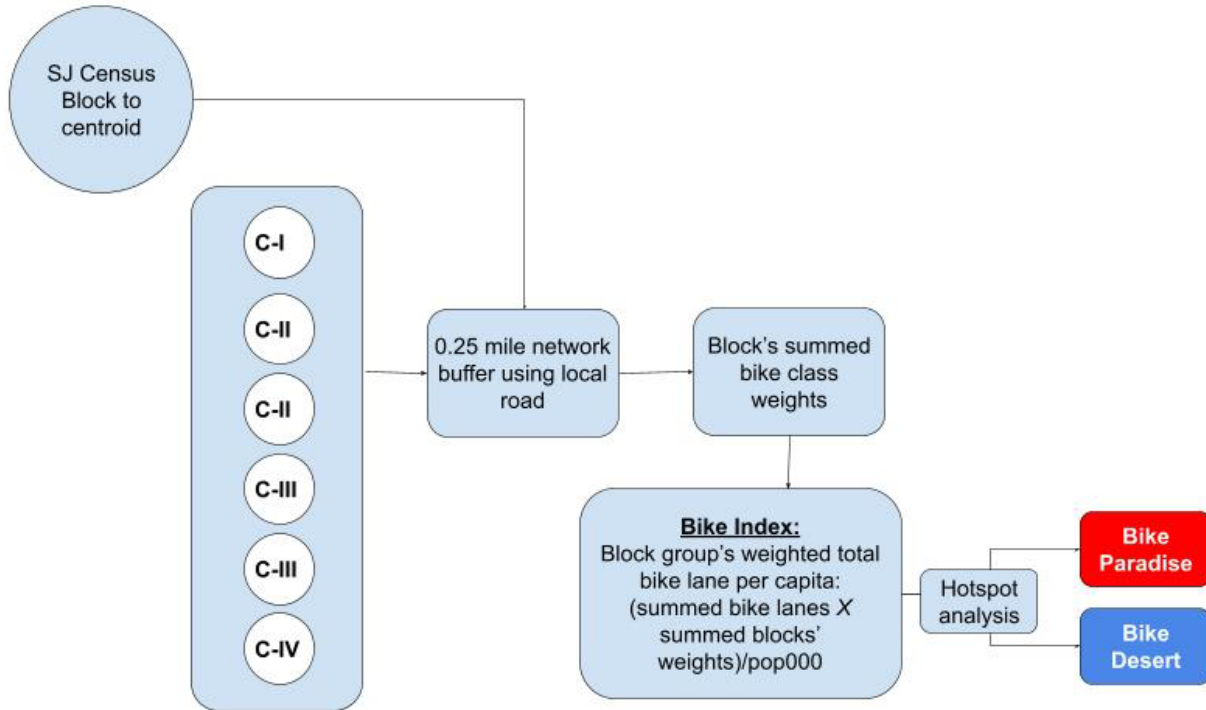
For both bike paradise and desert areas we included the results of our cluster analysis, which has a 95% or higher level of confidence. In other words, bike desert or paradise areas are where local Getis Ord G^* found a non-random spatial cluster of high or low bike index at a 95% or higher level of confidence.

Equity Assessment

We used spatial visualization as well as a pairwise Pearson correlation analysis³ to map and assess if different socio-demographic attributes differ in terms of access to quality bike infrastructure in San José. For the spatial visualization, we used choropleth mapping with Jenks natural breaks classification, an effective method for data clustering to determine the best arrangement of values into different classes while minimizing each class's average deviation from the class mean and maximizing each class's deviation from the means of the other classes. In other words, this method reduces the variance within classes and maximizes the variance between classes (North, 2009).

³ The pairwise Pearson correlation matrix helps identify a bivariate relationship—or correlation—between two variables. The Pearson correlation method works as a primary check for the relationship between two variables. The Pearson coefficient of correlation is a measure of the strength of the linear relationship between two variables (Cleophas & Zwinderman, 2018).

Figure 5. Analytical Diagram



2.3 Results

Our analysis includes 586 census block groups that have their population centers within the City's boundary. Table 5 presents a descriptive analysis of these block groups showing that African American and American Indian people make up the smallest ethnic demographics in San José. Accordingly, in a San José block group, on average, almost three percent of residents are Black and less than one percent is American Indian, whereas more than a third of a neighborhood in San José on average is Asian, Hispanic, or White. The maximum share of American Indian residents of a neighborhood is just 3%, while this value for Asian, Hispanic, or White residents could be almost 90%.

Table 5. Descriptive Summary of Racial Attributes and Bike Infrastructures

<i>Variable</i>	<i>Mean</i>	<i>StDev</i>	<i>Min</i>	<i>Max</i>
<i>Racial and Income Attributes</i>				
PctWhite	39.58	19.05	5.34	88.80
PctBlack	3.05	2.23	0.00	16.78
PctAmcInd	0.78	0.55	0.00	2.72
PctAsian	36.73	21.85	2.12	88.83
PctHisp	30.33	20.55	0.79	90.55
Income per Capita	\$51,120	\$24,855	\$8,618	\$143,967
<i>Bike Infrastructure</i>				
Weighted Bike Length per Capita	0.36	0.88	0.00	13.34
Bike Length per Capita	0.83	1.36	0.00	26.68
Bike Index (based on Weighted Bike Length per Capita)	2.67	6.63	0.00	100.00

The mean difference between weighted bike length per capita and (unweighted) bike length per capita shows that, without counting for different bike classes, there is a chance of overestimating bike infrastructure availability. Accordingly, average bike length per capita across San José block groups is almost three times bigger than the weighted bike length per capita. We also used an independent t-test to determine whether the mean difference between bike length per capita and bike length per capita variables is statistically significantly different from zero (Table 6).

Table 6. Two-sample t-test with Equal Variances

Variabl e	Observ ations	Mean	StErr	StDev	95% confidence interval	
BikeLn PC	586	0.838033	0.056179	1.359952	0.72769 53	0.94836 99
WBike LnPC	586	0.355538	0.036530	0.884299	0.28379 21	0.42728 41
Combi ned	1,172	0.596785	0.034225	1.171688	0.52963 54	0.66393 53
diff		0.482495	0.067012		0.35101 85	0.61397 06
diff = mean(BikeLnPC) - mean(WBikeLanePC)				$t = 7.2002$		
$H_0: \text{diff} = 0$			Degrees of freedom = 1170			
$H_a: \text{diff} < 0$		$H_a: \text{diff} = 0$		$H_a: \text{diff} > 0$		
$\text{Pr}(T < t) = 1.0000$		$\text{Pr}(T > t) = 0.0000$		$\text{Pr}(T > t) = 0.0000$		

Using the weighted bike length per capita (WBLPC) and hotspot analysis, we identified a bike paradise (i.e., a spatial cluster of high WBPLC values at a 95% level of confidence) and a bike desert (i.e., a spatial cluster of low WBPLC values at a 95% level of confidence). These areas are presented in Panel 2 of Figure 6 below, which shows the bike paradise commencing in downtown and extending to the north side of the City, whereas the bike desert is focused on East San José. As explained earlier, the bike paradise and desert areas are identified using hotspot analysis via local Getis Ord G^* and the Bike Index. Figure 6 presents the results of this analysis.

The other notable finding is the close proximity of the bike desert and paradise to each other, continuing the sharp lines of segregation in the City. The recent Assessment of Fair Housing (AFH) shows that large patterns of housing segregation continue, and that the City is divided by Highway 101 with strong disparities in race and income on either side of the freeway (Alaban, 2021). Similarly, the bike desert and paradise are also separated by Highway 101.

Figure 6. Identifying San José’s Bike Desert and Paradise from Weighted Bike Length per Capita Using Hot Spot Analysis

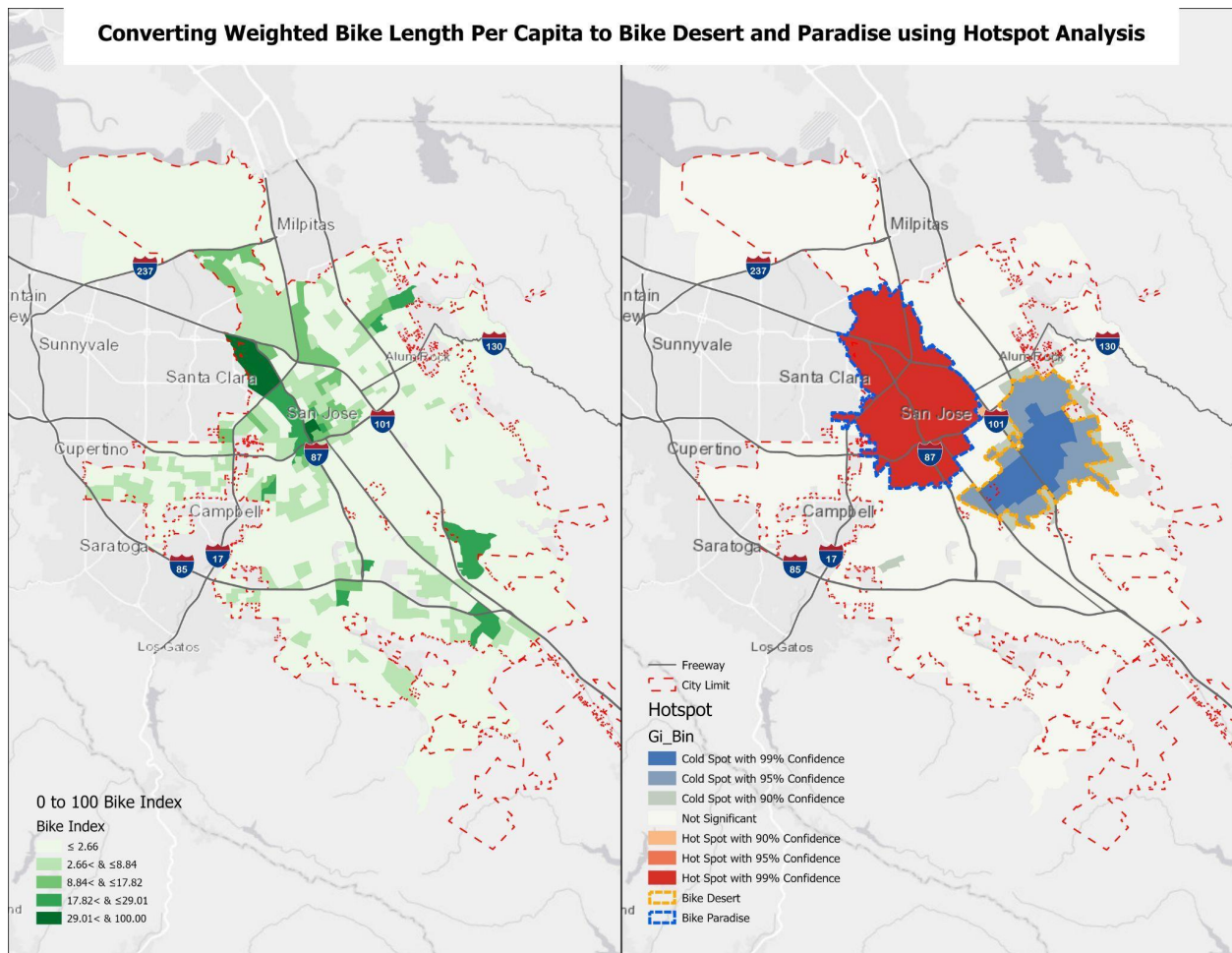


Figure 7. Comparison of Maps Developed with Weighted Bike Index Versus Unweighted Bike Length per Capita

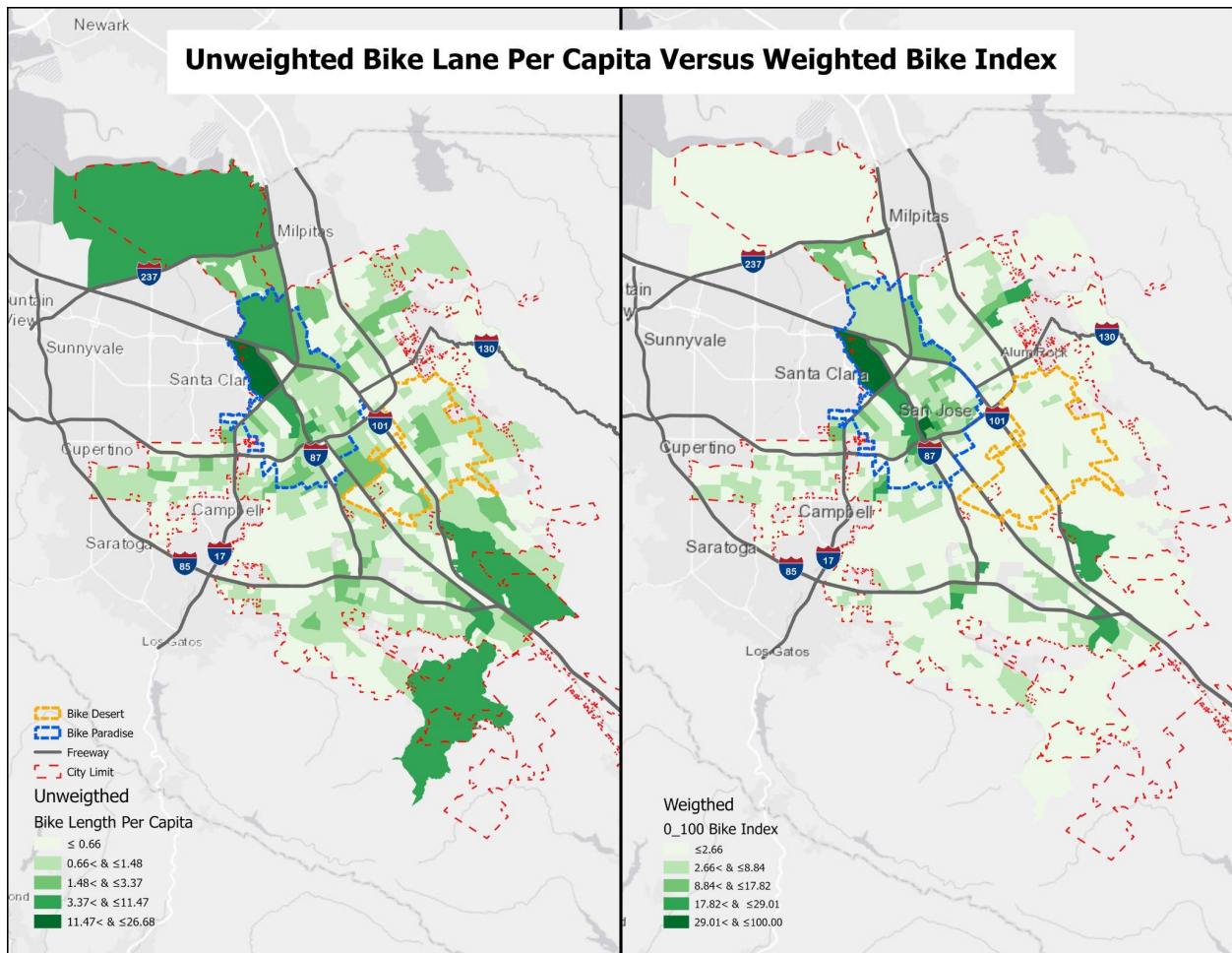


Figure 8 highlights the major differences between accounting and not-accounting for different bike classes. Comparing these two maps, the first major difference is a bigger area that is found to be poorly supported by bike infrastructure according to the Bike Index. Despite the major differences between the two maps, one key similarity between both is the fact that East San José is found in both maps to be poorly supported by bike infrastructure. We have two different ways of assessing access to bike infrastructure. Our way, which takes into consideration the quality of the infrastructure, shows that access to higher quality bike infrastructure is concentrated in downtown, South San José, western parts of San José, and a few neighborhoods in the northeast. Having found that bike lanes per capita over-estimate available facilities, it is critical to assess the equity aspect of bike infrastructure distribution across the City using the weighted Bike Index.

Figure 8. Comparison of Bike Desert and Paradise Socioeconomic Attributes

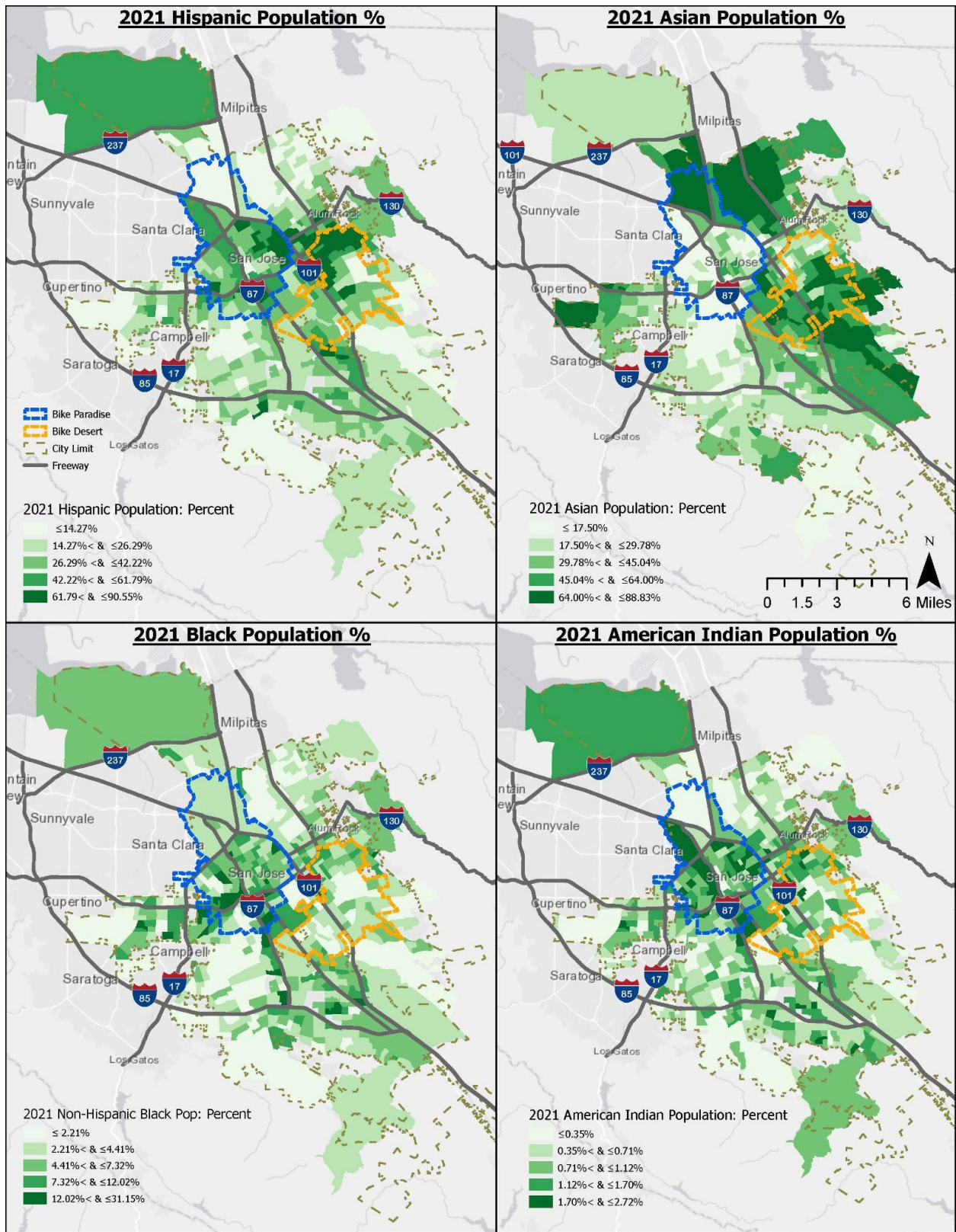
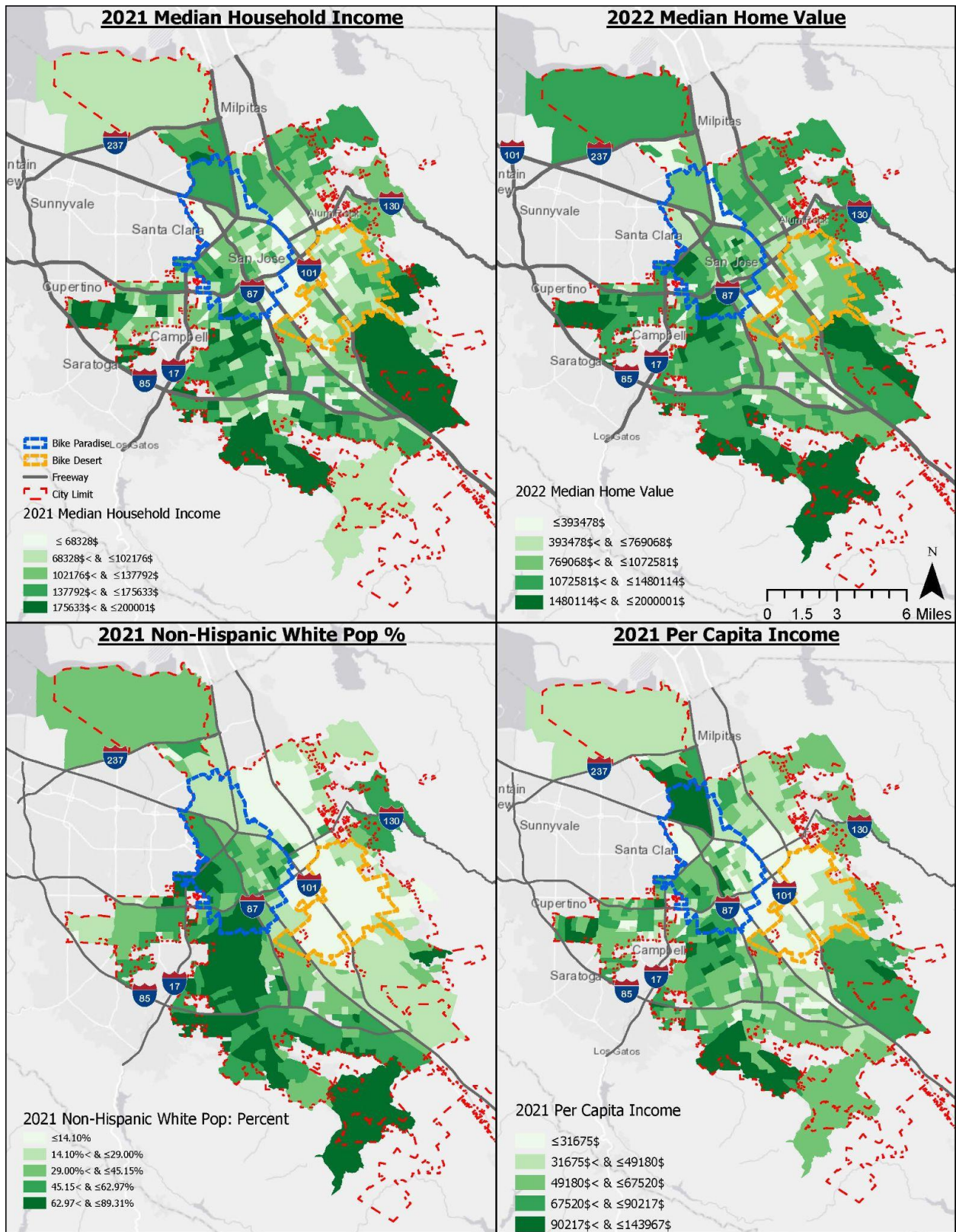


Figure 9. Comparison of Bike Desert and Paradise Socioeconomic Attributes



As Table 5 shows, after White and Asian population groups, Hispanics have the third largest share of San José's population. On average, a third of a San José neighborhood can be Hispanic and at most this value can be more than 90%. Despite a strong presence in San José, populations of Hispanic residents are clustered in the central and eastern parts of the City. Comparing Figure 7, which depicts a choropleth map of Hispanic residents alongside the Bike Index, East San José has the lowest Bike Index values, and these neighborhoods also have lower values for bike length per capita. These two low values reflect the lack of bike infrastructure of any class.

This situation is not limited to East San José; the Hispanic neighborhoods in the southern and western sides of downtown San José are also not well-served by bike infrastructure, despite being relatively close to downtown areas with the strongest bike infrastructure across the City.

According to Table 5, African American and American Indian are the two major census race categories that have the smallest presence in the City of San José. In a San José neighborhood, on average almost 3% of residents are Black while more than 30% are Asian, Hispanic, or White. Despite the very low share of Black residents citywide, there is a stronger presence in the central neighborhoods and downtown, as well as the northwest side of downtown. The conclusion could be, as shown in Figure 7, that block groups with a strong presence of Black residents are well served by existing bike infrastructure.

The very small presence of an American Indian population in the City makes it hard for them to cluster in a specific neighborhood. As shown in Figure 7, American Indians scatter across the City. Comparing the choropleth map of American Indians in San José with the map of the Bike Index suggests no specific relation between the Bike Index and the percentage of American Indian residents in a block group.

Asians have a relatively strong presence in the City of San José. According to Table 5, on average 40% of residents of a San José neighborhood (census block group) are Asian, and this value could even go up to nearly 90% considering the maximum value reported in Table 5. The percentage of Asians in a block group is higher in East San José, where the Bike Index values are lowest. Figure 8 suggests that there is a negative relationship between the block groups' percentage of Asian residents and the Bike Index. However, a statistical test is needed to draw a clear conclusion, which is conducted in the next section, with the results provided in Table 7. Table 7 presents the result of the Pearson (pairwise) correlation between racial attributes and Bike Index values. This allows us to quantify the relationships between each of the racial categories and Bike Index values in San José block groups.

According to Table 7, while the spatial visualization led to the conclusion that East San José, home to Asian and Hispanic populations, is not well supported by the existing bike infrastructures, the results of Pearson pairwise correlation analysis show no significant relationship between the Bike Index and Hispanic percentage. However, the Bike Index and Asian population percentage have a significant negative relationship. Therefore, the statistical analysis also confirms the spatial analysis findings that East San José is not well supported by bike infrastructures.

Table 7. Pairwise Pearson Correlation Coefficients

	<i>BikeIndex</i>	<i>PctAmcInd</i>	<i>PctAsian</i>	<i>PctHisp</i>	<i>PctBlack</i>	<i>PctWhite</i>	<i>IncPc</i>
<i>BikeIndex</i>	1						
<i>PctAmcInd</i>	0.072**	1					
<i>P-value</i>	0.0814						
<i>PctAsian</i>	-0.0797*	-0.4533**	1				
<i>P-value</i>	0.054	0					
<i>PctHisp</i>	0.0076	0.6554**	-0.4870**	1			
<i>P-value</i>	0.8551	0	0				
<i>PctBlack</i>	0.0479	0.5068**	-0.3479**	0.5408**	1		
<i>P-value</i>	0.2466	0	0	0			
<i>PctWhite</i>	0.1023**	0.0355	-0.7325**	-0.1979**	-0.0745*	1	
<i>P-value</i>	0.0132	0.3907	0	0	0.0717		
<i>Income</i>	0.0848**	-0.4567**	0.0113	-0.6971**	-0.4287**	0.5198**	1
<i>P-value</i>	0.0401	0	0.7845	0	0	0	

* Significant ($p\text{-value} \leq 0.1$); ** Highly significant ($p\text{-value} \leq 0.05$)

Additionally, according to Figure 8, which also shows a block groups' percentage of White residents, the City is almost evenly divided along Highway 87. In West San José, there is a much higher percentage of White residents compared to East San José. Comparing this spatial disparity with the Bike Index in Figure 8, we can see that the northern and western neighborhoods both have a more robust bike infrastructure where more White residents live. However, even some West San José neighborhoods with a strong presence of White residents have a lower Bike Index. Although the neighborhoods with a low Bike Index are mostly in East San José, where there are fewer White residents, the conclusion could be drawn that there is a positive relation between the percentage of White residents and the Bike Index. Table 7 confirms the positive and strong correlation between that percentage of the White population and Bike Index values. While the correlation between the percentage of African American or American Indians and the Bike Index also is positive, it is not as strong as this value for the percentage of the White population. The two races that are negatively correlated with our Bike Index are the Hispanic and Asian populations.

According to Figure 9, the City of San José also has a spatial disparity when it comes to per capita income. Per capita income is higher in the western and southern parts of the City. In comparing the Bike Index with per capita income, while the low-income areas also have a low Bike Index, not all of the high-income neighborhoods have a high Bike Index. With that said, most of the neighborhoods that fall in the highest category of per capita income are also in or are adjacent to neighborhoods that are well served by bike infrastructure. Also, as presented in Table 6, there is a

statistically significant positive correlation between the Bike Index and per capita income. In other words, wherever San José has higher per capita income neighborhoods, there is higher quality bike infrastructure.

3. Assessing Bike Use Patterns and Motivators

3.1 Background

A key finding in the analyses presented thus far is that the conventional way of measuring bike infrastructure access (i.e., bike lane length per capita) potentially overestimates available facilities. While bike lane length per capita shows good coverage of the City, the weighted Bike Index presented in the last section shows otherwise. The results from the last section showed that the historical patterns of segregation by Highway 101 also continue to be reflected in the provision of adequate bike infrastructure and reinforce the segregation of San José. However, this pattern can be missed with the use of bike lane length per capita. Thus, the weighted Bike Index helps with a more accurate equity assessment of bike infrastructure in San José, especially by accounting for different bike classes. In the last section, we developed a methodology to have a more accurate measure of bike infrastructure (i.e., bike infrastructure supply) by accounting for different bike classes. In this section, we use this measure to assess against the individuals' bike travel patterns, broken down by racial and income attributes (demand) using a StreetLight dataset. The StreetLight dataset supports mobility planning across the U.S. and contains the locations and attributes of trips collected from personal devices and the internet of things (IoT). The dataset then transforms and normalizes this data to travel behavior (Yang et al., 2020). The dataset includes several socioeconomic attributes of the individuals for whom the travel behavior is reported. Assessment of these supply and demand measures helps answer this project's fourth research question, i.e., if could the availability of infrastructure alone attract riders from underserved communities. To answer this research question, we quantify the factors that contribute to bike commutes use using multiple additional datasets (in addition to the StreetLight dataset) to compile socioeconomic and built environment confounding variables.

3.2 Methods

In order to assess bike use differences across different socioeconomic and racial groups, and to quantify the factors that contribute to bike commute use, we drew upon descriptive analysis, spatial visualization, principal component analysis (PCA), and multiple regression models. Our analysis includes 218 census tracts in San José and for which StreetLight data is available. Although in the previous section we used census block groups as the unit of analysis (which is the smallest geographical unit for which the Census Bureau publishes sample data), here we apply the same method and estimate a weighted bike lane length per capita at the census tract-level to account for the tabulation block delineation and numbering in this section.⁴

⁴ Block Groups are defined before tabulation block delineation and numbering but are clusters of blocks within the same census tract that have the same first digit of their 4-digit census block number from the same decennial census.

Data and Variables

Table 8 includes the information for the data and variables we used for our analysis in this section. This main data for this research comes from a StreetLight dataset that includes bike travel attributes (i.e., the socioeconomic status of the individuals for whom the travel behavior is reported).

Table 8. Variable Description and Data Sources

Variable	Description	Source	Mean (StDev**)
<i>Bike Ridership</i>			
<i>BUPC</i>	Avg # of bike trips per capita	StreetLight	97.26 (4)
<i>Avg Ride</i>	Avg Bike trips (3-year avg)	StreetLight	248.84 (265.56)
<i>PctHisp</i>	% Hispanic bike riders	StreetLight	33 (14)
<i>PctBlack</i>	% African American bike riders	StreetLight	3 (1)
<i>PctAsian</i>	% Asian riders	StreetLight	29 (13)
<i>PctWhite</i>	% White riders	StreetLight	1 (0.00)
<i>Socioeconomic Index estimated using PCA</i>			
<i>Inc_Med</i>	Household Median Income	ACS* 5Yr estimate 2022	100261.70 (32858.81)
<i>Edu_Pct</i>	% bachelor's degree holders	ACS* 5Yr estimate 2022	28.01 (9.77)
<i>Emp_Pct</i>	% employed residents	ACS* 5Yr estimate 2022	94.59 (11.37)
<i>Wte_Pct</i>	% White residents	ACS* 5Yr estimate 2022	28.43 (17.64)
<i>Built Environment Index estimated using PCA</i>			
<i>PopDen</i>	Persons per acre	SLD*** 2018 estimates	18.27 (9.92)
<i>ActDen</i>	Population plus employment per acre	SLD*** 2018 estimates	22.98 (12.85)
<i>EmpEnt</i>	5-tier employment entropy****	SLD*** 2018 estimates	0.57 (0.21)
<i>RdDen</i>	Total road network density (4-way intersection per Sq Mi)	SLD*** 2018 estimates	24.31 (8.43)
<i>JobAcc</i>	Number of accessible jobs in 45-min drive	SLD*** 2018 estimates	109031 (39838.81)
<i>WalkSc</i>	National walkability index*****	SLD*** 2018 estimates	12.90 (3.97)
<i>Bike and pedestrian infrastructure</i>			
<i>WBLPC</i>	Weighted bike length in miles per capita	Measured in the research	0.17 (0.42)
<i>SWPC</i>	Sidewalk length in miles per capita	UrbanFootprint	7.32 (35.83)

* American Community Survey

** Standard deviation

*** Smart Location Database

**** The entropy measure acts as a proxy for land use diversity by quantifying the relative blend of the number of jobs in different employment sectors. The entropy variable uses the 5-tier employment categories (i.e., retail, office, industries, services, and entertainment) to calculate employment mix.

***** Walkability score is based on a value that ranks selected indicators from the Smart Location Database that have been demonstrated to affect the propensity of walking.

Analytical Methods

Our research in this section employs descriptive analysis, spatial visualization, PCA, and multiple regression models to assess the bike trip differences among different racial and ethnic groups and whether and to what extent the availability of infrastructure alone could attract riders from underserved communities.

Descriptive and spatial analyses help us assess and visualize bike use differences across different socioeconomic and racial groups. We further this analysis by using *multiple linear regression models* to quantify the factors that contribute to bike commute use. These models also help assess if the availability of infrastructure alone could attract riders from underserved communities. As part of the research, we accounted for four main assumptions of ordinary least squares (OLS) regression including linearity, normality, multicollinearity, and homoscedasticity.⁵ The remaining sections present the results of these analyses as well as further methodological details.

3.3 Results

Bike Use Differences Across Different Socioeconomic and Racial Groups

According to Table 9, which presents the bike ridership average between 2018 and 2021, the City had, on average, close to 250 bike trips per census tract, and this value goes up to a maximum of 2,085 in a census tract. Among all the racial categories, the White, Hispanic, and Asian categories have the highest share among bike users. On the other hand, the user shares from African American, American Indian, or Islander communities are very low. This could relate to the fact that these categories have a small presence in the City of San José. The low-income category holds the biggest share of bike users while the difference between other income categories is not significant. Similarly, the mean difference between the educational attainments of the users does not seem to be significant either.

⁵ The linearity was tested using a scatter plot chart mix, which suggests the need to log transform the variables. For multicollinearity, the team used the variance inflation factor (VIF) analysis, which suggested the use of *principal component analysis* (PCA)—a widely used linear transformation technique that combines data for multiple variables into one or fewer factors. In other words, the factor computed via PCA is valid if it has a strong linear correlation with the input variables (Jolliffe & Cadima, 2016).

Table 9. Descriptive Analysis of Bike Travel Variables

	<i>Variable</i>	<i>Mean</i>	<i>StDev</i>	<i>Min</i>	<i>Max</i>
	Overall ridership	248.84	265.56	0	2085
<i>Racial Category (share)</i>	% White	45.67	12.90	0	0.77
	% Black	3.11	0.98	0	0.07
	% AmericanIndian	0.90	0.31	0	0.02
	% Asian	28.78	12.56	0	0.67
	%Hispanic	33.13	13.98	0	0.66
<i>Income group (share)</i>	% Income50kt	15.82	3.03	0	0.25
	% Income75kt	13.42	2.31	0	0.20
	% Income100k	10.90	2.14	0	0.17
	% Income125k	7.79	2.04	0	0.14
	% Income150k	9.44	3.27	0	0.21
	% Income>150K	9.64	5.41	0	0.30
<i>Educational Status (share)</i>	% HighSchool	18.26	4.51	0	0.35
	% SomeCollege	26.55	3.83	0	0.34
	% BachDegree	21.96	6.20	0	0.35
	% GradDegree	12.90	6.37	0	0.37

Figure 10. Overall Bike Use: 2018–2021 Average

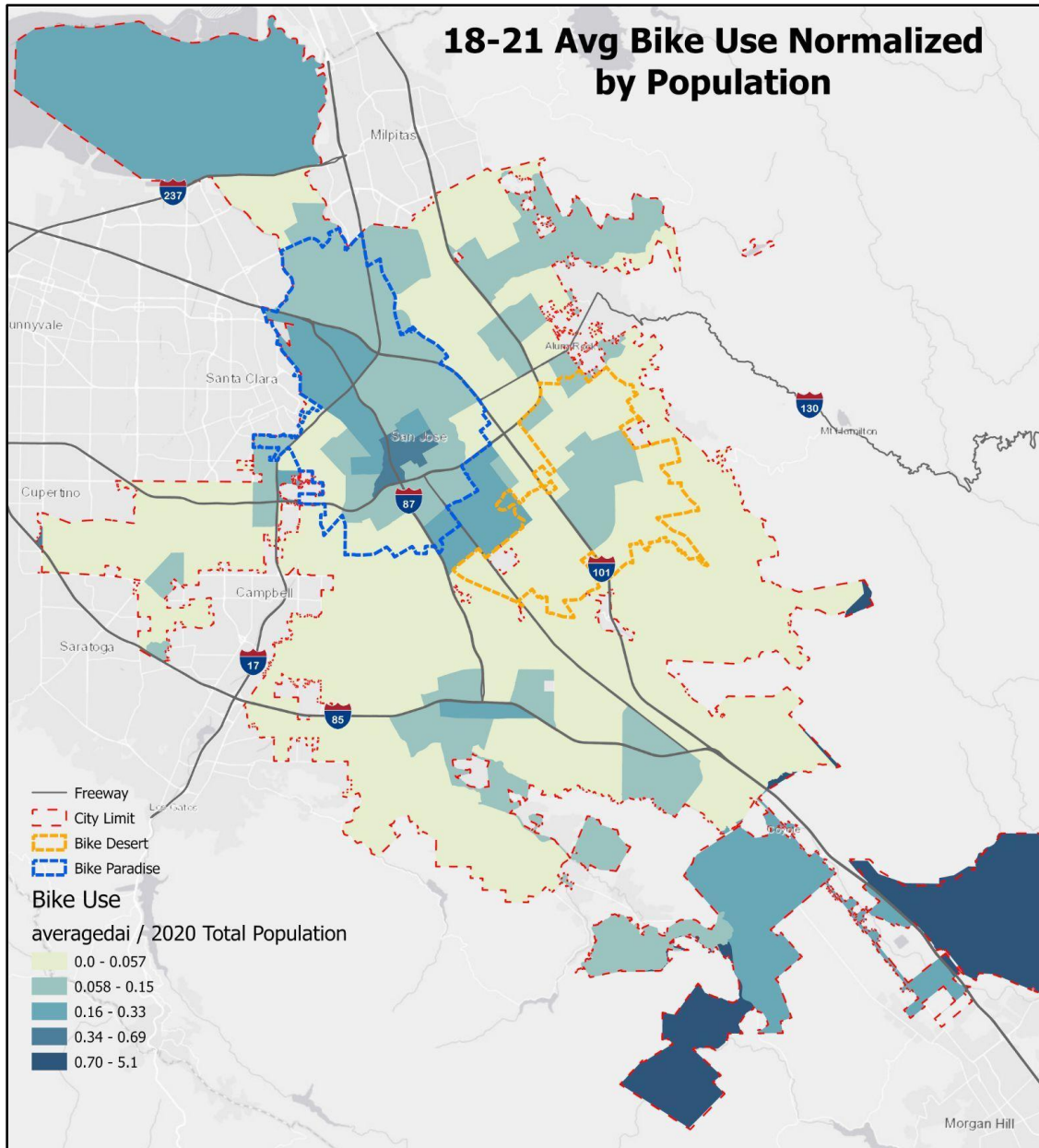


Figure 10 spatially visualizes overall bike ridership overlaid with the neighborhoods encompassed in San José’s bike desert and bike paradise. The panels in Figure 10 compare the sociodemographic differences of ridership.

Figure 10 illustrates that the City’s bike paradise has a high bike use demand, which supports the City’s contention that providing infrastructure can lead to increased bike use and potentially a shift in the mode of commute. However, the City’s bike desert area also shows some bike use demand, which calls for the provision of quality bike lanes that support the safety and comfort of bicyclists in order to achieve the City’s Vision Zero goals. Figure 10 allows us to assess the bike use differences among the major racial categories of San José’s residents.

Figure 11. Racial Breakdown of 2018–2021 Average Bike Use

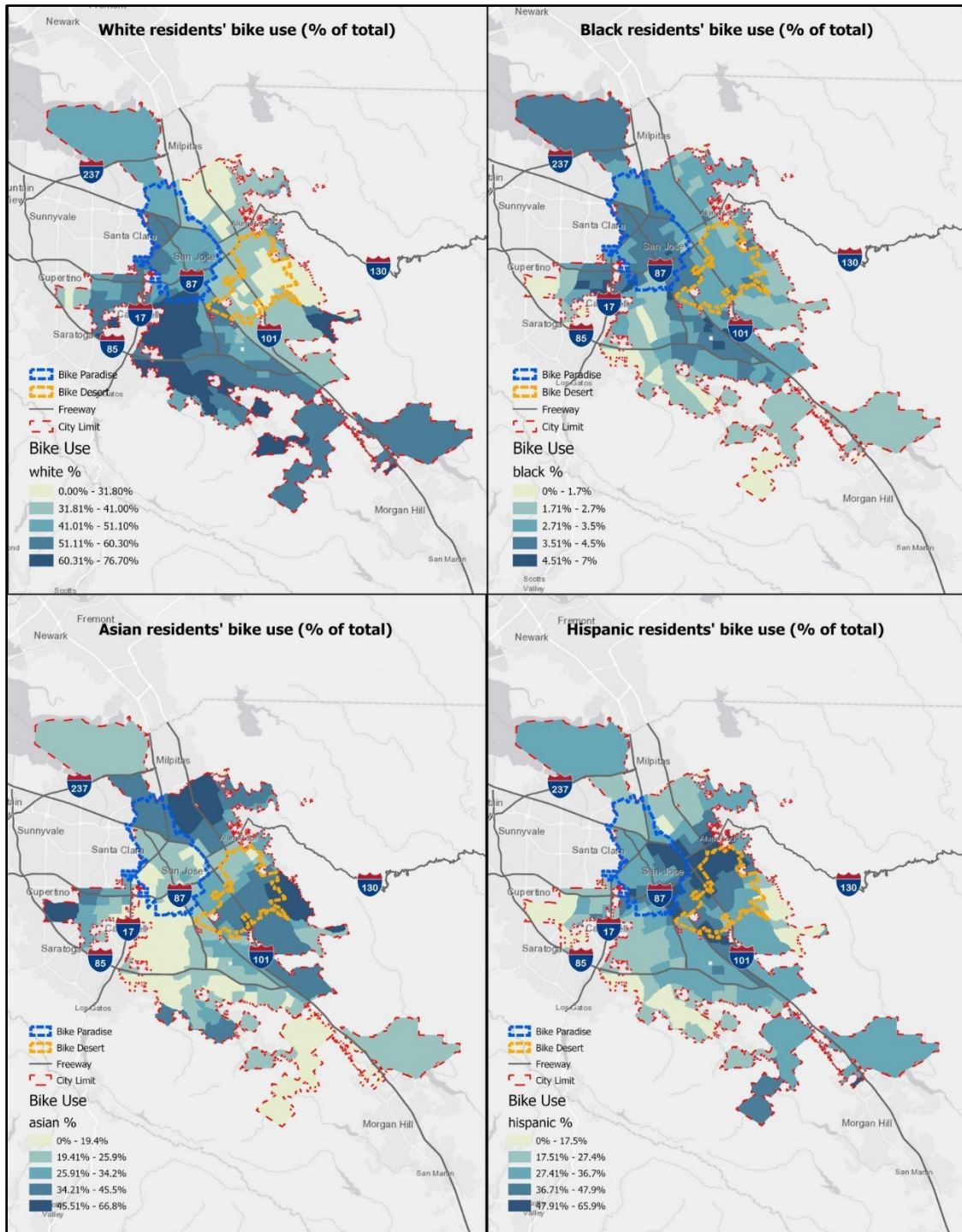


Figure 11 shows spatial differences in the bike use of each racial category. For instance, West San José is mostly home to White bike users, while East San José is mostly home to Hispanic and Asian bike users. This could simply relate to race-based spatial differences in San José, as shown in Figures 1 and 2. The other notable finding from Figure 11 is that Hispanic and Asian bike users are mostly in the bike desert area. This finding also attests to the continuation of historical patterns of housing segregation in bike use. As shown in Figures 1 and 2, the City of San José is divided by Highway 101, with strong disparities in race and income on each side. This is the same spatial pattern in availability of bike infrastructure. Our equity assessment of bike infrastructure in the previous section confirmed that East San José is poorly supported by bike infrastructure—which is where we find a concentration of Hispanic bike users.

While the equitable distribution and provision of infrastructure is critical for the City, the major question that Figure 11 raises is whether the impacts of the urban environment and bike infrastructure are different. For instance, it is widely discussed in the literature that the built environment influences individuals' travel behavior (Cervero & Kockelman, 1997). Another line of studies touches on the presence of tree canopies as a key factor in encouraging bike rides. Tree canopies can mediate urban heat and support a more comfortable bike ride (Kim, 2020). These issues lead us to the next part of our study where we assess the magnitude of these factors in overall bike use, as well as bike use by racial category.

Contributing Factors to Bike Use in San José

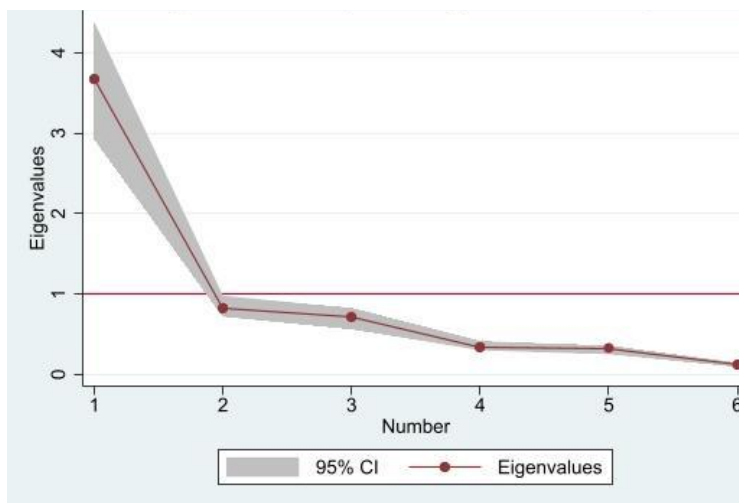
Using regression models, we report here on the impact of different factors on overall bike use. Our models include factors that account for the built environment of an area and socioeconomic status of a rider, as well as bike and pedestrian infrastructure. In the linear regression models, the research team accounted for the four main assumptions of ordinary least squares (OLS) regression including linearity, normality, multicollinearity, and homoscedasticity. The linearity was tested using a scatter plot chart mix, which suggested the need to log transform the variables. To eliminate the risk of multicollinearity, the team used the variance inflation factor (VIF) value of 2.7 as a threshold, which is appropriate because it is widely accepted that VIF values above 2.7 could be problematic (Akinwande et al., 2015). The maximum VIF among all of our models is 2.65, and the average VIF of all models is 1.8 (see the Appendices for the results of all regression models). In addition, for alleviating multicollinearity issues with built environment and socioeconomic variables, we used principal component analysis (PCA), a widely used linear transformation technique that combines data for multiple variables into one or fewer factors. In other words, the factor computed via PCA is valid if it has a strong linear correlation with the input variables (Jolliffe & Cadima, 2016). Our built environment index includes indicators of density, land use diversity, job accessibility, road density, and walkability. The eigenvalues, loading factors, and pairwise correlation tests between the built environment composite value and input variables are presented in Figure 12 and Table 10.

Table 10. PCA Results Pairwise Correlation Assessment and Loading Factors

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
<i>PopDen</i>	0.3283	0.5066	-0.6943	0.3337	0.1645	-0.1225
<i>ActDen</i>	0.3105	0.5834	0.6827	0.2795	-0.1318	-0.0403
<i>EmpEnt</i>	0.3868	-0.586	0.0612	0.6856	0.0336	0.1793
<i>RdDen</i>	0.4572	-0.0004	-0.1788	-0.3252	-0.6758	0.4433
<i>JobAcc</i>	0.4544	-0.0075	0.1203	-0.4008	0.7015	0.3552
<i>WalkSc</i>	0.4803	-0.244	0.0404	-0.2722	-0.0747	-0.7928
Eigenvalue	3.67	0.83	0.71	0.34	0.33	0.12
Proportion explained	0.61	0.14	0.12	0.06	0.05	0.02

From the six components values that the PCA estimated, composite 1 (comp 1) was retained since it had an eigenvalue of 3.7 (eigenvalues are presented in Figure 11), which is notably greater than the standard value of 1 (Johnstone, 2001). This component value, which indicates the built environment composite value, accounted for more than 60% of variance in the dataset of the six built environment variables included in this model (Table 10). These metrics indicated the high validity of the PCA results.

Figure 12. Scree Plot of Eigenvalues After PCA



In summary, as both Figure 12 and Table 10 demonstrate, our PCA has only one component to retain—comp 1—which represents the built environment composite value. This value demonstrates how supportive the census tract’s built environment is for bike commute patterns. An increase in this value indicates an increase in density, land use diversity, and job accessibility, as well as the walkability of a census tract. The same process was conducted for socioeconomic factors, including race, income, employment status, and educational attainment, which are all

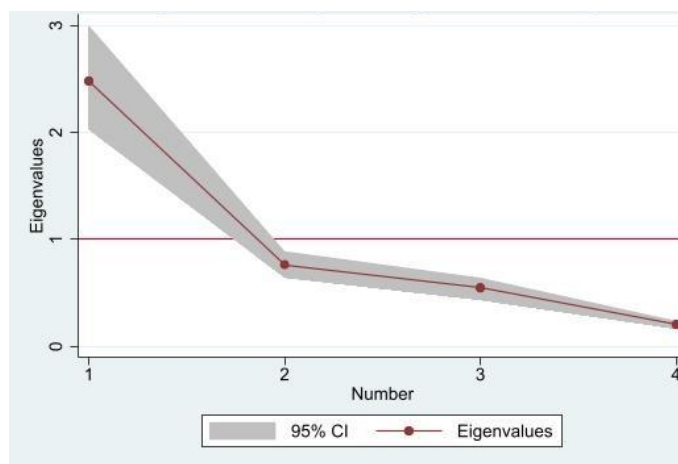
indicators in a socioeconomic composite value. The eigenvalue, loading factors, and pairwise correlation tests between the socioeconomic composite value and input variables are presented in Figure 13 and Table 11.

Table 11. PCA Results: Pairwise Correlation Assessment and Loading Factors

Variable	Comp1	Comp2	Comp3	Comp4
<i>Edu_Pct</i>	0.5763	-0.1764	-0.2475	-0.7586
<i>Inc_Med</i>	0.5451	0.0326	-0.5867	0.5979
<i>Emp_Pct</i>	0.3952	0.8304	0.3922	-0.0207
<i>Wte_Pct</i>	0.4631	-0.5276	0.6638	0.2579
Eigenvalue	2.48	0.76	0.54	0.21
Proportion explained	0.62	0.19	0.14	0.05

Our PCA results for the socioeconomic composite value are quite similar to the PCA results for the built environment composite index. In other words, only one component had the acceptable (i.e., greater than 1) eigenvalue as presented in Figure 12 and Table 11. Figure 12 below depicts the eigenvalues for the four components that PCA estimated for the socioeconomic composite value. As presented in Table 11, our built environment composite value accounted for more than 60% of the variance in the dataset of the four socioeconomic variables included in this model. These metrics indicated the high validity of the PCA results for the socioeconomic composite value.

Figure 13. Scree Plot of Eigenvalues After PCA



In summary, as both Figure 12 and Table 11 show, our PCA has only one component to retain, comp 1, which represents the socioeconomic composite value. This socioeconomic composite value is computed in a way that indicates the wealthiness of residents. In other words, the areas

with a higher socioeconomic composite value show the areas with higher income, more employed residents, more educated residents, and mostly White residents.

For normality, except for the two indices (socioeconomic index and built environment index) developed above, we log transformed all other variables, including the outcome variable. Finally, we controlled for the assumption of homoscedasticity by using robust standard error estimates. According to White (1983), robust standard errors relax the homoscedasticity assumption by adjusting the test statistics and p-values with respect to the level of heteroscedasticity of the error term.

Table 12. Regression Results

<i>Dependent Variable</i>	<i>LnBUPC (i.e., overall use)</i>					<i>PctHisp</i>					<i>PctBlack</i>				
	<i>B</i>	<i>t</i>	<i>P> t </i>	<i>[95% conf. interval]</i>		<i>B</i>	<i>t</i>	<i>P> t </i>	<i>[95% conf. interval]</i>		<i>B</i>	<i>t</i>	<i>P> t </i>	<i>[95% conf. interval]</i>	
<i>LnWBLPC</i>	0.19	3.24	0.002	0.07	0.30	0.00	-0.95	0.34	-0.01	0.00	0.001	2.13	0.0035	0.000	0.002
<i>LnSWPC</i>	0.74	2.86	0.005	0.23	1.25	0.07	3.18	0.00	0.03	0.11	-0.006	-1.77	0.079	-0/013	0.001
<i>SESIndex</i>	-0.18	-2.94	0.004	-0.29	-0.06	-0.10	-11.91	0.00	-0.11	-0.08	-0.001	-0.92	0.36	-0.003	0.001
<i>BEIndex</i>	0.11	0.85	0.399	-0.14	0.36	0.03	3.94	0.00	0.01	0.04	0.002	3.26	0.002	0.001	0.003
<i>_cons</i>	-2.98	-1.11	0.267	-8.28	2.32	-0.34	-1.58	0.12	-0.75	0.08	0.095	2.73	0.007	0.026	0.163
R2:0.36, N:109					R2:0.65, N:110					R2:0.39, N:110					

Table 13. Regression Results

<i>Dependent Variable</i>	<i>PctWhite</i>					<i>PctAsian</i>				
	<i>B</i>	<i>t</i>	<i>P> t </i>	<i>[95% conf. interval]</i>		<i>B</i>	<i>t</i>	<i>P> t </i>	<i>[95% conf. interval]</i>	
<i>LnWBLPC</i>	-0.019	-3.880	0.000	-0.029	-0.009	0.016	2.810	0.006	0.005	0.028
<i>LnSWPC</i>	0.066	2.290	0.024	0.009	0.124	-0.091	-3.470	0.001	-0.143	-0.039
<i>SESIndex</i>	0.053	5.800	0.000	0.035	0.071	0.009	1.010	0.314	-0.008	0.025
<i>BEIndex</i>	0.035	2.870	0.005	0.011	0.059	-0.025	-2.130	0.035	-0.048	-0.002
<i>_cons</i>	-0.251	-0.880	0.382	-0.818	0.316	1.212	4.530	0.000	0.682	1.742
R ² : 0.45, N:110					R2:0.09, N:110					

Tables 12 and 13 report the results of our regression models. In our assessment, the tree canopy indicator was found to be insignificant in relation to bike use—both as regards overall bike use or bike use for any racial category, which could be explained by San José’s moderate weather (Nankervis, 1999). Starting with the first model, which assesses the contributing factors to overall bike use, our model confirms that the availability of sidewalks, adequate bike infrastructure, and built environmental factors have a positive and significant correlation with overall bike use. A model which could explain almost 40% (the first R-squared presented in Tables 12 and 13) of the variance is a strong affirmation of the City’s efforts to establish and maintain adequate bike infrastructure by showing that its plans are succeeding in attracting users. Among all the variables, weighted bike length per capita (which accounts for the safety and comfort of different bike lane classes) has the strongest impact on bike use. In other words, a 1% increase in this variable correlates with a 20% increase in bike use per capita.

While the bike network developed by the City is found through our model to be successful, looking at different racial categories, we can confirm that Asian and Black populations are the strongest users of this system. On the contrary, White and Hispanic populations are found to be the least likely to use the network. The other major bike use difference between the different racial categories is the impact of the built environment. Our results show that, in all our models, built environmental factors play a key role in residents' bike trips; however, this impact is highest for the Hispanic population. The bike trip for Hispanic residents also have a strong relation with the availability of sidewalks, after which the percentage of White bike riders has a strong positive relationship with sidewalk status. This contrasts with bike trip shares for Asian and Black residents, which have a significant negative relationship with sidewalk availability. This finding highlights a significant difference in sidewalk availability across the City. Similar to the racial segregation across the City found by the FHA, this shows that areas with a higher presence of Asian or Black communities lack sidewalks.

The last factor to explore is the socioeconomic index. This index is computed in a way that indicates the wealth of residents. In other words, the areas with higher index values have higher incomes, more employment and education, and more White residents. Our first model confirms our socioeconomic wealth index has a negative and significant relationship with bike use per capita. One unit increase of this index correlated with a nearly 20% decrease in bike use. In other words, bike users are more likely to be from less wealthy communities and are mostly non-White. This variable does not have a similar pattern across different racial groups. Our socioeconomic index only has a positive relationship with the percentage of White bike users, which could be related to the fact that the percentage of White residents is one of the inputs for this composite variable. In other words, this category has possibly higher income and better employment status in tandem with higher educational attainment.

Therefore, the major takeaway is that our model confirmed the success of developing a bike network. Our models showed that the bike network developed by the City could bring demand for bike rides; however, we need to further explore this demand. Our models showed that there is

a higher demand for bike rides among residents from low income and non-White communities. Thus, it is imperative that the City ensures the presence of bike infrastructure in the areas with non-White and low-income residents. However, as Figure 11 showed, the population that is more likely to ride bikes (non-White and low-income residents) are mostly in the bike desert areas. In summary, the demand justifies investment in transportation infrastructure, and our analyses showed the demand for bike infrastructure in bike deserts.

4. Conclusion: Takeaways for Bike Plans

This research has multiple takeaways for planning efforts to improve bikeability across U.S. cities amid a growing interest in supporting and encouraging bike mobility. This interest is also supported by the allocation and expansion of federal funding for bike infrastructure. However, these expansions and improvements require analytical methods that support equity in developing infrastructures for quality bike networks. The quality of bike networks is highly dependent on different bike path classes that provide different safety and comfort levels for cyclists (Kent & Karner, 2019).

The first major finding of this research demonstrated that the conventional way of measuring bike infrastructure access (i.e., bike lanes per capita), if it does not account for the safety and comfort levels of cyclists, could potentially overestimate the availability of bike infrastructure. When it comes to transportation planning, cities need to ensure that their measures and analyses for planning bike systems do not overestimate the availability of facilities. Otherwise, this could lead to false assessments of the equity aspects of bike plans. City officials and staff need more tested methodological frameworks with clear workflows and details to measure bike infrastructure accounting for both quality and access. With the use of statistical and spatial analyses, our findings in Section 2 showed that the conventional ways of measuring bike infrastructure access (i.e., bike lanes per capita) provide a misleading understanding of the availability of quality bike networks across the City of San José. To be specific, while bike lanes per capita shows bike infrastructure coverage across the City, the Bike Index developed in this project, which accounts for safety and comfort differences between different bike lane classes, shows a significantly different picture. Using the Bike Index shows major disparities and equity challenges across the City in the availability of safe and comfortable bike infrastructure.

An accurate measure of bike infrastructure can then support an equity assessment by identifying the location of a city's bike deserts and bike paradises. The Bike Index developed and used for the equity assessment in this project shows that a historical pattern of spatial segregation continues in the provision of adequate bike infrastructure. More specifically, San José's bike desert (which was identified using hotspot analysis) mostly covers East San José, which is home to a large percentage of the City's Hispanic and Asian population. San José's bike desert was also found to be home to lower income residents with a significantly lower housing value.

On the other hand, the City's bike paradise covers neighborhoods in the downtown and north of downtown areas, as well some western neighborhoods in San José. This assessment suggests that San José has equity considerations that require attention when it comes to building and expanding its bike network. A starting point is the bike desert identified in this analysis. The City can strengthen the quality of the bike network in this area through more Class IV (i.e., protected/separated bike lane) and buffered Class II bike lanes. Connecting this infrastructure with the transit network (i.e., San Francisco Bay Area Rapid Transit District and Santa Clara Valley

Transportation Authority) will also support local and regional accessibility for the residents of these areas.

The City needs to cover the areas that lack quality bike lanes to address equity, particularly if there is an unanswered demand in such areas. Section 3 of this report used StreetLight data to assess whether and to what extent an unanswered demand exists in such areas. Findings indicate that San José's bike desert area does have notable bike trips despite the inadequate infrastructure. Findings in Section 3 show the demand for quality bike infrastructures or, in other words, that San José residents are using the quality bike lanes wherever the City provides them. To be specific, a 1% increase in Bike Index developed in this project (i.e., weighted bike length per capita) correlates with a 20% increase in bike trips.

Meanwhile, lacking a quality bike lane means using sidewalks, which can increase the risk of bicyclists–pedestrian collisions. Findings from Section 3 show that a 1% increase in sidewalk length per capita correlates with an almost 75% increase in bike trips. These numbers provide a key takeaway for the City of San José—the expansion of a safe and comfortable bike network strongly supports the City's Vision Zero goals (City of San José Department of Transportation, 2020). Through the Vision Zero's action plans, the City aims to support equity by focusing on safety improvements and program resources for high crash corridors and districts, and not just for those with the most requests. Our project supports this action item by identifying the boundary of the bike desert. Furthermore, our empirical evidence showed that the availability and expansion of a safe and comfortable bike network in the bike desert is necessary because there is an unanswered demand for bike lanes according to average bike use data. The focus on bike desert neighborhoods not only supports bicyclists' health, but can also mitigate the frequency of bicyclists–pedestrian crashes, as lacking a quality bike lane makes it more likely that bicyclists will use sidewalks according to Section 3's results.

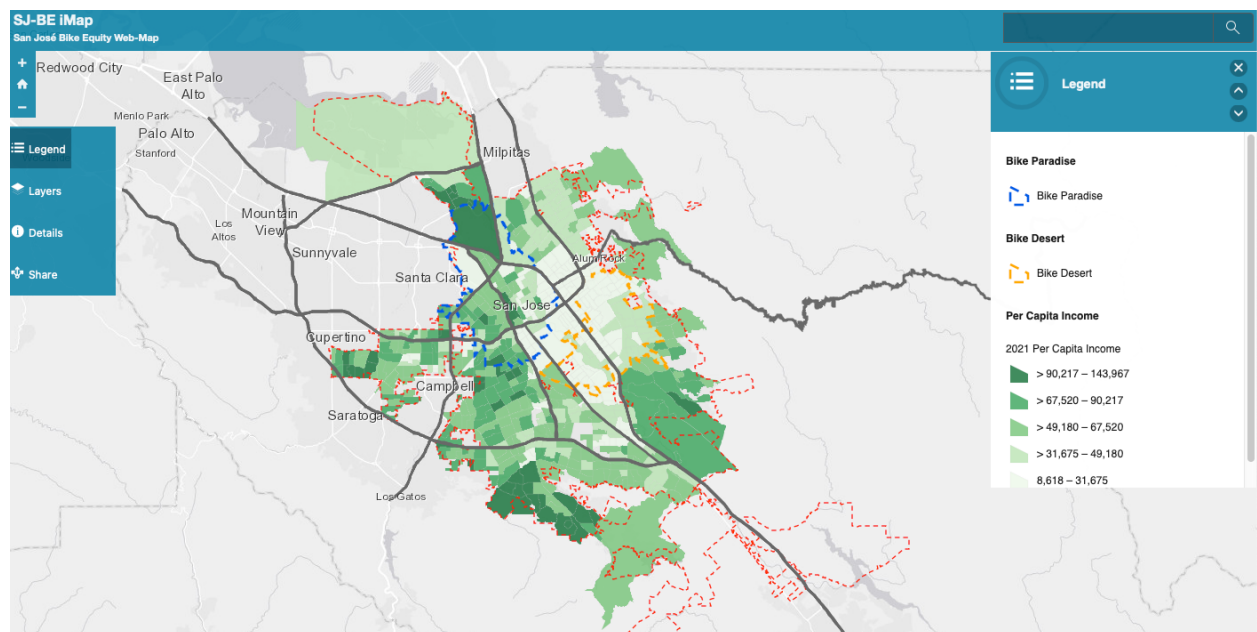
Technology Transfer Application; San José Bike Equity Web Map (SJ-BE iMap)

In order to transfer the results of this project, we also developed a tool which is publicly available to use on the following webpage:

<https://arcg.is/Pen1n1>

This tool allows for the assessment of San José’s socioeconomic attributes at the neighborhood level with respect to our bike score, as well as bike desert and paradise areas. The tool supports further planning and policy actions by presenting the location of bike deserts at the granular level. Furthermore, it provides spatial visualization of bike paradises and deserts vis-à-vis the socioeconomics of a neighborhood’s residents. This visualization allows planners and policy makers to identify the locations where the more marginalized communities are not provided access to quality bike infrastructures in San José. Thus, this tool supports the City of San Jose’s key goal for the Better Bikeways Project that aims for the equitable allocation of bike infrastructure.

Figure 14. SJ-BE iMap



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