

An equity analysis of the 2014 Seattle Bicycle Master Plan:  
initial findings and recommended methods improvements

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**Abstract**

An equity analysis of the 2014 Seattle Bicycle Master Plan:  
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This report conducts an equity analysis on the 2014 Seattle Bicycle Master Plan for the purpose of assessing the level of access to bicycle facilities for bicycle dependent populations. Initial findings reveal higher overall levels of access for census block groups in Seattle with relatively high equity scores. However, some clusters of block groups with high equity scores in the northern and southern portions of Seattle were found to have relatively low bicycle facility access. In addition, the average level of access for block groups with higher than the citywide average of youth and older adults was found to be significantly lower than block groups below the citywide average. The methods and results from this analysis are suggested for use in modifying or expanding the bicycle networks to address the inequities identified, and for application in the 2015 Seattle Bicycle Master Plan Implementation Plan. These initial findings should be verified through additional analysis that addresses the limitations of the methods chosen and provides additional context. The limitations of the methods chosen are specifically addressed and recommended improvements given for the additional analysis required and for future equity analyses in other communities.

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## **1 - INTRODUCTION**

### **1.1 - Equity and Transportation**

Transportation networks typically have a wide variety of effects, both positive and negative, on the communities in which they exist. Expanding a transportation network into a new neighborhood may provide the benefit of increased access for people in that immediate area, but may also cause burdens in the form of displacement of businesses and residences due to needed facilities related to this expansion. Additionally, choosing to expand a network into one neighborhood may mean that a different neighborhood was not chosen for expansion. This process leads to an uneven distribution of the positive and negative effects of a transportation network across a specific area (Martens et al, 2012).

An understanding and evaluation of these positive and negative effects is useful to ensure that certain groups of people are not disproportionately affected in a negative manner. Federal orders, such as US Executive Order 12898, require federal agencies to evaluate the effects of their programs and projects on low-income and minority populations (Federal Register, 1994). Local initiatives may also require local transportation agencies to evaluate and work to mitigate any disproportionately negative effects of their decisions and programs on selected groups of people (King County, 2010; City of Seattle, 2009). This is done to ensure that the benefits of public investments in transportation do not place a disproportionately negative effect on traditionally disadvantaged groups of people.

This same logic and these same requirements may be applied to publicly provided bicycle networks as well. Bicycle networks provide an additional transportation option, in addition to

private and public transportation modes, which can be of significant importance for people who may rely on alternative transportation options for their transportation needs. The use of an equity analysis can help to highlight inequities in access to bicycle facilities by these groups of people. These findings may be used to identify areas where changes can be made in the bicycle network to eliminate inequities in access identified.

## **1.2 - Purpose of Report**

The purpose of this report is threefold. The first is to improve upon the existing equity analysis that appears in the second chapter of the 2014 Seattle Bicycle Master Plan. The existing equity analysis in that document draws on methods from a previous analysis (Dill and Haggerty, 2009), that was developed for the Portland Bicycle Master Plan for 2030. The equity analysis in this report is based on methods used in both the Seattle and Portland equity analyses. It improves the equity analysis in the Seattle Bicycle Master Plan by evaluating the provision of bicycle facilities across the city by both the Existing and Planned Bicycle Networks, as well as evaluating the provision of low-stress bicycle facilities within these two networks. Low-stress bicycle facilities in this report include neighborhood greenways, multi-use trails, and cycle tracks (City of Seattle, 2014). It also highlights any meaningful differences in average levels of bicycle facility access by each different bicycle dependent population analyzed.

The second purpose highlights inequities in levels of access to bicycle facilities by bicycle dependent populations to ensure they are not disproportionately disadvantaged. The results are suggested to be used to modify or expand the planned bicycle networks to eliminate identified inequities. The methods and results are also suggested for use in the 2015 Seattle Bicycle Master Plan Implementation Plan.

Finally, this analysis should inform and improve future equity analyses. Through the process of conducting this analysis, a number of limitations to the methods were realized. They primarily involve the source of data and the measure of access chosen. Of main concern was the lack of income as an indicator due to the exclusive use of 2010 Decennial Census data. Based on these limitations, a number of improvements to the methods are suggested. By highlighting these limitations and suggesting improvements, this report seeks to: inform the future analysis required to confirm and provide additional context to the initial findings, and provide insight and suggestions for future equity analyses in community bicycle plans.

## **2 – BACKGROUND AND LITERATURE REVIEW**

### **2.1 - Equity and Transportation at the Federal Level**

Equity has officially been a consideration in transportation related planning since the adoption of Title VI of the Civil Rights Act of 1964, which states that public funds to which all taxpayers contribute not be used in a manner which encourages, entrenches, subsidizes or results in racial discrimination (Golub and Martens 2014). U.S. Executive Order 12898, enacted in 1994, requires federal agencies to assess whether their planned actions or projects disproportionately affect low-income and minority populations (Federal Register, 1994). This order also requires local jurisdictions that use federal funding to assess the potential effects of their projects on low-income and minority populations (Miller, 2005).

In 2012 the Federal Highway Administration (FHWA) put forth Order 6640.23A that aims to address disproportionately high environmental or human health effects of their policies, actions, and programs on low-income and minority populations, as well as equally distributing the benefits and burdens of these actions (FHWA, 2012). United States Department of Transportation (DOT) Order 5610.2(a), an update to the original Order issued in 1997, was also issued in 2012 and aims to achieve the same result as the FHWA Order within the United States DOT (DOT, 2012). These orders provide a useful starting point for understanding equity and transportation. Primarily, ensuring that the advantages and disadvantages of transportation projects are equally distributed and the adverse effects are not disproportionately placed on minority and low-income populations.

## **2.2 - Equity and Transportation at the Local Level**

Equity has also been addressed at the local level in Washington, as both King County and the City of Seattle have adopted initiatives to address issues related to race and social justice inequities in the provision of their programs and services. King County Ordinance 16948, adopted in 2010, calls for King County to “consider equity and social justice impacts in all decision-making so that decisions increase fairness and opportunity for all people...” (King County, 2010). This includes decisions related to transportation provision, such as public transportation service delivered through King County Metro. The groups this ordinance specifically identifies for consideration are people of color, low-income, and those with limited English language abilities (King County, 2010). These groups are consistent with those identified in the Federal Orders discussed above, but also include people with limited English language abilities.

The City of Seattle began work on their Race and Social Justice Initiative in 2004 and in 2009 adopted Resolution 31164 that works toward “affirming the City’s race and social justice work and directing City Departments to use available tools to assist in the elimination of racial and social disparities...” (City of Seattle, 2009). This initiative was recently updated and revised, with the creation of a three year implementation plan for 2012-2014, and most recently with a new three year implantation plan for 2015-2017 that aims to end institutional racism in the City of Seattle (City of Seattle, 2015b). This initiative provides a mandate for the various departments throughout the City of Seattle to evaluate the outcomes of their programs and services for people of color, including immigrant and refugee communities and work to eliminate any disparities in the delivery of these services for these groups.

### **2.3 - Identifying Bicycle Dependent Populations**

The Federal, County and City Orders and Ordinances provide a starting point for identifying groups of people who should be included as part of an equity analysis relating to transportation. A number of academic studies and reports pertaining to equity and transportation may be used to provide justification for inclusion of these and other groups of people who may be disproportionately dependent on public transportation.

This transit dependent population is often defined by identifying groups of people who may not have regular access to their own motor vehicle for their transportation needs (Farber et al, 2014; Golub and Martens, 2014). Some indicators of these groups include: households without a motor vehicle, people with significant physical disabilities, low-income households, people too young or too old to drive, unemployed adults and recent immigrants unable to drive (NHCRP, 2001). Certainly, not everyone who falls into one of these designations is inherently transit dependent, but these indicators are useful in identifying people who may be (NHCRP, 2001). This is also not an exhaustive list of people who may be transit dependent, but rather groups of people who may be identified using readily available sources of data, such as the US Census. Many of the same groups of people identified who may be disproportionately public transit dependent may also be the same as those who may be disproportionately bicycle dependent. These groups of people will be referred to subsequently in this report as bicycle dependent populations.

Of the groups of people discussed thus far, only those too old to drive and people with significant disabilities may be precluded from being bicycle dependent due to the possibility of not being able to safely ride a bicycle. The inclusion of these two groups may be appropriate because some

bicycle facilities are built to accommodate and serve both bicycles and pedestrians. For example, neighborhood greenways, which form 41 percent of the Planned Bicycle Network in Seattle, are designed to include pedestrian and bicycle improvements such as safe arterial crossings and sidewalk improvements (City of Seattle, 2014).

#### **2.4 - Equity and Transportation in Academic Literature**

Much of the research involving transportation and equity is focused on public transportation and the distribution of benefits and burdens from these systems. This literature will be used to inform and create an understanding of equity and its relation to bicycle networks.

This approach states that an equitable transportation system should distribute the benefits and burdens from transportation projects equally across all income levels and communities (Sanchez and Brenman, 2007). Some of the typical burdens, or impacts, associated with transportation network provision and expansion include: increased noise and air pollution due to increased traffic and residential or business displacement due to facility expansion (FHWA, n.d.). Bicycle networks do not produce these same impacts. Bicycle facilities are usually built in the public right-of-way, utility corridors, or railroad corridors and do not typically involve displacement of households or businesses. Bicycles that travel on these facilities do not produce harmful emissions or excessive noise, unlike diesel powered buses typically used as part of a public transportation system. While there may be impacts associated with the expansion of a bicycle network, such as loss of on-street parking, these impacts are not universally understood or quantifiable and evaluation of all impacts associated with expansion of a bicycle network are beyond the scope of this report.

One of the primary benefits associated with a transportation network is the level of access that is provided to that network (Martens et al, 2012). In the context of a public transportation network, access is gained through specific access points along a route (Murray, 2001). Examples of this may be stops along a bus route, or larger transit stations that provide access to a heavy or light rail network. Access is limited to these specific stops or stations that serve as access points and these may not be equitably distributed. Bicycle networks do not have these same limitations. Bicycle facilities are generally accessed at any intersection of a bicycle facility with a street. In urban areas, such as Seattle, a dense street network provides relatively consistent access to bicycle facilities. Access to a bicycle network may be limited in areas due to a lack of safe pedestrian or bicycle crossing signs or lights at some intersections, but adding this variable into a measurement of access was beyond the scope of this report. For this report, access to the bicycle network was considered consistent across the length of each bicycle facility.

Access to the network may be considered the primary benefit delivered by a bicycle network, and a lack of access a burden. An equity analysis for a bicycle network may measure the distribution of bicycle facilities across a specified area to evaluate whether areas with lower levels of access are located in areas with relatively high bicycle dependent populations. This is done to evaluate whether the burdens of low levels of access are not disproportionately placed on bicycle dependent populations.

### **2.5 - Equity in Community Bicycle Planning**

The extent to which equity is applied in bicycle planning in the United States is varied. An investigation into the treatment of equity by various cities through their individual bicycle master plans can provide insights into the different ways equity is considered in their plans as well as

the methods used to measure equity. The League of American Bicyclists (LAB) publishes a list of bicycle-friendly communities (LAB, 2014), and provides different ratings for communities for bicycle friendliness: Platinum, Gold, Silver or Bronze (LAB, n.d.). While equity is not explicitly stated as one of their criteria, it was assumed by the author that communities with the highest rankings may be communities with progressive policies in their bicycle plans relating to equity. One potential drawback to this assumption is that communities that prioritize the provision of facilities to underserved groups may not score highly in this system due to the lack of equity as one of the ranking criteria. This assumption was made and the LAB list of bicycle-friendly communities used due to the lack of a ranking system that includes equity as one of the criteria.

The bicycle plans published by Tuscon, Arizona (City of Tuscon, 2009), and Scottsdale, Arizona (City of Scottsdale, 2008), both with a Gold rating for bicycle friendliness by the LAB, make no mention of equity in their bicycle plans. Davis, California, a Platinum-rated city, also does not discuss the equitable distribution of bicycle facilities in their 2009 plan (City of Davis, 2009). Boulder, Colorado, a Platinum-rated city, states that their bicycle network provides equitable access to mobility, but does not explicitly state any policies or methods to enforce or evaluate equity (City of Boulder, 2014).

Minneapolis, Minnesota, a Gold-rated city, discusses geographic and demographic equity and the need to provide bicycle facilities at an equal level to all areas of the city and all demographics of people (City of Minneapolis, 2011). In this plan, the discussion of equity results in the creation of broad initiatives to achieve these geographic and demographic equity goals, such as identifying areas of the city to prioritize construction of new bicycle facilities (City of

Minneapolis, 2011). This plan does not specify a method to evaluate whether these equity initiatives will achieve geographic or demographic equity.

Finally, Fort Collins, Colorado, a Platinum-rated city, discusses equity as one of its seven key goals for their 2014 Bicycle Plan (City of Fort Collins, 2014). The goal of this equity objective is to provide high quality bicycle facilities in all parts of the city. This plan identifies a number of outcomes targeted to be completed by 2020, with one key outcome being to increase the amount of the population living within a quarter mile of a low-stress bicycle facility to 80 percent by 2020 (City of Fort Collins, 2014). While this is a broad objective aimed at achieving geographic equity in Fort Collins, it also does not specify a method to be used to evaluate bicycle facility access.

## **2.6 - Bicycle Network Equity Analysis Methods**

The first equity analysis method in a bicycle master plan in the US was likely developed as part of the Portland Bicycle Plan for 2030. This made Portland's plan one of the first bicycle planning documents to move the equitable distribution of bicycle facilities beyond a policy statement or an objective. The City of Portland contracted with the Portland Bureau of Transportation and Portland State University to develop the equity analysis method (City of Portland, 2010). This allowed the city of Portland to systematically evaluate the distribution of bicycle facilities across the city and identify areas with higher than average percentages of bicycle dependent populations (Dill and Haggerty, 2009). Identifying areas of the city with higher than average bicycle dependent populations and low bicycle facility access highlights areas which can be targeted for bicycle network expansion to decrease identified inequities. This method can be repeated as the

Portland bicycle network continues to be built to consistently evaluate the distribution of facilities, as specified by their plan (City of Portland, 2010).

The City of Seattle borrowed concepts from the Portland method when drafting their bicycle master plan (City of Seattle, 2014). As in Portland, the Seattle equity analysis identifies areas of the city with higher than average bicycle dependent populations and low levels of bicycle facility access. The Seattle method uses slightly different indicators of bicycle dependent populations. Seattle uses a different data source (American Community Survey data rather than 2000 Decennial Census data), and a larger scale of analysis (census tracts rather than block groups), than were used in the Portland method. The Seattle method only evaluates the distribution of existing bicycle facilities without evaluation of planned facilities and also does not analyze the distribution of low-stress bicycle facilities (City of Seattle, 2014).

The equity analysis in this report strengthens the analysis in the 2014 Seattle Bicycle Master Plan. By measuring access to all four bicycle networks (the Existing and Planned Complete Networks and the Existing and Planned Low-Stress Networks) this analysis will evaluate how well bicycle facility access improves for areas of the city with high bicycle dependent populations. In addition, it will examine average bicycle facility access to all four bicycle networks by each indicator, highlighting statistically significant differences in average access by block groups above or below the citywide average. The limitations of these methods will be explained in detail in the discussion section of this report, and suggestions made for improvements to the methods in future analyses.

### **3 – METHODS**

#### **3.1 – Overview of Equity Analysis Method**

The general method of this analysis, a quantitative assessment of the distribution of bicycle facilities and the identification of bicycle dependent populations across the city, was chosen to address the question of equity in the provision of bicycle facilities. This is based on the methods used in the Seattle and Portland equity analyses. Indicators of bicycle dependent populations are chosen from available data sources, in this case the 2010 US Decennial Census, and areas with high proportions of these groups of people are identified. The levels of access these groups have to bicycle facilities in the Existing and Planned Bicycle Networks is calculated which allows areas with low levels of access and high proportions of these groups to be identified. Details regarding the choices made for specific aspects of this analysis are discussed subsequently.

#### **3.2 - Scale of Analysis**

The scale of analysis used was the 2010 US Census block group. This scale was chosen based on the Portland method, which was done at the block group level using 2000 US Census data (Dill and Haggerty, 2009). The Seattle method was conducted at a larger scale, the census tract level (City of Seattle, 2014). The block group level of analysis was chosen for this report to provide a finer scale of analysis than the Seattle analysis to reveal new or different results. Block groups range in population size between 600 and 3,000 (US Census Bureau, 2012b). Census tracts range in population size between 1,200 and 8,000 people, with an optimal size of 4,000 people (US Census Bureau, 2012c).

### 3.3 - Measuring Equity

#### *Equity Indicators and Data Source*

The indicators of bicycle dependent populations, also referred to as equity indicators in this report, were based on the indicators used in the Portland and Seattle methods. The Portland method used indicators from the 2000 US Decennial Census: income, race and ethnicity, youth eighteen and under, and adults sixty-five and above (Dill and Haggerty, 2009). The Seattle method chose indicators available from American Community Survey (ACS) data: people of color, households below 200 percent of poverty level, households with no automobile, youth under eighteen, and adults sixty-five and above (City of Seattle, 2014).

Ultimately, only the US 2010 Decennial Census was used to provide variables for equity indicators. The implications of this decision will be discussed in detail in the limitations section of this report. The indicators chosen for this analysis were: non-white population, Hispanic or Latino population, youth under eighteen, and adults sixty-five and above.

Income was not included as an indicator in this study because it was not recorded in the 2010 US Decennial Census, but rather by the ACS (US Census Bureau, 2012). The absence of income as an indicator in this analysis dramatically hinders the ability of this analysis to identify bicycle dependent populations and will be addressed further on in this report.

The use of adults sixty-five and above is consistent with both the Portland and the Seattle analysis methods. Older adults were also previously identified as an indicator of bicycle dependent populations. The use of youth under eighteen, instead of youth ages eighteen and under used in the Portland method, was based on prioritizing only the inclusion of youth and not

adults in this analysis. In the United States, people are considered adults at the age of eighteen, and an indicator meant to record the youth population would be most accurate by only including people under eighteen. Finally, youth were previously identified as being an indicator of bicycle dependent populations.

Two indicators were chosen for this analysis related to race and ethnicity, the non-white population, pertaining to race, and whether a person was of Hispanic or Latino origin, pertaining to ethnicity. Both of these indicators are consistent with bicycle dependent populations, because they may include people with limited English language abilities and recent immigrants unable to drive. The use of non-white as an indicator is consistent with both the Seattle and Portland methods. The non-white indicator captures race and is consistent with the goals of the Seattle Race and Social Justice Initiative. It also includes some people who may have limited English language abilities or recent immigrants unable to drive, such as Asian or Pacific Islanders (US Census Bureau, 2012d)

People of Hispanic or Latino origin were not explicitly included in the Seattle and Portland methods, though Seattle used “people of color” which may have included people of Hispanic or Latino origin. Ultimately, using Hispanic or Latino origin as an indicator was chosen based on the ability of this indicator to identify bicycle dependent populations due to their possibly being recent immigrants or with limited English language abilities, as discussed previously.

### *Equity Score*

An equity score is a method used to assign individual study areas a value based on whether it is above or below citywide averages for each indicator and assigns each area a final aggregated equity score based on all indicators used. The use of an equity score for this analysis was based on its use in the Seattle method (City of Seattle, 2014). The Portland method did not aggregate block groups into a single equity score, but instead chose to identify block groups with higher than average percentages of each indicator individually (Dill and Haggerty, 2009).

The advantage of using an aggregated equity score is the ability to identify areas with the highest proportion of individuals from all of the indicators analyzed. Aggregating the results, instead of analyzing them individually, highlights areas across the city that have the highest proportion of all bicycle dependent populations considered. This provides a more precise way of identifying areas of the city to prioritize development of new bicycle facilities instead of having to choose between, for example, an area with a higher proportion of a minority population or an area with a higher proportion of older adults.

The method of creating an equity score in this study was based on the Seattle method (City of Seattle, 2014). The average percentage of people for each indicator was calculated for every block group across the City of Seattle. If a block group had a higher than the citywide average of any given indicator it was given a score of one. If a block group had a lower than average percentage of any given indicator it was given a score of zero. Thus, each block group in the city has a final equity score between zero and four, with four being block groups with higher than average percentages of people from each indicator. The analysis in the Seattle Bicycle Master Plan focused only on areas with the highest equity score, though this analysis will focus on block

groups with the two highest equity scores (3 and 4), due to the low number of block groups (19 of 477), with equity scores of four.

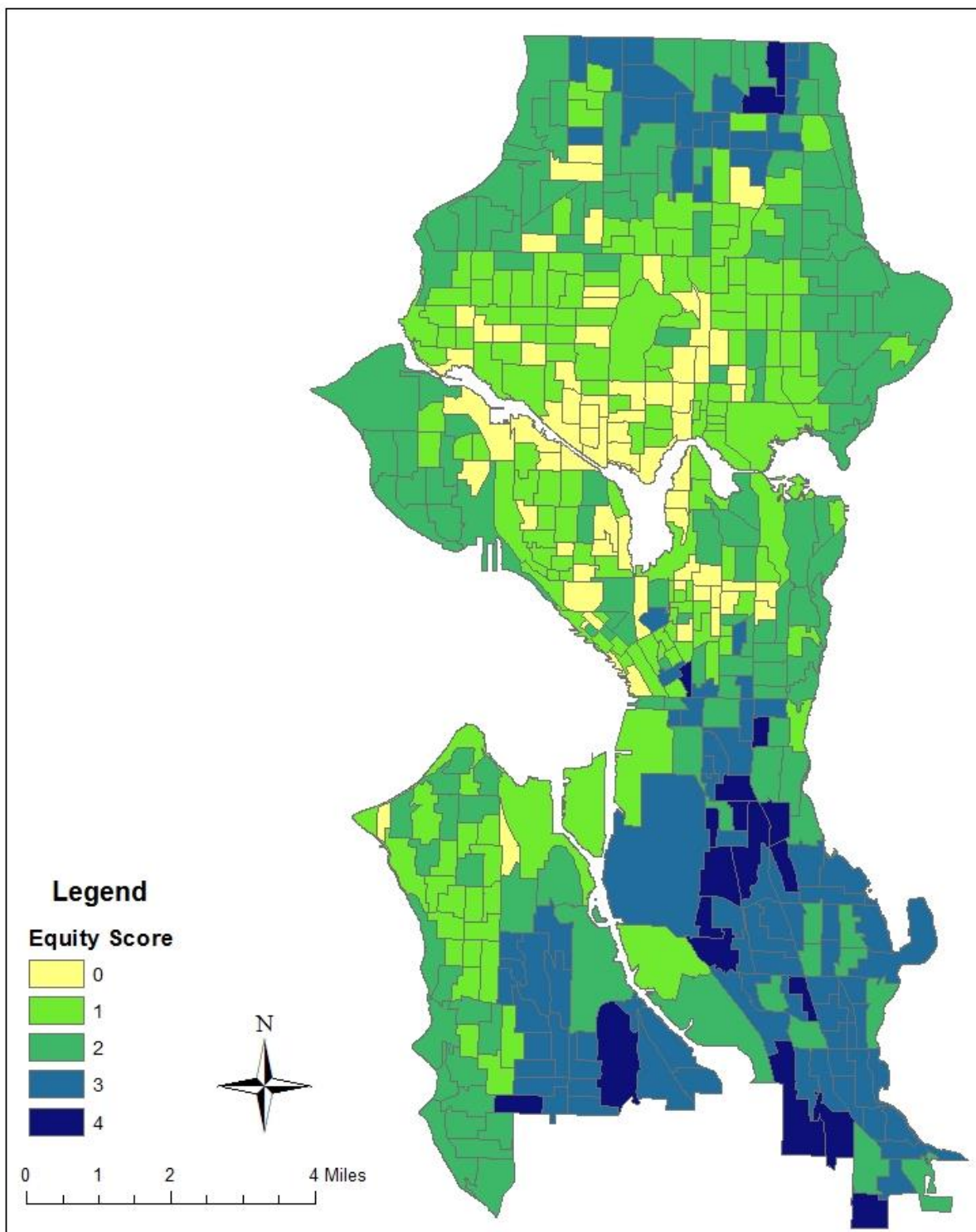
Table 1 provides the average percentage of people of each indicator in block groups for the City of Seattle, and the number of block groups which were above or below the citywide average.

Figure 1 shows the final equity score for each block group for the City of Seattle based on 2010 US Decennial Census data. The conceptual limitations of weighting each of these indicators equally in the scoring method, as well as the use of a binomial scoring system, are addressed in the discussion section of this report.

**Table 1.** Equity Indicator Summary

<b>Equity Indicator</b>	<b>Description of Analysis</b>	<b>Average Values (&gt; or &lt;)</b>	<b># of Census Block Groups<sup>1</sup></b>
Non-White	Above Seattle average Non-White	>29.96%	169
	At or Below Seattle average Non-White	<=29.96%	308
Hispanic or Latino	Above Seattle average Hispanic or Latino	>6.57%	145
	At or Below Seattle average Hispanic or Latino	<=6.57%	332
Youth Age 0-17	Above Seattle average Youth Age 0-17	>15.59%	275
	At or Below Seattle average Youth Age 0-17	<=15.59%	202
Adults Age 65+	Above Seattle average Adult Age 65+	>10.95%	191
	At or Below Seattle Average Adult Age 65+	<=10.95%	286

1 - Total number of Census Block Groups in Seattle is 477



**Figure 1.** Equity Scores by block group for the City of Seattle (2010 Decennial Census)

Map by author

### **3.4 - Measuring Network Access**

#### *Measure of Access*

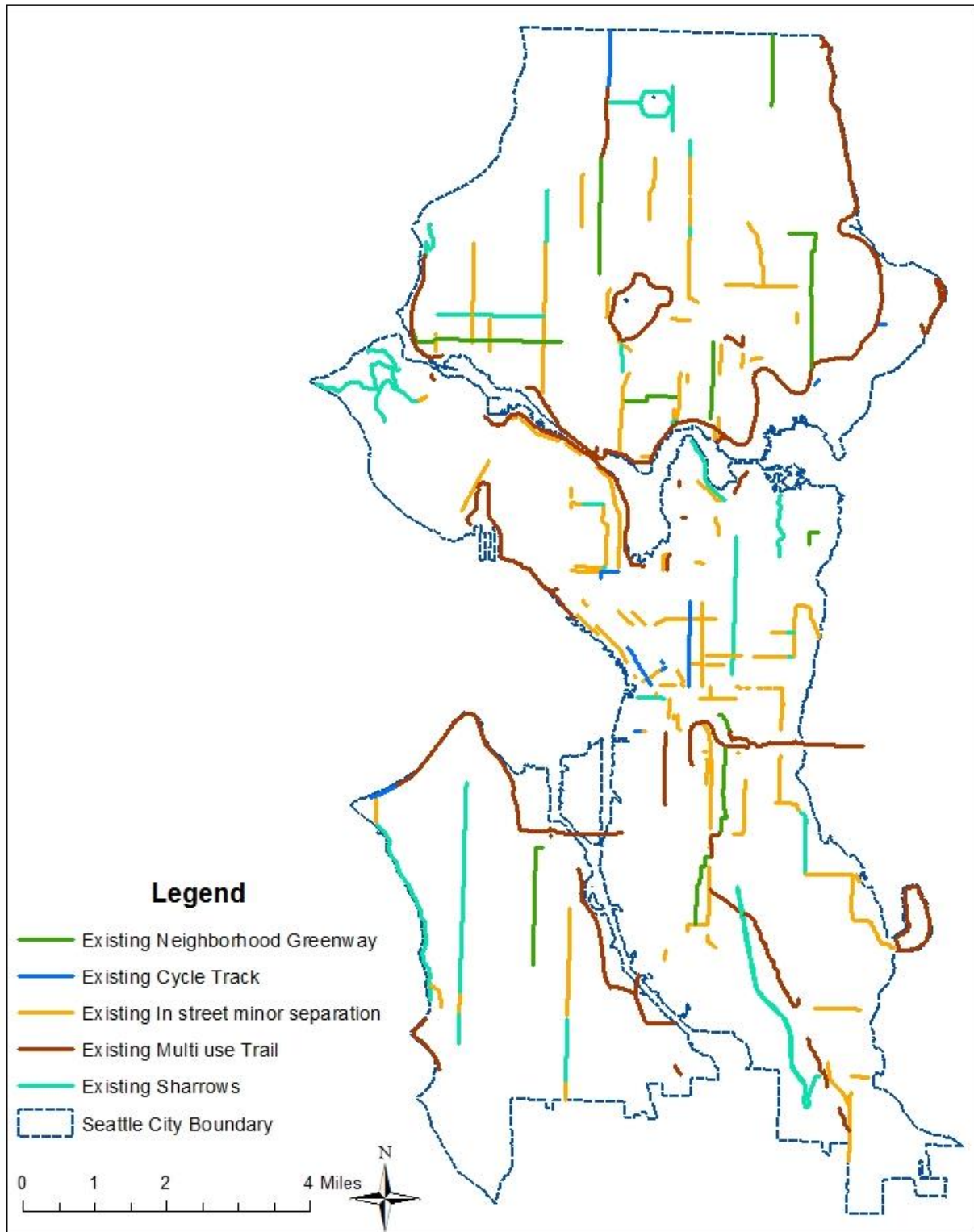
This analysis, following both the Portland and Seattle methods, uses bicycle facility miles per square mile in each study area as the measure of bicycle facility access. There are limitations to using this measure of access, as block groups are defined based on the population in each block group and are not a uniform size (US Census Bureau, 2012b). Accordingly, as Figure 1 shows, the size of block groups in Seattle is not uniform. The limitations of using this level of access are addressed in the discussion section of this report.

#### *Bicycle Facilities in the 2014 Seattle Bicycle Master Plan*

The 2014 Seattle Bicycle Master Plan identifies five different types of bicycle facilities: multi-use trails, neighborhood greenways, cycle tracks (also known as protected bike lanes), shared streets (which include sharrows and advisory bike lanes), and in-street, minor separations (which includes both buffered and non-buffered bicycle lanes) (City of Seattle, 2014). The combination of these different bicycle facilities comprise two different bicycle networks designated by the Seattle Bicycle Master Plan, the Citywide Network and Local Connector Network.

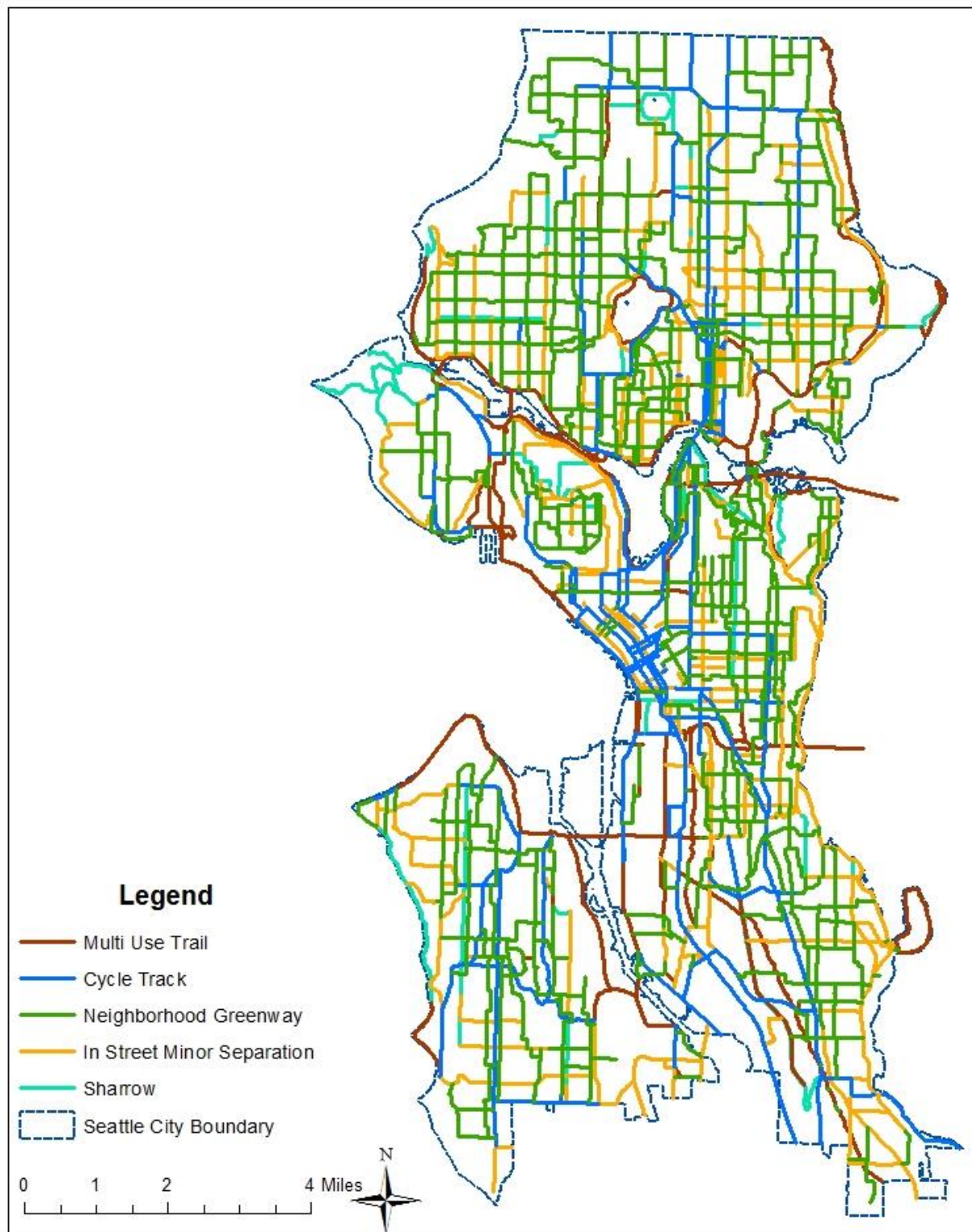
The Citywide Network is composed of multi-use trails, neighborhood greenways and cycle tracks, and is meant to be a network for all ages and abilities that provides access to important destinations within neighborhoods as well as access to adjacent neighborhoods (City of Seattle, 2014). The Local Connector Network uses all five of the bicycle facility types. It is meant to provide local access to the Citywide Network while also serving local destinations within neighborhoods (City of Seattle, 2014). The inclusion of in-street, minor separation and shared street facilities in the Local Connector Network means that not all facilities therein are designed

for all ages and abilities. For the purposes of this report, the Citywide Network and Local Connector Network were combined into one bicycle facility network defined as the Complete Bicycle Network. The existing facilities in the Complete Bicycle Network are shown in Figure 2, and the combination of the existing and planned facilities are shown in Figure 3. This provides one bicycle network for analysis. This approach is consistent with how the Portland method measured access to a similarly defined bicycle network in Portland (Dill and Haggerty, 2009).



**Figure 2.** Existing bicycle facilities in the Complete Bicycle Network

Map by author



**Figure 3.** Existing and planned bicycle facilities in the Complete Bicycle Network

Map by author

### *Low-Stress Bicycle Facilities*

The Portland method also defined a network of low-stress bicycle facilities and analyzed access to this network (Dill and Haggerty, 2009). This approach is useful in that it demonstrates how well low-stress bicycle facilities, which are relatively safer for travel, are distributed. The bicycle facilities that were considered low-stress in the Portland method were bicycle boulevards (known as neighborhood greenways in the Seattle Bicycle Master Plan), off-street paths (known as multi-use paths), and advisory bike lanes (considered a sub-category of shared streets).

The decision of which facilities to be included in the Low-Stress Bicycle Network in this analysis was based on the facilities which the Seattle Bicycle Master Plan considers to be appropriate for all ages and abilities. For this analysis, all neighborhood greenways, cycle tracks, and multi-use paths from the Citywide Network and Local Connector Network were combined to form the Low-Stress Bicycle Network. Advisory bike lanes were not included as part of the Low-Stress Bicycle Network because they were not considered to be a facility built for all ages and abilities by the Seattle Bicycle Master Plan.

### *Quartile Ranking System*

To determine which block groups had the least access to bicycle facilities, a ranking system was constructed. Following both the Portland and Seattle method, this was done in this analysis using a quartile ranking system. After calculating the number of bicycle facility miles per square mile for each block group, the block groups were placed in quartiles. The block groups in the lowest quartile (Q1), were considered the lowest served. This was the only quartile focused on in both the Portland and Seattle method, and will be the focus of this analysis. Table 2 summarizes how

many block groups were in each quartile and the ranges of bicycle facility miles per square mile in each quartile for all four bicycle networks.

**Table 2.** Quartile summaries for Complete and Low-Stress Existing and Planned Bicycle Networks.

Quartile	Complete Bicycle Network				Low-Stress <sup>2</sup> Bicycle Network			
	Existing Network		Planned Network		Existing Low-Stress Network		Planned Low-Stress Network	
	Bicycle Facility Miles per Square Mile	# of Census Block Groups	Bicycle Facility Miles per Square Mile	# of Census Block Groups	Bicycle Facility Miles per Square Mile	# of Census Block Groups	Bicycle Facility Miles per Square Mile	# of Census Block Groups
Q1 (Lowest)	0	202	0 - 5.53	120 (8) <sup>1</sup>	0	352	0 - 3.40	120 (22)
Q2	0.01 - 1.90	92	5.54 - 8.19	119	0.01 - 1.54	42	3.41 - 5.99	119
Q3	1.91 - 3.67	92	8.20 - 10.49	119	1.55 - 3.24	42	6.00 - 7.98	119
Q4 (Highest)	3.68 - 12.10	91	10.50 - 40.29	119	3.25 - 8.75	41	7.99 - 31.79	119

1 - Numbers in parentheses indicate the number of Census Block Groups with no bicycle facilities.

2 - Low-Stress Bike Facilities include Neighborhood Greenways, Multi-Use Trails and Cycle-Tracks as designated in the Seattle Bicycle Master Plan for 2014

Due to the lack of coverage of Seattle's Existing Complete and Low-Stress Bicycle Networks, the number of block groups in Q1 (202 and 352 respectively), is larger than a quarter of all block groups (477). This is because more than a quarter of all block groups in these networks have no bicycle facilities currently. Both the Planned Complete and Low-Stress Bicycle Network serve enough block groups to allow Q1 to represent a quarter (120), of the total number of block groups, as shown in Table 2. The results in Table 2 will be discussed in greater detail in the results section.

### **3.5 - Data Sources**

This analysis was conducted using ESRI Arcview Software with shapefiles acquired from Seattle Department of Transportation (SDOT) and the Washington State Geospatial Data Archive (WAGDA) US Census Geodatabase. SDOT supplied the shapefiles for the Seattle Bicycle Network. The Local Connector Network and the Citywide Network shapefiles for both the existing and planned network were merged together for this analysis. Ultimately, four shapefiles representing the Seattle Bicycle Network were used: the Existing and Planned Complete Bicycle Networks, and the Existing and Planned Low-Stress Bicycle Networks. The existing networks are comprised of facilities constructed as of December 2014, when this data was received. The planned networks represent all existing bicycle facilities and those planned for the future. The data acquired from WAGDA was a 2010 US Census block group shapefile that included block groups for all of King County. Block groups which fell within the Seattle municipal boundary were extracted and used in this analysis. In addition, database files from WAGDA included demographic information from the 2010 US Decennial Census for each block group.

## **4 - RESULTS**

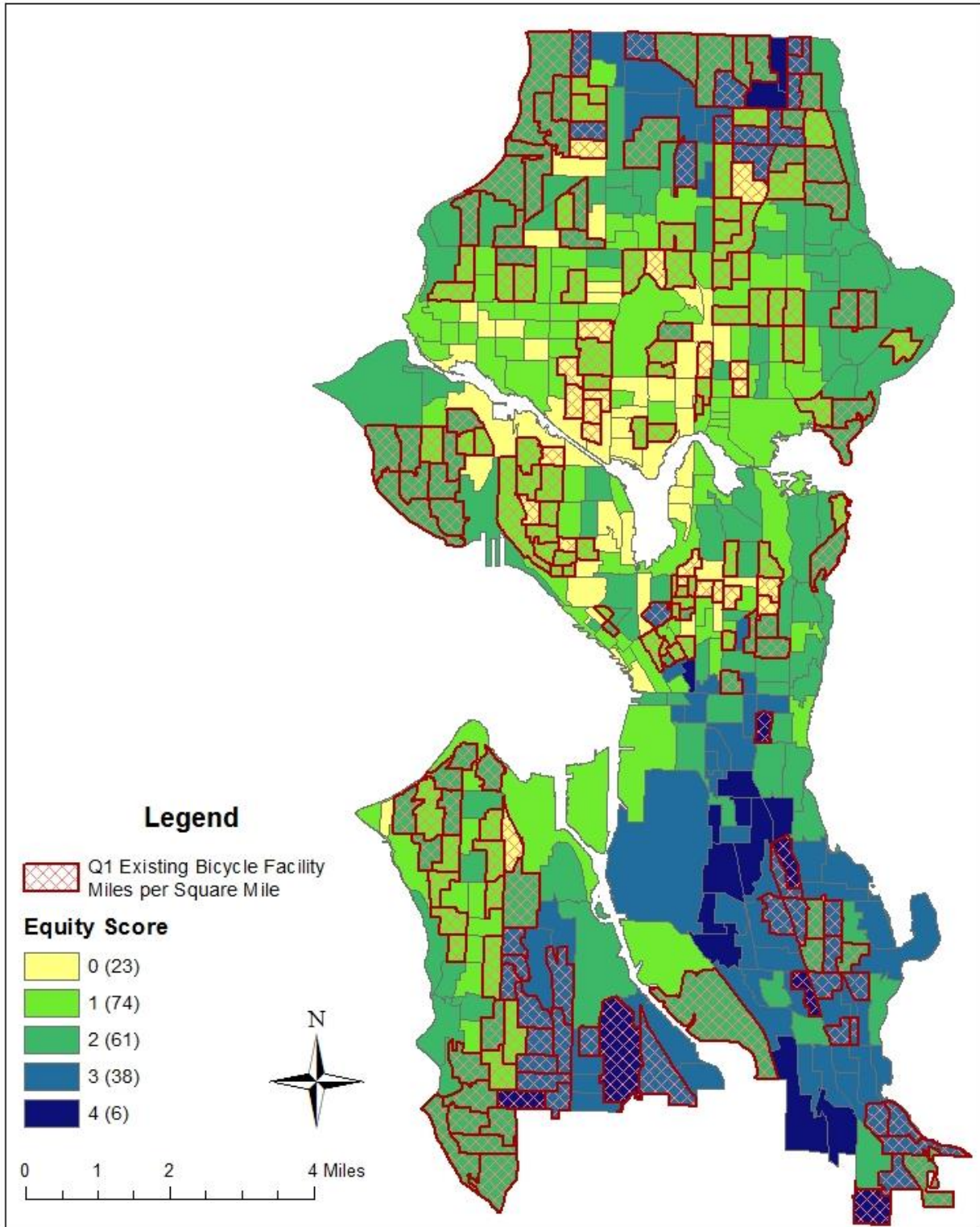
### **4.1 - Complete Bicycle Networks**

The results for the four networks analyzed are presented in four separate maps. These maps show the equity score for each block group and highlight any block groups in the lowest quartile (Q1) of bicycle facility access with red outlines and hatching. In the legend of each map, the number in parentheses next to the equity score represents the number of block groups with that score in Q1. These results are also summarized in Tables 3 and 4. Finally, Table 5 summarizes the average number of bicycle facility miles per square mile by indicator for each bicycle network.

As shown in Figure 5, the block groups in Q1 are not clustered in any single geographic area of Seattle in the Planned Complete Bicycle Network. The central and northern areas of Seattle appear to be the best served by the Planned Complete Bicycle Network. This result makes sense as many bicycle commuters pass through these areas on their way to Downtown Seattle or the University of Washington. These areas do not have high equity scores and tend to have equity scores between zero and two, which indicate the number of indicators each block group has an above average percentage of.

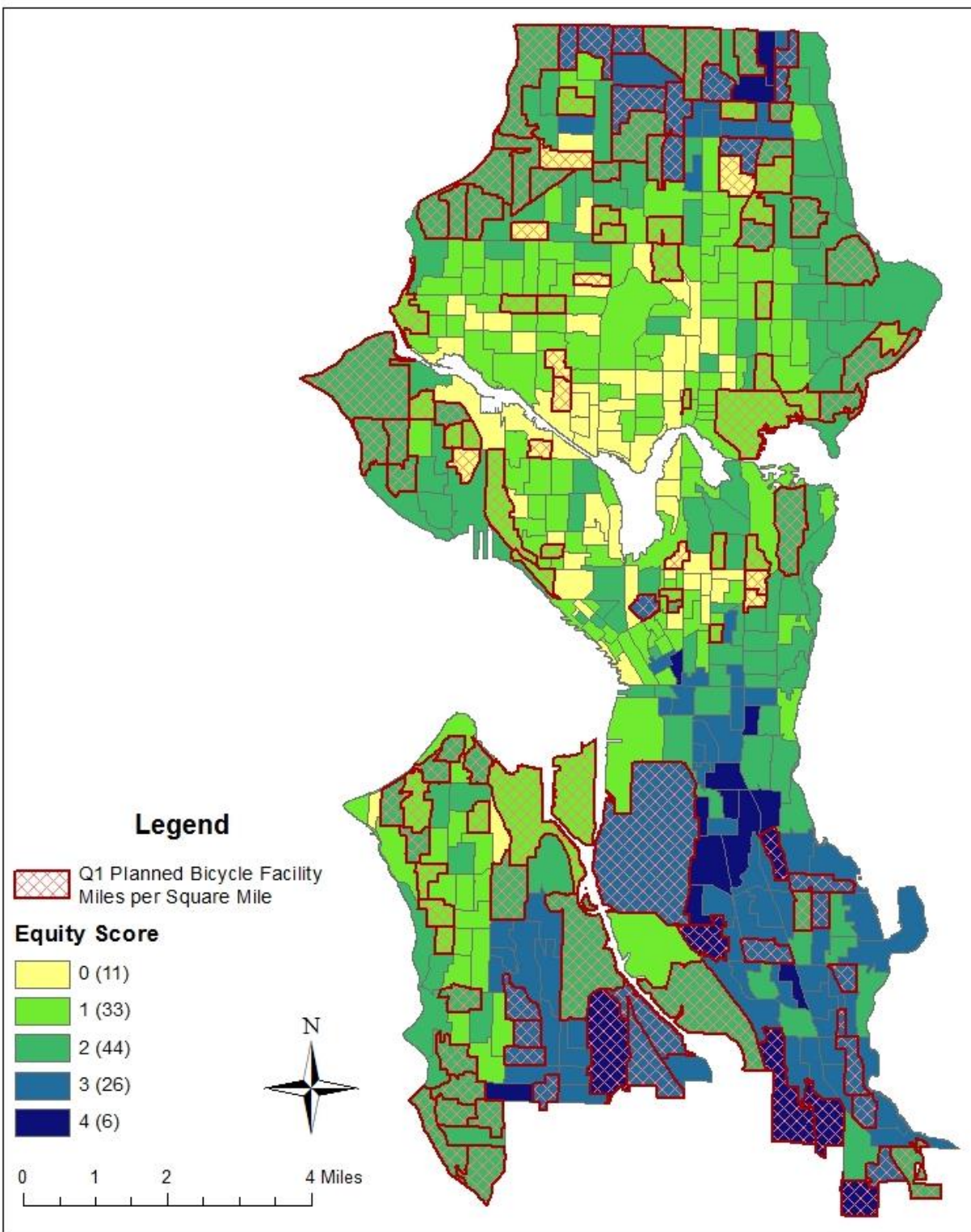
Comparing the results between the Existing and Planned Complete Networks in Figures 4 and 5, a number of areas with high equity scores of three and four decrease in the number of block groups in Q1. The Delridge neighborhood in south Seattle decreases its number of high scoring block groups in Q1 from twelve to four. Access is also improved in the Columbia City and Northern Rainier Valley areas in southeast Seattle, as a cluster of high scoring block groups in Q1 decreases from eleven to six. Access is still limited in the Haller Lake neighborhood in north

Seattle, as the cluster of block groups in Q1 with high equity scores increases from three to six. South Park at the southern border of Seattle also has limited access as three of the four block groups in this neighborhood are in Q1. Finally, access is limited in the Southern Rainier Valley as six block groups with equity scores of three and four are in Q1



**Figure 4.** Block groups in Q1 for Existing Complete Bicycle Network

Map by author



**Figure 5.** Block groups in Q1 for Planned Complete Bicycle Network

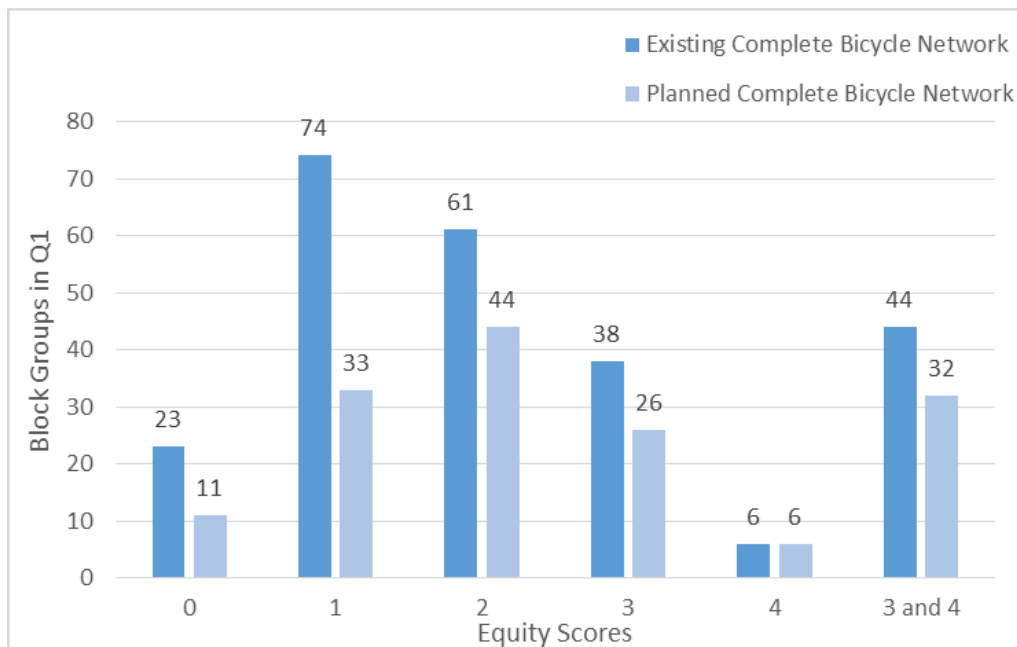
Map by author

Referring to Table 2 on page 23, the number of block groups with no bicycle facilities decreases dramatically (202 to 8) between the Existing and Planned Complete Bicycle Network. The extent to which the Planned Complete Bicycle Network covers the City of Seattle can be seen in Figure 3 on page 21. This improvement can also be seen in the difference in ranges for each quartile between the Existing and Planned Bicycle Networks shown in Table 2. In the Existing Bicycle Network, the lower and upper boundaries for the highest quartile of access (Q4) are 3.68-12.10 facility miles per square mile. The Planned Bicycle Network's Q1 has an upper range of 5.53 facility miles per square mile, which is less than two miles larger than Q4 for the Existing Bicycle Network. Finally, the average facility miles per block group increases from 1.77 to 8.38 (473 percent) between these two networks.

As demonstrated in Table 3 and Figure 6, the number of block groups in Q1 for each equity score decreases between the two networks, except for block groups with a score of four. Although, this equity score only contains six block groups in Q1, the smallest amount for any of the scores. The most dramatic decrease is seen in block groups with a score of one, which decreased by 55.4 percent, though every other decrease was at least twenty-five percent. While the block groups in Q1 with an equity score of four did not decrease between the two networks, block groups with equity scores of three and four fell 27.3 percent, from forty-four to thirty-two. Finally, of the eight block groups in the Planned Complete Bicycle Network not served by any bicycle facilities, none had equity scores of three or four.

**Table 3.** Equity score summaries for block groups in Q1 for Existing and Planned Complete Bicycle Networks.

<b>Complete Bicycle Network</b>			
<b>Equity Score</b>	<b>Existing Network</b>	<b>Planned Network</b>	<b>% Decrease Between Existing and Planned Network</b>
	<b># of Census Block Groups in Q1</b>	<b># of Census Block Groups in Q1</b>	
<b>0</b>	23	11	52.2%
<b>1</b>	74	33	55.4%
<b>2</b>	61	44	27.9%
<b>3</b>	38	26	31.6%
<b>4</b>	6	6	0.0%
<b>3 and 4</b>	44	32	27.3%



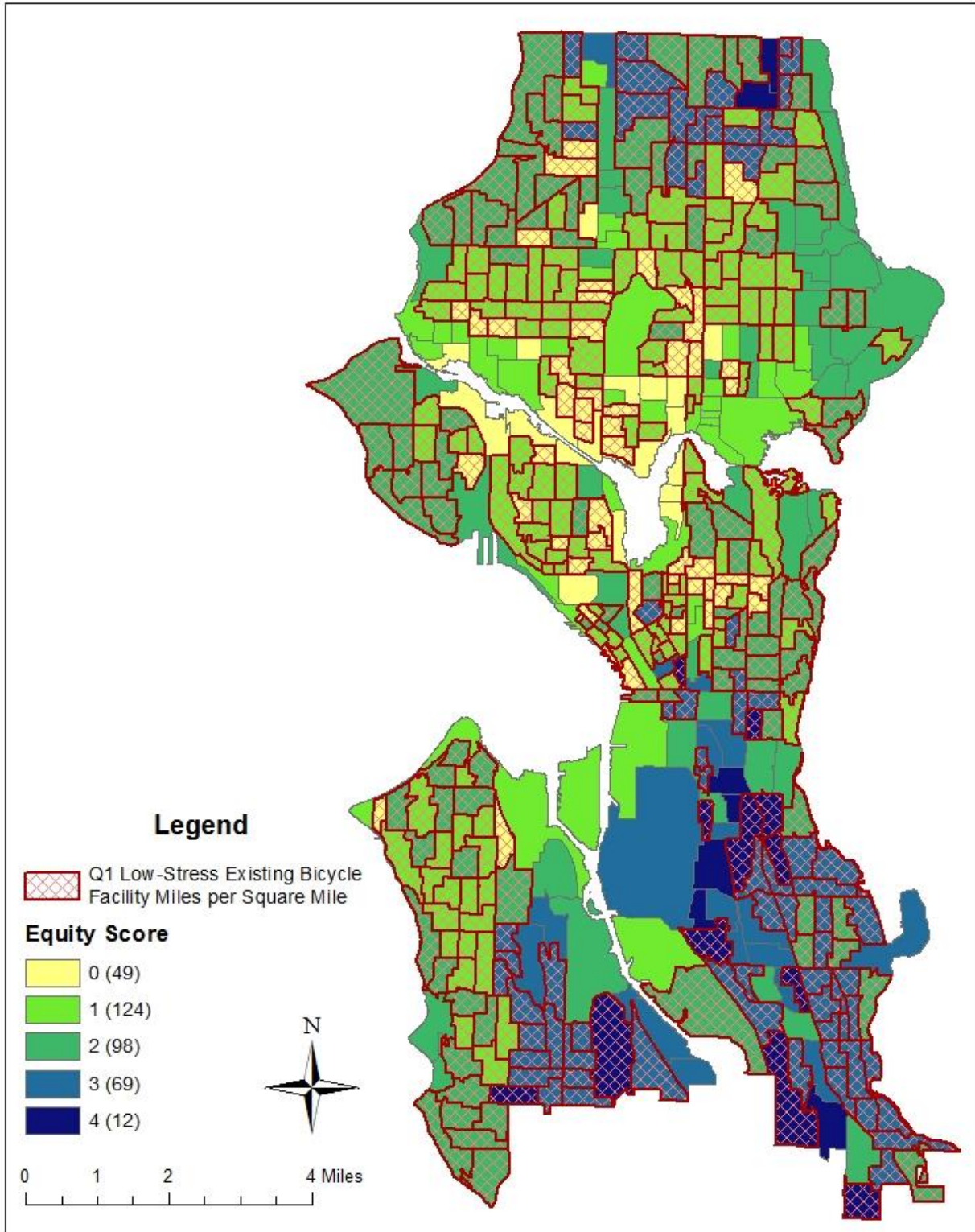
**Figure 6.** Comparison of block groups in Q1 for Existing and Planned Complete Bicycle Networks.

## 4.2 – Low-Stress Bicycle Networks

In comparison to the Existing Complete Bicycle Network, the Low-Stress Existing Bicycle Network covers much less of the city, as only 125 of the 477 block groups are served by low-stress facilities. These block groups are almost exclusively served by multi-use paths, shown as brown lines in Figure 2 on page 20 and include: the Burke-Gilman Trail, Ship Canal Trail, Elliott Bay Trail, Alki Trail, I-90 Trail, Chief Sealth Trail, and the Duwamish River Trail.

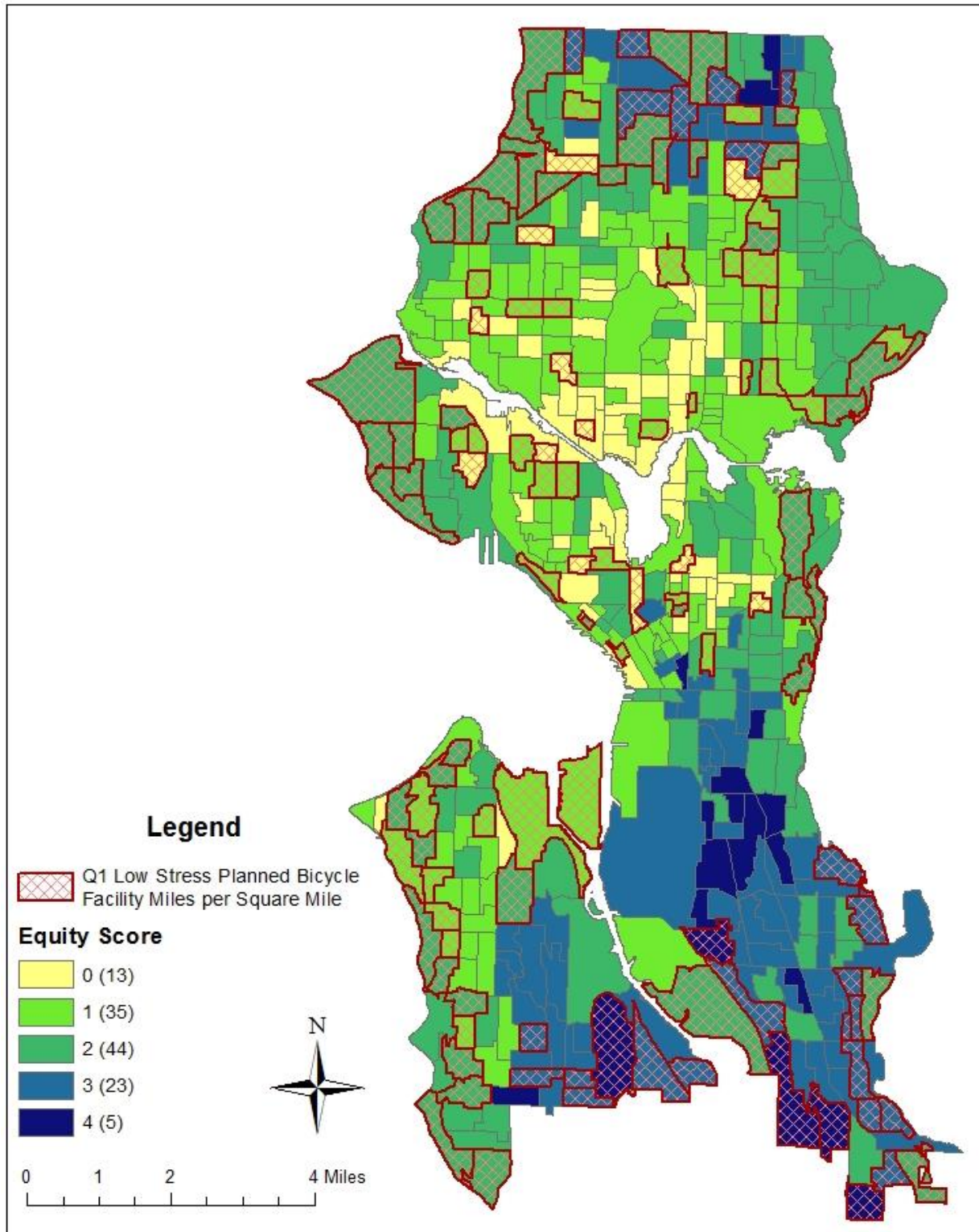
As shown in the difference between Figures 6 and 7, the Planned Low-Stress Bicycle Network increases the level of access throughout the city dramatically. This comparison reveals a number of high equity score areas with increased levels of access. At the northern border of the city near Haller Lake, a cluster of high scoring block groups in Q1 drops from seventeen to seven. Near the center of the city in the Central District, Capitol Hill, and Cascade areas, block groups in Q1 with high scores drop from nine to zero. The Rainier Valley, in southeast Seattle, sees a similar result with high scoring block groups in Q1 dropping from thirty-nine to fifteen. Finally, the Delridge area in southwest Seattle sees a drop in high scoring block groups in Q1 from seventeen to seven.

The areas with high equity scores which continue to have limited access in the Planned Low-Stress Bicycle Network include: South Park and the southern portion of Delridge in southwest Seattle, and the eastern and southwestern portions of the Rainier Valley in southeast Seattle. South Park and southwest Delridge have a total of seven, and east and southwest Rainier Valley have twelve high scoring block groups in Q1. While these areas did receive some increases in their levels of access, their limited access was worth highlighting due to the number of block groups in Q1 with high equity scores.



**Figure 7.** Block groups in Q1 for Existing Low-Stress Bicycle Network

Map by author



**Figure 8.** Block groups in Q1 for Planned Low-Stress Bicycle Network

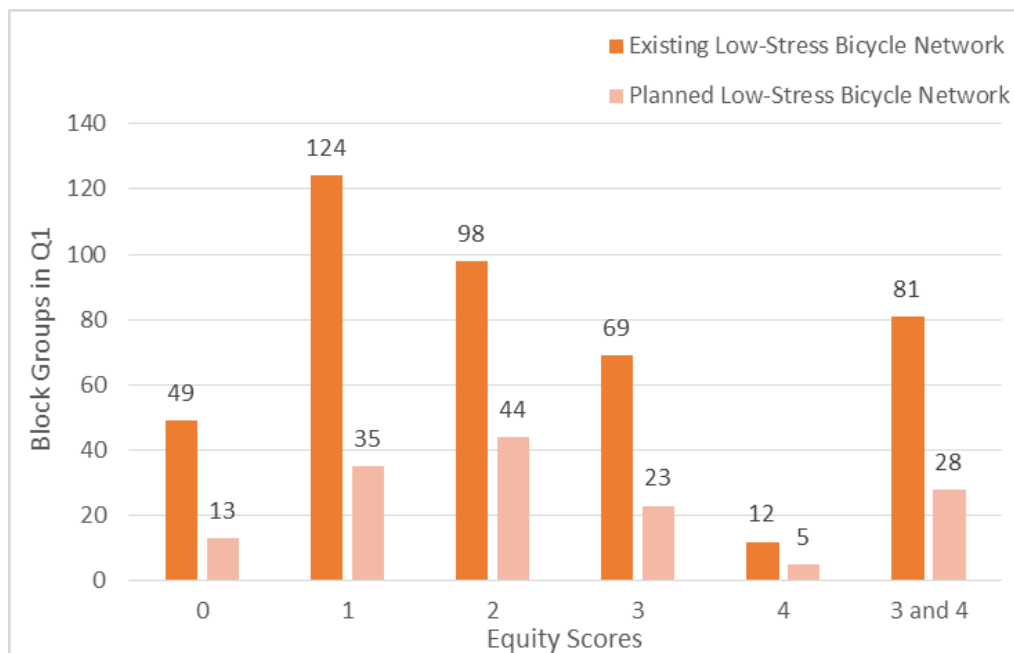
Map by author

Referring back to Table 2, the number of block groups with no low-stress facilities drops dramatically (352 to 22) between the Existing and Planned Low-Stress Bicycle Networks. The extent to which the Planned Bicycle Network increases access to low-stress bicycle facilities is shown in Table 2 in the differences between the quartile ranges of the two networks. Q4, in the Existing Low-Stress Bicycle Network has a low range of 3.25 facility miles per square mile, while Q1 in the Planned Low-Stress Bicycle Network has an upper range of 3.40, only 0.15 bicycle facility miles per square mile larger than Q4. Finally, the average low-stress facility miles per block group increases from 0.67 to 5.97 (891 percent) between the two networks.

As demonstrated by Table 4 and Figure 7, the number of block groups in Q1 for each equity score decreases by at least fifty percent between the two networks. Block groups with a score of three or four fell 65.4 percent, from eighty-one to twenty-eight. Finally, of the twenty-two block groups with no low-stress facilities in the Planned Low-Stress Bicycle Network, none had high equity scores of three or four.

**Table 4.** Equity score summaries for block groups in Q1 for Existing and Planned Low-Stress Bicycle Networks.

<b>Low-Stress Bicycle Network</b>			
<b>Equity Score</b>	<b>Existing Network</b>	<b>Planned Network</b>	<b>% Decrease Between Existing and Planned Network</b>
	<b># of Census Block Groups in Q1</b>	<b># of Census Block Groups in Q1</b>	
<b>0</b>	49	13	73.5%
<b>1</b>	124	35	71.8%
<b>2</b>	98	44	55.1%
<b>3</b>	69	23	66.7%
<b>4</b>	12	5	58.3%
<b>3 and 4</b>	81	28	65.4%



**Figure 9.** Comparison of block groups in Q1 for Existing and Planned Low-Stress Bicycle Networks.

### **4.3 - Average Access by Equity Indicator and Bicycle Network**

Table 5 provides a summary of the average number of bicycle facility miles per square mile in each network for block groups above or below citywide averages for each indicator. The purpose of this table is to highlight any differences in the average levels of access for block groups above or below the citywide average for each equity indicator. Differences in average levels of access for block groups were tested for statistical significance using standard t-tests and deemed significant with  $p < 0.05$ , the level of significance used in the Portland method. For example, block groups above the citywide average of youth under eighteen had an average of 1.445 facility miles per square mile in the Existing Complete Bicycle Network. This is significantly different than the 2.22 average facility miles per square mile for block groups at or below the citywide average of youth under eighteen within that same network. The citywide average of each indicator as well as the number of block groups above or below these averages may be reviewed in Table 1 on page 16.

The average level of access increases dramatically for each equity indicator between the Existing and Planned Complete and Low-Stress Bicycle Networks. Average levels of access increase between 400 and 500 percent in Planned Complete Network and between 600 and 1000 percent in the Planned Low-Stress Network. Average access for block groups above the citywide average of youth under eighteen increased by the highest amount in both planned networks

Of primary importance from this table is whether any differences exist in average levels of access for block groups above or below citywide averages for each indicator. For the non-white indicator, the average level of access was higher for block groups above the citywide average across all four of the networks analyzed. For the Hispanic or Latino indicator, the greatest

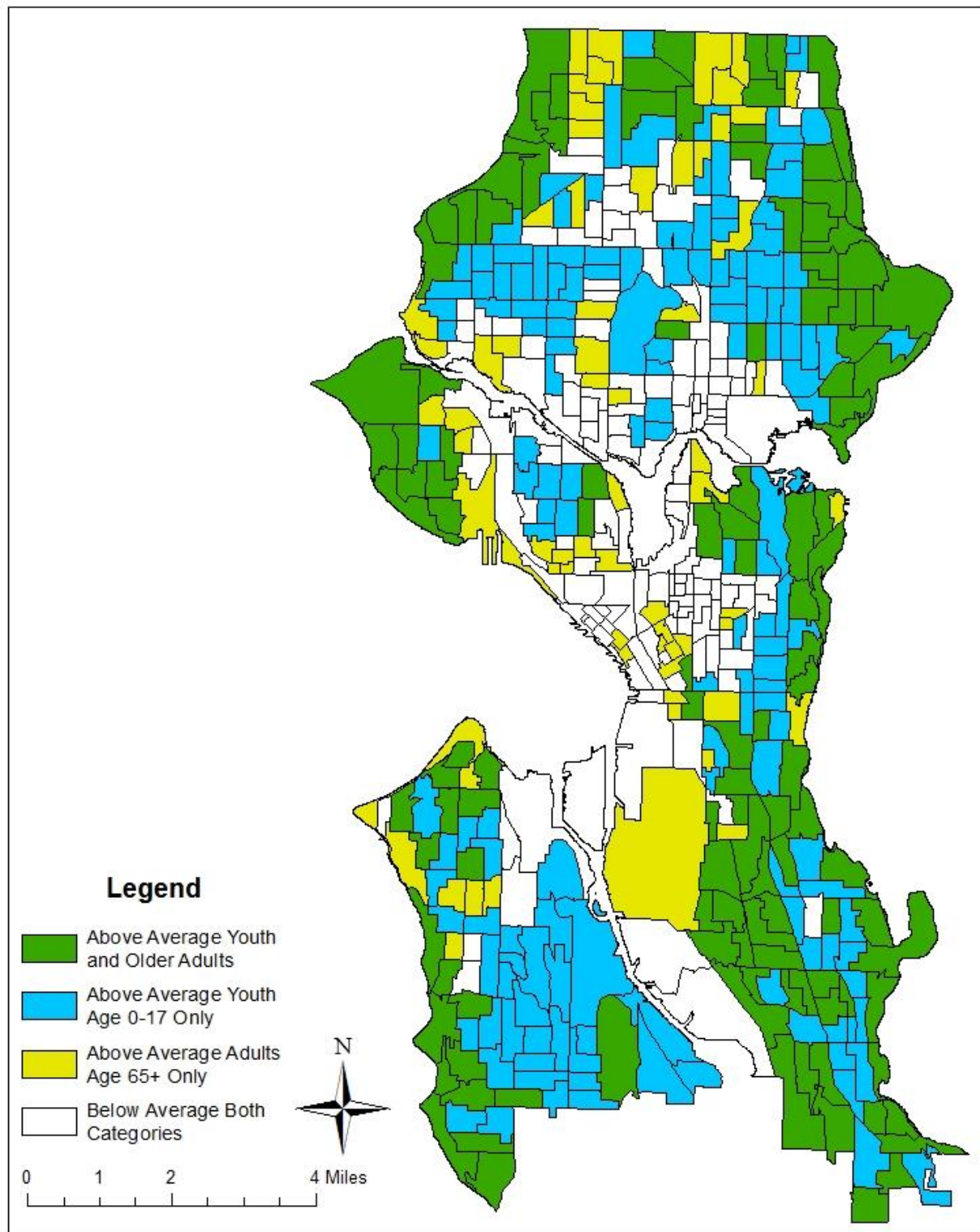
difference in access was seen in the Planned Complete Bicycle Network, where block groups above the citywide average had 0.488 less average bicycle facility miles. This difference was not shown to be statistically significant, however. For youth under eighteen, block groups above the citywide average had lower average levels of access across all four bicycle networks analyzed and these differences were all shown to be statistically significant. For adults sixty-five and above, block groups above the citywide average were shown to have significantly lower average levels of access in both the Planned Complete and Low-Stress Networks.

Due to these significant differences, the locations of block groups in Seattle with higher than the citywide average percentages of youth and older adults are identified, shown in Figure 10. The block groups with above average percentages of both youth and older adults are shown in green. Many of these block groups are located in areas with low access mentioned previously, such as the Rainier Valley in south Seattle and Haller Lake in north Seattle.

**Table 5.** Summary of average bicycle facility miles by equity indicator and bicycle network

Equity Indicator	Description of Block Groups Above or Below Citywide Average for Each Indicator	Average Bicycle Facility Miles per Square Mile in each Block Group		% Increase between Existing and Planned Complete Network	Average Low-Stress Facility Miles per Square Mile in each Block Group		% Increase between Existing and Planned Low-Stress Bicycle Network
		Existing Complete Bicycle Network	Planned Complete Bicycle Network		Existing Low-Stress Bicycle Network	Planned Low-Stress Bicycle Network	
Non-White	Above Citywide Average	2.002	8.803	440%	0.751	6.302	839%
	At or Below Citywide Average	1.647	8.148	495%	0.626	5.783	924%
Hispanic or Latino	Above Citywide Average	1.767	8.041	455%	0.608	5.958	980%
	At or Below Citywide Average	1.775	8.529	481%	0.697	5.971	857%
Youth Age 0-17	Above Citywide Average	1.445*	7.511*	520%	0.507*	5.220*	1030%
	At or Below Citywide Average	2.220	9.563	431%	0.892	6.984	783%
Adult Age 65+	Above Citywide Average	1.781	7.484*	420%	0.761	5.226*	687%
	At or Below Citywide Average	1.768	8.979	508%	0.609	6.461	1061%

\* indicates statistically significant difference in average number of facility miles compared to block groups at or below citywide averages for each indicator within the same bicycle network,  $p < 0.05$

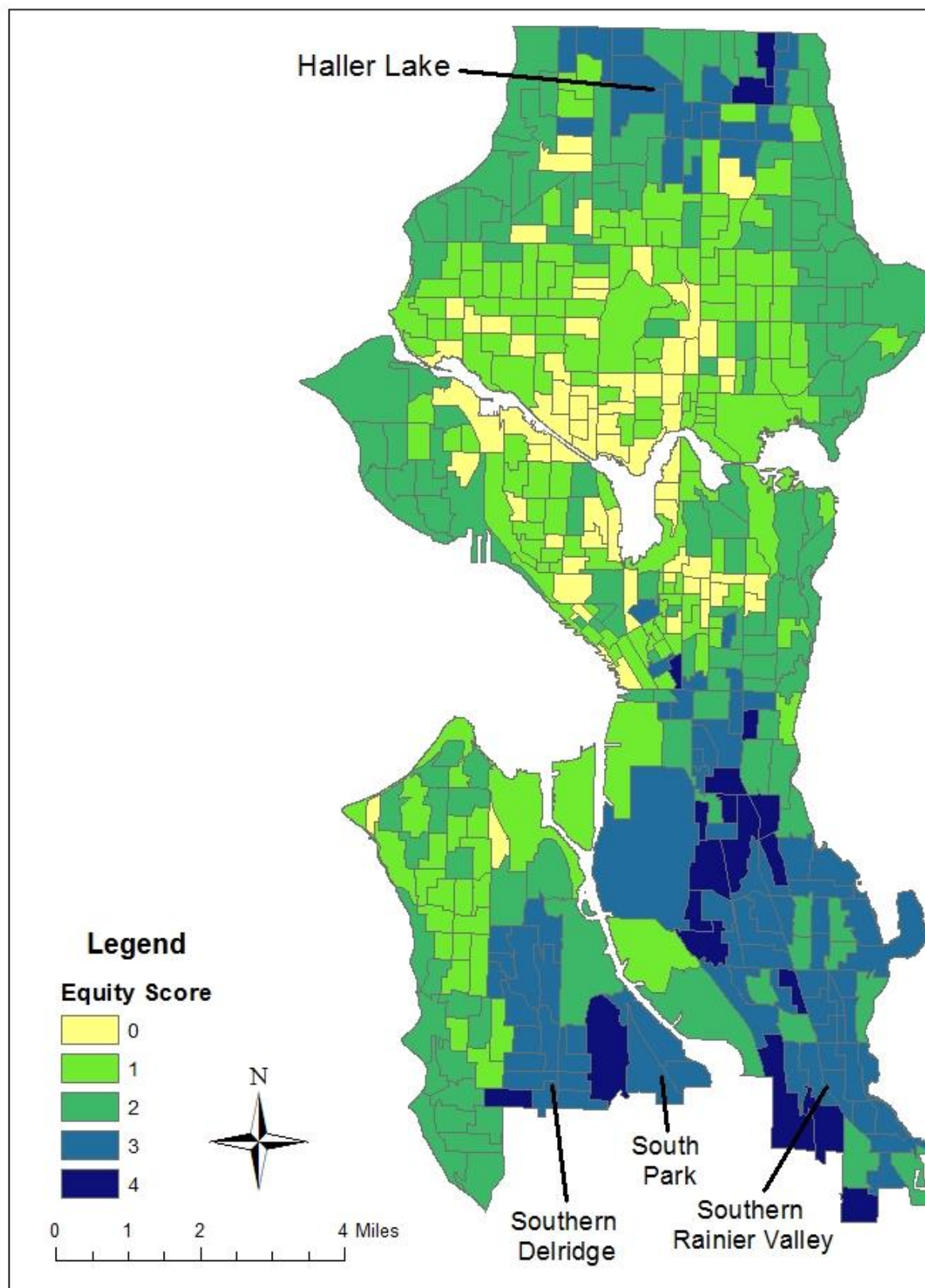


**Figure 10.** Block groups with above the citywide average percentage of youth under eighteen and adults sixty-five and above.

Map by author

#### **4.4 - Summary of Results**

In the Planned Complete Bicycle Network, the areas of concern are around Haller Lake in north Seattle and South Park and the southern Rainier Valley in south Seattle. In the Low-Stress Planned Bicycle Network, the areas of concern are in south Seattle in South Park and the southern portion of Delridge, and in the Southern Rainier Valley. These areas of the city are highlighted in Figure 11. Average levels of access were also shown to be significantly lower for block groups with higher than average percentages of youth across all four bicycle network, and for older adults in both the Planned Complete and Low-Stress Bicycle Networks. Many of these block groups were shown to be in the same areas with relatively low access mentioned previously and efforts to improve access in these areas will likely address the significantly lower average levels of access for youth and older adults.



**Figure 11.** Areas of Seattle shown to have low levels of access in planned bicycle networks.

Map by author

## **5 - DISCUSSION**

### **5.1 - Applications of Equity Analysis Results in Seattle**

#### *2014 Seattle Bicycle Master Plan*

This equity analysis highlights levels of bicycle facility access for bicycle dependent populations in Seattle's Existing and Planned Bicycle Networks. Some results indicate relatively high or equal levels of access by these populations such as low numbers of high equity score block groups in Q1 in the Planned Complete and Low-Stress Bicycle Networks. Other results indicate relatively low levels of access for these populations such as lower than average levels of access for block groups with higher than average percentages of youth and older adults. Instead of weighing these results against one another to establish an overall conclusion regarding the equitable nature of the entire 2014 Seattle Bicycle Master Plan (SBMP), the results should be used to identify opportunities to expand the bicycle network into these underserved areas and eliminate identified inequities.

Any recommendations for expanding the networks in the SBMP to eliminate inequities should be informed by other considerations not included in this analysis, such as safety and connectivity. This is to ensure that recommended improvements safely serve these areas and lead to purposeful destinations, rather than simply being supplied to satisfy a quota. These efforts should be achieved with the local knowledge of the people who live in these areas to ensure their needs are met by any recommended expansions.

### *Seattle Bicycle Master Plan Implementation Plan*

The methods and results from this analysis may be used in the Seattle Bicycle Master Plan Implementation Plan as well. This plan establishes a project prioritization process that assigns points to individual bicycle projects based on five different categories: safety, connectivity, ridership, livability and equity (City of Seattle, 2015). Each of these categories is allowed a different number of prioritization points, with the total number of points from all five categories being 100. Equity is the third highest category and allowed a maximum of twenty points in this system. A discussion of the appropriate number of points that equity should be given in this prioritization process is beyond the scope or intention of this report.

What this plan does not outline is a systematic process by which these points for individual projects are assigned. The points are assigned based on how well each project satisfies the criteria within each category, which are broadly stated goals relating to each category. The results from this analysis may be used to establish a systematic process to allocate some or all of the points each project is assigned in the equity category. For example, a portion of the points may be assigned based on the equity scores of the block groups each project serves. Establishing a systematic process by which to allocate project prioritization points provides one way of eliminating some amount of subjectivity that can accompany these quasi-quantitative prioritization processes.

The Seattle Bicycle Master Plan Implementation Plan also provides a list of projects that are planned to be built each year beginning in 2015 and running through 2019 (City of Seattle, 2015). The same methods used to evaluate the bicycle networks in this analysis may be used to

evaluate the collection of projects for each year as well as the entire five-year collection of projects. This would provide insight into how well each year's projects serve different areas of the city based on their equity scores and their current levels of bicycle facility access. Each year's collection of projects and the entire five-year collection of projects could be evaluated and modified accordingly based upon these results.

### *Seattle Race and Social Justice Initiative*

The methods of this analysis may also be useful for other Departments in the City of Seattle to achieve the goals of the Seattle Race and Social Justice Initiative (RSJI). Specifically, the equity scoring system in this analysis may be used by other Departments to identify areas of the city with high concentrations of social justice populations. The inclusion of additional social justice populations in this analysis, other than those mandated by the Seattle RSJI, may establish precedent for other Departments in Seattle to evaluate the effects of their programs and services on these other populations as well. This may lead to a broadened scope for the RSJI as it continues to be implemented and updated in Seattle.

### **5.2 - Limitations of Methods**

Before the results of this analysis may be used to begin addressing the inequities identified, additional analysis is required to validate the initial findings and provide useful context for the areas of identified inequities. This need for additional analysis is based on a number of limitations revealed regarding the methods used. These limitations make the use of these results as the sole basis for making changes in the bicycle network to eliminate inequities, problematic. The limitations of the methods in this analysis are addressed subsequently.

### *Limited Variables in 2010 Decennial Census Data*

The primary limitation to the methods of this analysis involves the exclusive use of 2010 Decennial Census Data as the source of indicators to identify bicycle dependent populations. The US Decennial Census records basic household and demographic variables, such as race, ethnicity, age, and occupancy status of households and reports these as representing conditions in April of the year the data was collected (US Census Bureau, 2012). While the variables available from the US Decennial Census are limited, it is based on a 100 percent count of the entire population and not subject to sampling error (US Census Bureau, 2009). Its exclusive use in this analysis meant that the indicators available to identify bicycle dependent populations was limited and could not include other important indicators, especially low-income populations.

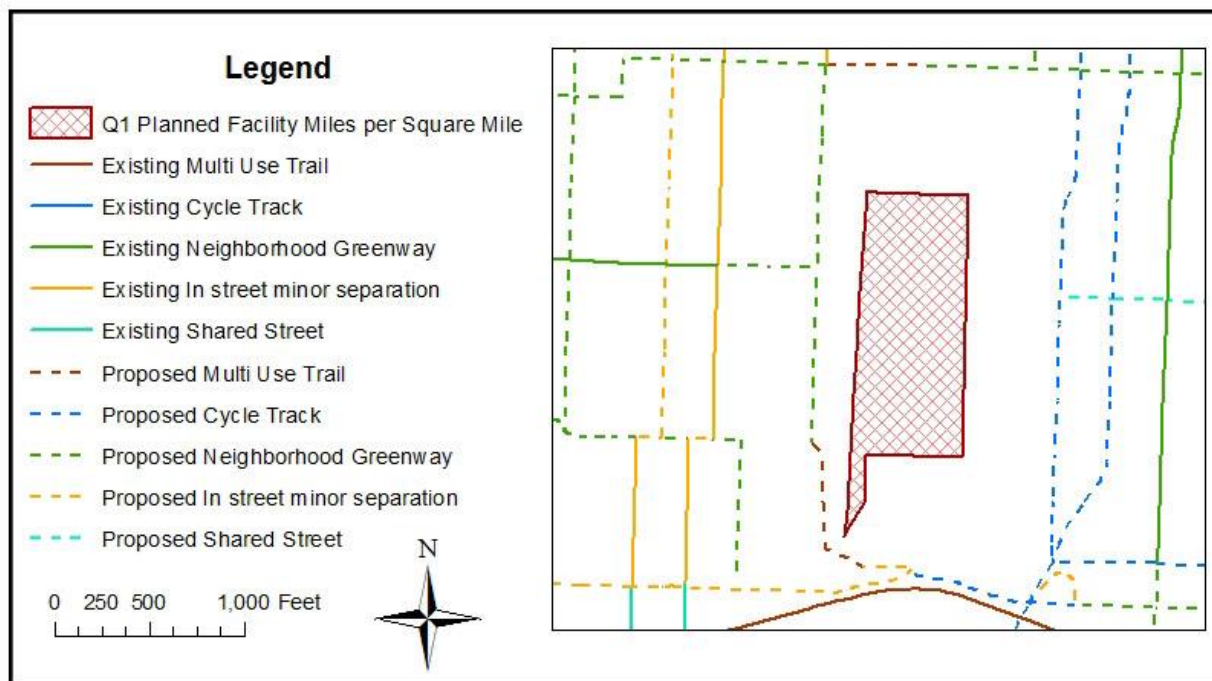
Using people with low income as a measure of equity related to transportation was universal across a number of studies relating to transportation and equity (Sanchez and Brenman, 2007; Martens et al, 2012; Golub and Martens, 2014; Farber et al, 2014; NHCRP, 2001). Low-income populations were also included in the Federal Orders discussed that specifically focused on equity and transportation (FHWA, 2012; DOT, 2012). Finally, low-income populations were included in both the Seattle and Portland equity analysis methods. This importance of income related data in an equity analysis was not completely understood by the author at the time the 2010 Decennial Census was chosen. However, the lack of income as an indicator significantly hinders the ability of this analysis to accurately describe the bicycle dependent population. Future equity analyses should prioritize the inclusion of low-income populations as an indicator based on the precedence of its use in most studies relating equity and transportation.

### *Age of 2010 Decennial Census Data*

2010 Decennial Census data is also limited because of how dated it was at the time of this analysis. This analysis was conducted in February, 2015, five years after the 2010 Census data was collected. For areas with a rapid growth rate, this may mean that demographic conditions are changing rapidly as the population increases. For example, in 2010 the City of Seattle had an estimated population of about 608,000 people (US Census Bureau, 2015). In 2013, Seattle was estimated to have grown to a population of about 652,000 people, a growth of 7.2 percent (US Census Bureau, 2015). Seattle's growth rate during this period outpaced both King County and the State of Washington, which each had a growth rate of 6.0 and 3.7 percent respectively (US Census Bureau, 2015b). Due to this high growth rate, the demographics throughout Seattle may have changed dramatically since 2010, and the ability of 2010 data to accurately display demographic conditions in Seattle currently and into the future is questionable. Newer sources of data should be used to present the most accurate representation of current demographic conditions.

### *Use of Only One Scale of Analysis*

The scale of analysis used in this report is problematic based on how the results are interpreted if taken out of context. For example, there are block groups in Q1 for bicycle facility access in both the planned networks that are surrounded by block groups not in Q1 that have relatively high levels of access. The use of a larger scale of analysis, such as the census tract scale, would likely not highlight these areas as having low levels of access. Some of these block groups may be found in the North and Central Seattle areas.



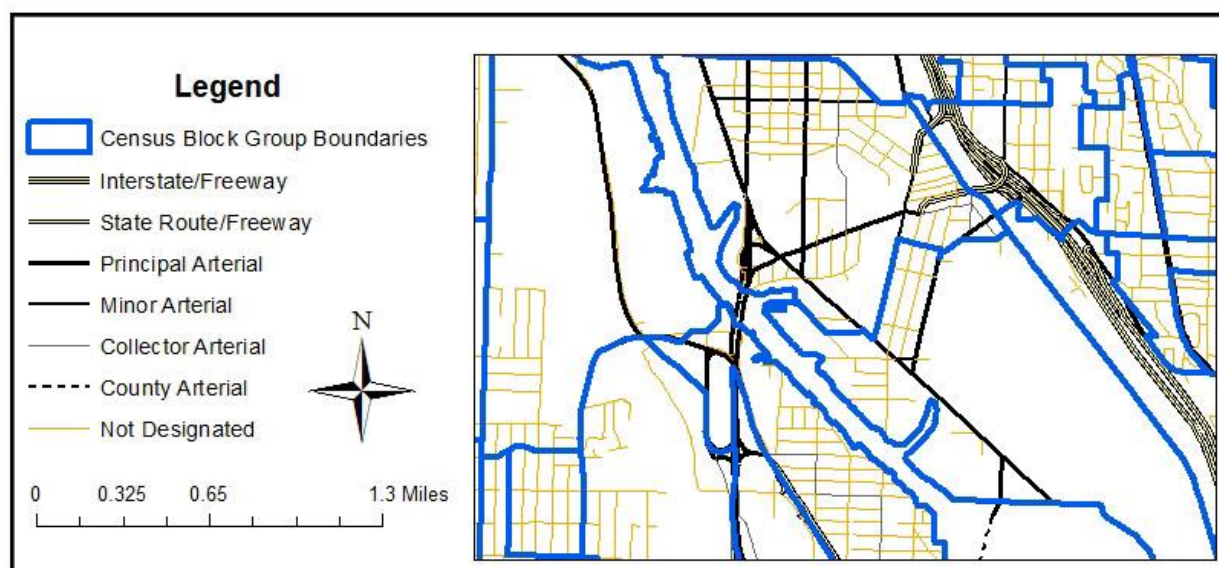
**Figure 12.** Block group in University District in Q1 for Planned Complete Bicycle Network.

Map by author

For example, one block group exists on the western edge of the University District neighborhood in north Seattle that is in Q1 for both the Planned Complete and Low-Stress Bicycle Networks. Figure 7 shows that the area immediately surrounding this block group is planned to be well served by bicycle facilities. In addition, the Burke Gilman Trail, one of the highest used multi-use paths in Seattle, lies about 500 feet south of this block group. The reason no bicycle facilities pass through this block group is because of the presence of Interstate 5 on its western boundary. The information gained from both a larger and smaller scale of analysis are both useful in an equity analysis, but the use of one scale of analysis may not provide enough detail on its own to make informed decisions.

### *Measure of Access*

The measure of access used in this study, bicycle facility miles per square mile of land, has limitations because of the range in the size of block groups. Block groups are designed to encompass between 600 and 3000 people (US Census Bureau, 2012b) but are not a uniform size (Figure 1). In Seattle, block groups range in size between 0.007 and 2.492 square miles, with an average size of 0.175 square miles. Many relatively large block groups have challenging topography and existing industrial, institutional and transportation facilities that limit the size of the street network available for bicycle facilities. Consequently, the opportunities to supply bicycle facilities is not consistent across all block groups in Seattle.



**Figure 13.** Census block groups in Duwamish River Valley with street network Shown.

Map by author

Some of these relatively large block groups exist throughout the Duwamish River Valley in south Seattle, shown in Figure 13. This area does not have a dense street network suitable for bicycle facilities compared to other urban areas of Seattle. The Duwamish River Valley contains the King County International Airport, US Highway 99, and Interstate 5 that pass through these

large block groups. These facilities and high capacity roadways have impacted the development of the street network in these areas. As a result, the opportunities for bicycle facilities to serve these block groups is constrained. Figure 5 on page 28 shows that many of these large block groups in the Duwamish River Valley are in Q1 for the Planned Complete Bicycle Network. An additional measure of access is needed, in addition to bicycle facility miles per square mile, to provide a more accurate representation of bicycle facility development opportunity throughout Seattle.

#### *Equity Score Method*

The equity scoring method in this analysis was based on its use in the Seattle method. This method does not allow for differences in the amount each block group differs from the citywide average for each indicator to be accounted for. For example, if one block group is one percent above the average and another ten percent above the average, they are both assigned a score of one and the variability between them not accounted for. A new method of assigning equity points should be used to account for these differences and allow block groups that vary significantly from the citywide average to be identified.

### **5.3 – Recommended Methods Improvements**

#### *American Community Survey Data*

The ACS records a wider range of variables from the population and is a more recent source of data compared to the 2010 Decennial Census. These advantages make it a better source for indicators of bicycle dependent populations in an equity analysis. Although, the data the ACS provides is different from the Decennial Census and has some disadvantages which should be understood.

The ACS is not based on a 100 percent count, but gathers information from about one in thirty-eight households in the US, which means it is subject to sampling error (US Census Bureau, 2014b). All of the estimates from the ACS are published with a margin of error at the ninety percent confidence level (US Census Bureau, 2009). The ACS also collects data over the entire course of a year, rather than at a single point in time as in the Decennial Census. Data from the ACS for geographic areas under 20,000 people (which includes block groups) are published as estimates for five years and are meant to represent conditions over this sixty-month period, rather than a single point in time.

Aggregating ACS data over a five-year period, allows the estimates to be based on larger samples of the populations. This reduces the margin of error due to sampling error for five-year estimates by 3.87 times compared to one-year estimates (US Census Bureau, 2008). The use of these five-year estimates allows the changing demographic conditions in certain areas occurring after 2010 to be captured, which is not possible with 2010 Decennial Census data. The most recent ACS data currently available represents the five-year period from 2009-2013, with five-year estimates for 2010-2014 expected for release by the end of 2015 (US Census Bureau, 2008). The use of these updated estimates is especially important in areas experiencing rapid population growth, such as Seattle.

ACS data was also used as the source of indicators in the Seattle equity analysis method. It may be assumed that ACS data would have been used in the Portland method if it had been available, because 2000 Decennial Census data was nine years dated at that time. ACS data at the block

group level did not become available until 2010 (US Census Bureau, 2009), one year after the Portland method was conducted.

The use of ACS data for an equity analysis, rather than 2010 Decennial Census data, allows the use of a wider range of variables to describe bicycle dependent populations. The most important of these variables is low-income populations. The ACS also publishes new five-year estimates each year and is able to represent demographic changes occurring in rapidly growing areas. These benefits outweigh any limitations of the ACS due to sampling error and warrant its use in future equity analyses over 2010 Decennial Census data.

#### *Households without Access to a Motor Vehicle*

An additional indicator of bicycle dependent populations available from the ACS are households without access to a motor vehicle (US Census Bureau, 2013). This indicator was used in the Seattle equity analysis method (City of Seattle, 2014). It was also used to identify transit dependent populations as part of the Environmental Assessment of the Viaduct Replacement Project in Seattle (WSDOT, 2008). While this indicator may be useful to describe bicycle dependent populations, it cannot be assumed that every household without access to their own motor vehicle lacks one due to circumstances outside of their control.

For example, some people in high income areas may choose not to own a vehicle based on a lifestyle preference, though they can afford their own vehicle. If this indicator is used, it should be used in conjunction with income and only include households without access to a vehicle that fall below a certain income level. This way, higher income households that choose not to own a

vehicle based on lifestyle preferences will not be included. While it may not be assumed that all low-income households lack access to a vehicle due to circumstances out of their control, this method may improve the usefulness of this indicator to describe bicycle dependent populations.

#### *Smaller Age Range for Youth Indicator*

While not discussed as a limitation in the previous section, the inclusion of children under five years old may not be appropriate, because these children are likely not old enough to use bicycle facilities on their own. The inclusion of children less than five years old as part of the youth indicator was based on their inclusion in both the Seattle and Portland methods. Future equity analyses may consider only including children ages five to seventeen as this may provide a more accurate depiction of the bicycle dependent youth population.

#### *Additional Scale of Analysis*

The limitation of using only one scale of analysis has already been mentioned. To address this problem, the census tract scale was suggested as a larger scale to complement the block group level and provide additional context. A different, larger scale (the neighborhood scale), may provide more useful results. The City of Seattle does not designate any official neighborhood boundaries, but the Seattle City Clerk's Office has designated unofficial neighborhood boundaries for internal purposes in a Neighborhood Atlas (City of Seattle, n.d.). A total of 36 neighborhoods are identified in this Neighborhood Atlas for the City of Seattle. This list does not include a number of smaller colloquial neighborhood names such as Tangletown or Ballard Interbay, though it is assumed that people in these smaller neighborhoods can identify with their larger neighborhoods.

These unofficial neighborhood boundaries have been designated in shapefiles accessible through WAGDA. The same method of calculating bicycle facility miles per square mile in block groups may be used to calculate bicycle facility miles for each neighborhood in the Neighborhood Atlas. With a total of 36 unofficial neighborhoods throughout the City of Seattle according to the Neighborhood Atlas (City of Seattle, n.d.), these neighborhoods could be placed in quartiles and those with the lowest levels of bicycle facility access identified.

While Census data is not provided at the neighborhood level, there are ways that the equity scores generated for block groups may be used to create average equity scores for each neighborhood. For example, block groups contained by more than fifty percent in a given neighborhood may be assigned to that neighborhood. Each neighborhood may be assigned an average equity score based on the total equity scores of all block groups within its boundaries. This would provide a rough equity score for each neighborhood, which could be supplemented in detail by the specific equity scores for each block group in each neighborhood.

Another advantage of using the neighborhood scale of analysis is that people tend to identify with the neighborhoods they live in, rather than census generated boundaries. It is also difficult to place block groups into context on a map without neighborhood boundaries as points of reference. Finally, if an entire neighborhood is shown to have relatively low levels of access, the smaller scale of analysis may be used to identify where this low level of access is located within a certain neighborhood.

### *Additional Measures of Access*

The use of an additional measure of access to the bicycle network can help to create a more accurate understanding of the bicycle facility development opportunity within each chosen area. Bicycle facility miles per square mile, in some cases, may not accurately represent the opportunities for bicycle facility development in a specific area and provide misleading conclusions.

An additional measure of access that may be used is bicycle facility miles per mile of bicycle-appropriate street network. The use of this measure of access would help correct for differences between two study areas which differ in square miles of land and the amount of street network available. Streets not suitable for bicycle facilities, such as highways, interstates and some bridges would need to be eliminated from consideration in the street network used to calculate access. One other measure of access which may be used is bicycle facility miles per person in each study area. This measure is not influenced by the variability in geographical size of each study area. Areas that include land uses not suitable for bicycle facility development would not be shown to have relatively low levels of access using these additional methods. This may help provide clarity and context for the areas of Seattle identified with low levels of access and high equity scores, mentioned previously.

### *Equity Scoring Method*

A number of possibilities exist to modify the chosen method of assigning equity scores to each block group. Instead of assigning a one or zero based on a block group being above or below the citywide average for an indicator, the degree to which each block group deviates from the citywide average may be used to assign its equity score.

For example, the average percentage of youth under eighteen in Seattle by block group is about fifteen percent. Block groups between fifteen and twenty-five percent may be given a score of one, and block groups above twenty-five percent a score of two. In this way, two block groups both above the citywide average, but one significantly higher than the other, may be differentiated. Alternatively, block groups may be given a score of one only if they are above a given threshold, such as ten percent or one standard deviation above the citywide average. This general approach is used by transit agencies to establish thresholds for when disproportionate burdens or disparate impacts occur for specific populations. For example, Pierce Transit defines a disparate impact as occurring in a specific area when the minority population in that area is ten percent above the average minority population in their entire service area (Pierce Transit, 2013). These approaches will lead to a more informative equity score that accounts for more variability and provides a greater level of detail than a simple binomial scoring system. It also ensures that two block groups above the citywide average, but one significantly higher than the other, are not treated the same and their differences accounted for.

Another variation to the equity scoring method is to weight the equity indicators differently from one another. For example, equity scores relating to income or race may be weighted higher than other indicators. Justification of this weighting may be made from academic literature, such as assigning different weights based on the degree a chosen indicator correlates with reliance on alternative transportation. Equity scores may also be weighted based on indicators of particular concern in the specific city or area the equity analysis is being conducted.

### *Fixed Levels of Access*

The use of a quartile ranking system to assess the varying levels of bicycle facility access of each study area is useful as a baseline measure and is appropriate for use in an equity analysis. It allows study areas with the lowest levels of overall access to be identified relative to other areas. As the bicycle network continues to be built, a quartile system should be used to ensure that areas with high equity scores are not consistently in the lowest quartile of access.

However, benchmarks for achieving equity should also be based on raising network access to a defined level and not solely on raising a study area out of the lowest quartile of access. The problem with only focusing on raising a study area's status in a quartile ranking system is that when one area's rank is raised, another study area's rank lowers. In this sense, there will always be the same number of study areas in the lowest quartile and progress toward increasing access hard to measure or achieve. Establishing fixed levels of access, independent of a quartile ranking system, allows these benchmarks of access to be achieved in the areas identified.

## 6 - CONCLUSION

The provision of transportation networks across an area or city inevitably leads to differences in the benefits and burdens experienced by people in these areas due to these networks (Martens et al, 2012). The use of an equity analysis brings some level of understanding to how these benefits and burdens are distributed across an area. This analysis sought to identify areas of Seattle with high proportions of bicycle dependent populations and low levels of bicycle facility access.

The initial findings from this method indicate that block groups around the neighborhoods of Haller Lake in north Seattle, and south Delridge, South Park, and the Rainier Valley in south Seattle have high proportions of bicycle dependent populations and low levels of access. In addition, block groups with higher than the citywide average of youth and older adults were found to have significantly lower levels of access compared to block groups with lower than the citywide average of these indicators. These results should form the basis for investigation into opportunities to modify or expand the bicycle network to correct these inequities. Further analysis is required, based on limitations of the methods chosen, to validate and provide additional context to the initial results.

These limitations mainly involve the source of data and the measure of access chosen. 2010 US Decennial Census data was exclusively used to supply demographic variables, but was extremely limited in its ability to supply relevant variables for bicycle dependent populations. Its lack of income related data was highlighted as the main concern with the chosen methods. Due to the time this analysis was carried out (2015), the ability of 2010 data to accurately describe current conditions in Seattle was also raised as a concern. The measure of access chosen, bicycle facility miles per square mile, is limited in its ability to provide an accurate measure of bicycle facility

access due to variability in street network density and overall size differences between block groups.

Based on these limitations, a number of improvements to the methods were recommended.

American Community Survey data was recommended for use because of its increased depth of variables available to identify bicycle dependent populations, especially income related data, and for its ability to depict changing demographic conditions in Seattle. A new equity scoring method was suggested to account for variability between block groups. The use of a neighborhood scale of analysis, in addition to the block group scale, was recommended to provide overall neighborhood levels of access and because of people's tendency to identify with their neighborhood, not census designated areas. The use of fixed levels of access as benchmarks to achieve when improving levels of access in specific areas was suggested rather than only aiming to improve an area's ranking in a quartile system. These recommended improvements are meant to provide direction for the future equity analysis needed to validate these results as well as for equity analyses conducted in other communities.

Finally, it should be acknowledged that the use of an equity analysis in the creation and modification of a bicycle network is only one aspect of the entire process. The need for an equity analysis as part of the creation of a bicycle network has been established through discussion of Federal and Local Orders and Initiatives relating equity and transportation (Federal Register, 1994; FHWA, 2012; City of Seattle, 2015b; King County, 2010). What an equity analysis does not examine are other important issues such as the level of safety and connectivity of a bicycle network, the two highest rated prioritization categories in the 2015 Implementation Plan for the

Seattle Bicycle Network (City of Seattle, 2015). Aiming to only address equity related issues leaves out these other important issues and may not lead to the development of a bicycle network that provides safe bicycle facilities that lead to relevant destinations or form a well-connected overall bicycle network. The responsible balancing of equity, along with these other issues represents one of the many difficult tasks facing cities in the creation of a bicycle network.

## 7 - REFERENCES

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## 8 – APPENDIX

### *Data Dictionary*

#### Census Data

- Census 2010 Block Groups
  - Source: US 2010 Decennial Census
  - Spatial Scale: This data was extracted to cover the entire Seattle Municipal Boundary.
  - This dataset was obtained from the WAGDA Census Geodatabase (<https://wagda.lib.washington.edu/data/type/census/geodb/>)

#### Bicycle Network Data

- Citywide Bicycle Network
  - Source: Seattle Department of Transportation (SDOT)
  - Spatial Scale: This data was downloaded to cover the entire Seattle Municipal Boundary.
  - Temporal Scale: This data is current as of 12/2014
  - This Network dataset contains the Citywide Network portion of the complete Bicycle Network. I combined this with the Local Connector Network to create a Complete Bicycle Network Dataset.
  - This dataset is also broken up into the existing and the proposed portions of the network and was used to create datasets that represent what is currently built and what will eventually be built.
- Local Connector Bicycle Network
  - Source: Seattle Department of Transportation (SDOT)
  - Spatial Scale: This data was downloaded to cover the entire Seattle Municipal Boundary.
  - Temporal Scale: This data is current as of 12/2014
  - This Network dataset contains the Local Connector Network portion of the complete Bicycle Network. I combined this with the Citywide Network to create a Complete Bicycle Network Dataset.
  - This dataset is also broken up into the existing and the proposed portions of the network and was used to create datasets that represent what is currently built and what will eventually be built.