EQUITY OF ACCESS TO BICYCLE INFRASTRUCTURE

GIS methods for investigating the equity of access to bike infrastructure

BY RACHEL PRELOG
TEXAS A&M UNIVERSITY

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CONTENT

RACHEL PRELOG holds a bachelors degree in Landscape Architecture from Colorado State University and is a graduate student in the Department of Landscape Architecture and Urban Planning at Texas A&M University. She currently works for the FC Moves department at the City of Fort Collins, Colorado. Her professional and academic interests in the built environment, sustainable transportation, social equity, and public health have led her to research equity issues related to healthy modes of transportation.

ON THE COVER: Traffic in a Chicago bike lane. Photo by Steven Vance.

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INTRODUCTION

Equitable transportation is more than a buzzword. The effort to make transportation accessible and safe for Americans from all socioeconomic and racial backgrounds has taken root in grassroots advocacy organizations, national foundations and even in the U.S. Congress.

The benefits of transportation investments are not distributed equally among communities, as some social groups have not reaped the rewards of developed transportation infrastructure. While the discussion of transportation equity has largely focused on accessibility to transit and the provision of auto-dominated infrastructure, a growing number of advocates and community organizations are calling for the consideration of bicycle equity in the conversation about current and future bicycle infrastructure development projects. Similar to overall transportation equity, bicycle equity seeks fair treatment and meaningful involvement in policy formation and decision-making regardless of race/ethnicity, national origin, or income and it explicitly seeks an equitable distribution of benefits from bicycle facility investments.

The purpose of this report is to provide tangible GIS methods for investigating the equity of access to bicycle infrastructure. In order to develop a full understanding of the context behind the methods, it will provide an overview of equity issues and define types of transportation equity paradigms related to bicycle equity. There is no single best way to measure access and bicycle equity for the variety of cities where bicycle equity is in question. However, this report provides a framework for how GIS can be used as a tool in decision-making and advocacy efforts with the understanding and provision that every community has a unique perspective, values, and equity concerns and may choose to apply different criteria to creating their own understanding of equity.

Who might find this report useful? Bicycle advocates, city or state staff, or anyone else who is interested in equitable transportation. Infrastructure is one element of the larger bike equity picture, but the visuals that this formula can create are a helpful tool in convincing stakeholders that inequitable planning is a problem. This gives you a tangible map for improvement and growth.

EQUITY

What is Transportation Equity?

In broad terms, equity is the guarantee of fair treatment, access, opportunity, and advancement for all, while at the same time striving to identify and eliminate barriers that have prevented the full participation of some groups. Equity objectives have been increasingly present in transportation planning documents and programs since the issue of Executive Order 12898 by President Clinton in 1994. This directive ordered all federal agencies to adopt, to the greatest extent practical and permitted by law, Environmental Justice as part of its mission.[1] However, transportation equity can be hard to evaluate because several interpretations and types of equity exist.[2] Furthermore, equity evaluations are highly susceptible to the values and concerns of stakeholders and to the equity paradigm considered. For example, policies and decisions may seem equitable when evaluated one way but inequitable when evaluated another.[3]

The EPA defines Environmental Justice as: [t]he fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate share of the negative human health or environmental impacts of pollution or environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local and tribal programs and policies.

At the highest level, transportation equity can be thought of in terms of horizontal equity and vertical equity. Horizontal equity, also called fairness and egalitarianism, is concerned with the fairness and equal distribution of impacts received between individuals and groups that share the same ability and needs. Under horizontal equity, transportation policies

1 *Clinton, William. (1994). Executive Order 12898. Federal Register 59.32 Section 1-101. Web.*
2 *Litman, Todd. (2014a). Evaluating Transportation Equity, World Transport Policy & Practice 8(2), 1-41. Web. Pg. 3*
3 *Litman, Todd. (2014a). Evaluating Transportation Equity, World Transport Policy & Practice 8(2), 1-41. Web. Pg. 3*

are equitable if they are fair, with all groups receiving similar allocations of resources and bearing equal cost. Vertical equity or outcome equity is concerned with the distribution of impacts across social groups that differ in their ability and/or need. Under vertical equity, transportation policies are equitable if they are redistributive favoring disadvantaged groups and compensating for overall inequalities.[4]

These equity concepts can be broken down further. The table below summarizes some of the more common equity definitions.

Bicycle Equity

Historically, certain segments of society have been better represented in planning decisions and investments.[5] This is true to bicycle transportation planning, as well. Therefore, bicycle equity stems from an understanding that unbalanced conditions exist that require a deeper look. It may be that some groups are better able mobilize resources to leverage their positions, realizing their needs and wants, while simultaneously marginalizing other populations.

Bicycle equity is often addressed using two main approaches, advocacy targeting special groups and advocacy for equitable spatial distribution of infrastructure. The first seeks programmatic solutions, which create special protections and services for disadvantaged groups, and increases their involvement in decision-making. The second seeks structural changes to the planning process that affect overall policies and the eventual distribution of infrastructure.[7]

This paper focuses on ways to influence structural change to the decision-making processes. It illustrates the use of GIS to identify who is benefiting from current bicycle networks and who is disadvantaged through the creation of a Bicycle Equity Index (BEI). The BEI is a composite measure that uses common indicators of disadvantage such as race/ethnicity, class, and travel characteristics. A strength of the BEI is that it provides a combined measure of disadvantage, however, some agencies and/or analysts may be interested in

4 U.S. Department of Transportation. (2013). Guidebook for State, Regional, and Local Governments on Addressing Potential Equity Impacts of Road Pricing. (Publication No. FHWA-HOP-13-033).

5 Stantchev, Damian and Merat, Natasha. (2010). Thematic Research Summary: Equity and Accessibility. Transport Research Knowledge Centre.Web. and Fruin, Geoffrey, Sriraj, P.S. (2006). "Approach of Environmental Justice to Evaluate the Equitable Distribution of a Transit Capital Improvement Program." Transportation Research Board 1924.139–145. Print.

7 Litman, Todd and Brenman, Marc. (2012). New Social Equity Agenda for Sustainable Transportation." Presented at the 2012 Transportation Research Board Annual Meeting Paper 12-3916. Web.

Table 1. Taxonomy of Transportation Equity[6]

Type	Description
Horizontal	Equal distribution of impacts between groups considered equal in ability or need
Vertical with regard to social class	Progressive distribution of impacts across groups with greater need and less ability
Vertical with regard to mobility need and ability	Equal distribution of impacts between groups that differ in their mobility ability and need
Opportunity Equity	Costs and benefits assigned in proportion to group size regardless of group characteristics
Market Equity	Costs assigned in proportion to the benefits received regardless of group characteristics
Spatial Equity	Costs and benefits are distributed equally over space
Intergenerational Equity	The extent to which costs and benefits are distributed to the present or the future

6 Litman, Todd. (2014a). Evaluating Transportation Equity, World Transport Policy & Practice 8(2), 1-41. Web. Pg. 4 and U.S. Department of Transportation. (2013). Guidebook for State, Regional, and Local Governments on Addressing Potential Equity Impacts of Road Pricing. (Publication No. FHWA-HOP-13-033). Web.

evaluating other inequality measures for varying equity objectives. To illustrate, this paper contains a case study in which various demographic measures are disaggregated and examined in relation to access coverage alongside the BEI.

These proposed methods use GIS software and U.S. Census data to spatially identify populations in relation to the provision of bicycle infrastructure. Equity is then examined through the lens of who has access to infrastructure and who does not.

CHICAGO CASE STUDY

Background

The city of Chicago boasts more than 200 miles of on-street bikeways and 36 miles of trails. Chicago's Streets for Cycling Plan 2020 set, "the framework for Chicago to be the most bike friendly city in the U.S.,"[7] by providing Chicagoans of all ages and abilities a bicycle network that is safe and comfortable to use. As Chicago moves to create a more comprehensive bicycle network most of the city will be covered in a dense network of bicycle lanes. This analysis seeks to investigate the equity of access to Chicago's current bicycle network and identify areas that would benefit from better access.

ANALYSIS

Access Coverage

This evaluation of bicycle infrastructure access was based on a fundamental understanding that access is a measure of spatial separation of human activities and services. Access to transportation is an origin-destination based measurement based on distance and/or cost.[8] To measure access to bicycle infrastructure, the home was the ideal point from which to measure this separation of people from infrastructure. The home often serves as the "first and last mile," of one's commute, both an origin point and a final destination. Importantly, since census data are collected from households it allows one to attribute indicator information to a physical location.

The operation of measuring access is referred to as "access coverage." Access coverage is determined through a buffer distance placed around a point of interest creating a catchment zone. Access is then measured by the proportion of the area that falls within the buffer compared to the area as a whole.[9]

A quarter mile buffer was used to determine whether individuals had access to bicycle infrastructure. This is a standard measure on which sustainable transportation is designed. Research suggests that living within a quarter mile of on-street bicycle facilities greatly increases the odds of bicycle use.[10]

To investigate the equity of who had access to bicycle infrastructure, demographic characteristics of residents were obtained from the 2009-2013 American Community Survey's 5-year estimates. This is the most recent census data available for which block group geometry is available.

Bicycle facilities data was obtained from the City of Chicago. The shapefiles provided data from which current conditions and a full build scenario of the Streets for Cycling Plan 2020 was analyzed. Due to the availability of current demographic data only bicycle facilities existing in 2013 were used to examine current conditions.

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7 Chicago Streets for Cycling Plan 2020 (2012) Chicago, Illinois.

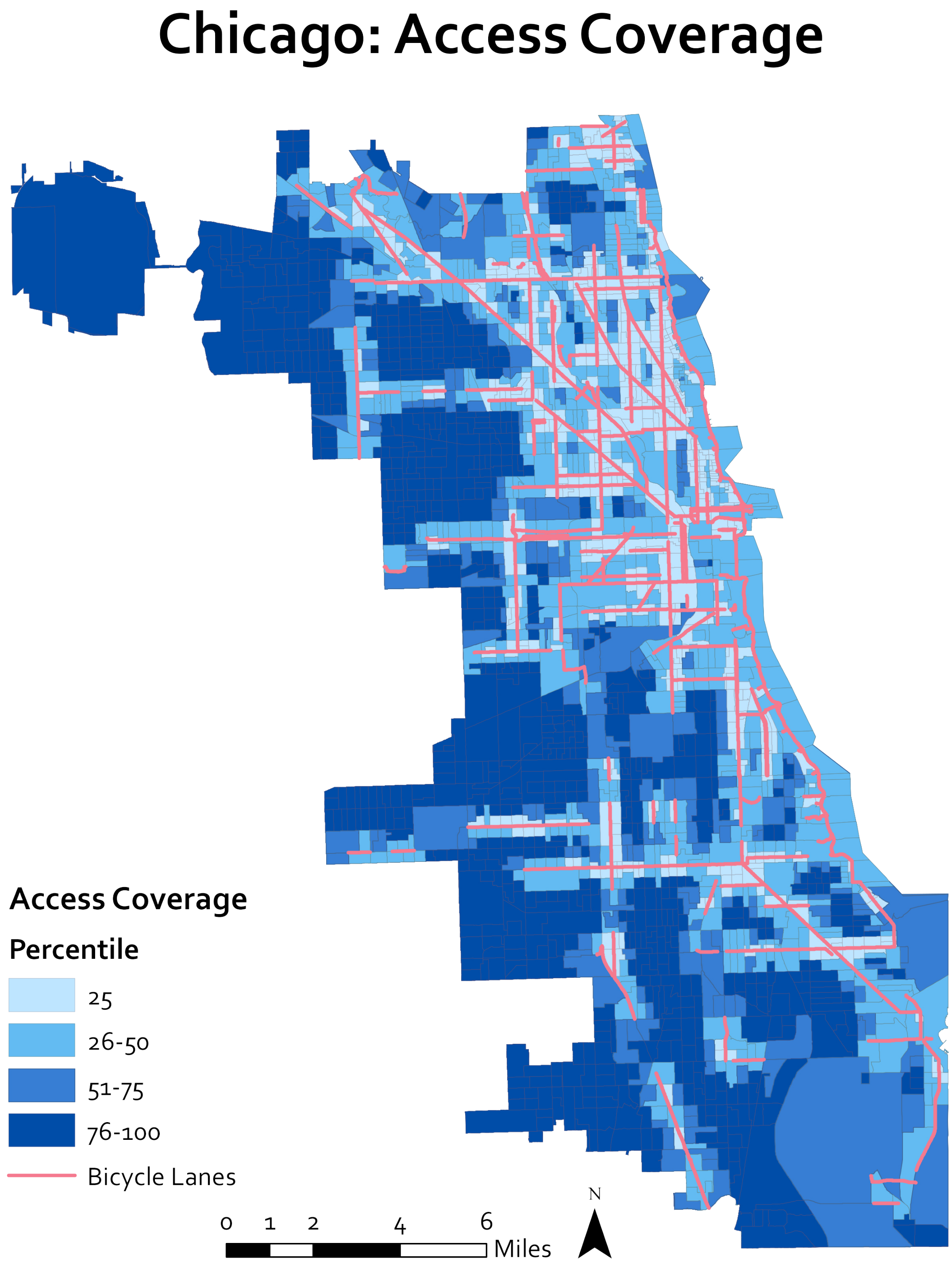
8 Kwan, M. (1998). Space-Time and Integral Measures of Individual Accessibility: A Comparative Analysis Using a Point-based Framework. Geographical Analysis, 30(3), 191-216.

9 Murray, Alan. (2003). A Coverage Model for Improving Public Transit System Accessibility and Expanding Access. Annals of Operations Research (23), 143-156. Web.

10 Krizek, Kevin J. and Johnson, Pamela. (2006). Proximity to Trails and Retail: Effect on Urban Cycling and Walking. Journal of the American Planning Association. 72.1 Web.

RESULTS

The majority of Chicago's bicycle network radiates out from its downtown and along the eastern edge of the city. This provides 49% of Chicago's block groups and 50% of its population, with average or above average access to bicycle facilities. Furthermore, the network is increasingly fragmented as on heads to the southwestern edge of the city. As a result there are several neighborhoods along the western and southern edge of the city where Chicago's residents are underserved by the current network. This not only results in a lack of transportation choices but also lower bike safety and overall health benefits for these communities as these residents are forced to travel in harsh urban conditions.

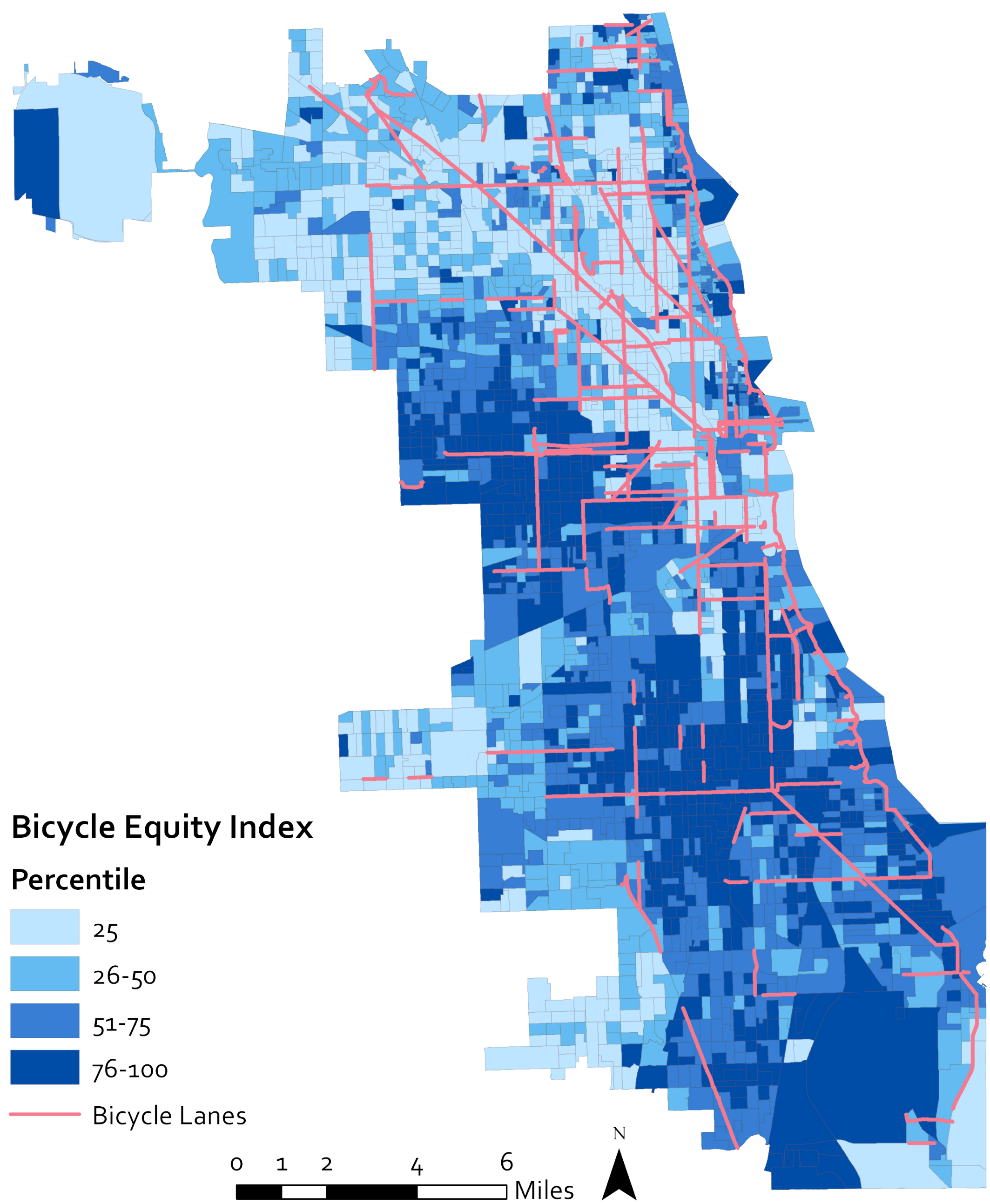


Bicycle Equity Index (BEI)

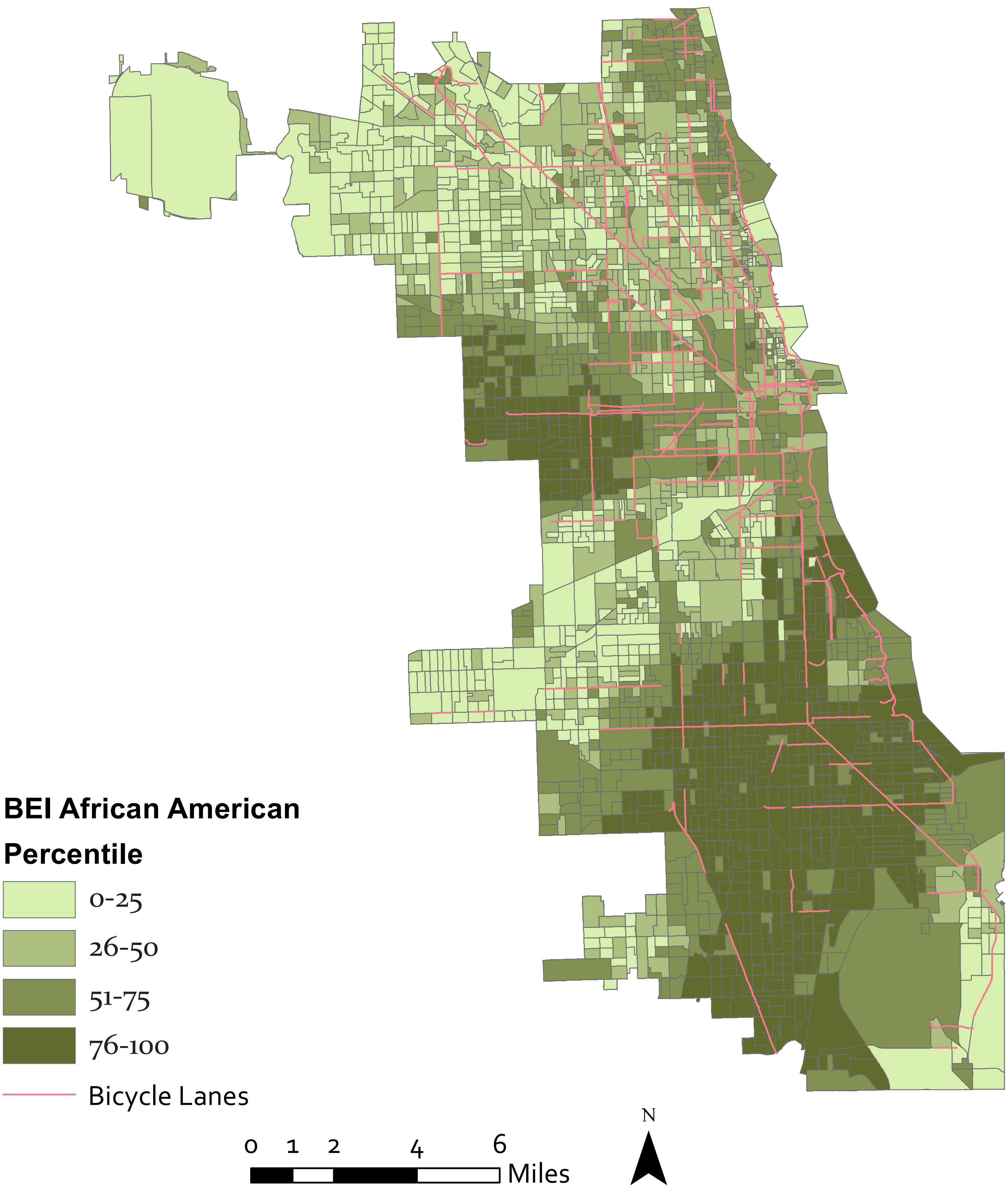
When looking at the socieeconomic characteristics of residents, disadvantaged populations identified by the BEI appear to be located primarily in West Side, Southwest Side, and Far Southeast Side neighborhoods with smaller pockets of disadvantage scattered throughout the city. The larger clusters border several highways including the I-290, US-90, and the US-90/US-94 interchange.

When these demographic groups were looked at individually one can see strong clustering of racial/ethnic groups through parts of Chicago. There are strong similarities between the distribution of disadvantaged populations identified by the BEI and the distribution of African American and Hispanic/Latino communities.

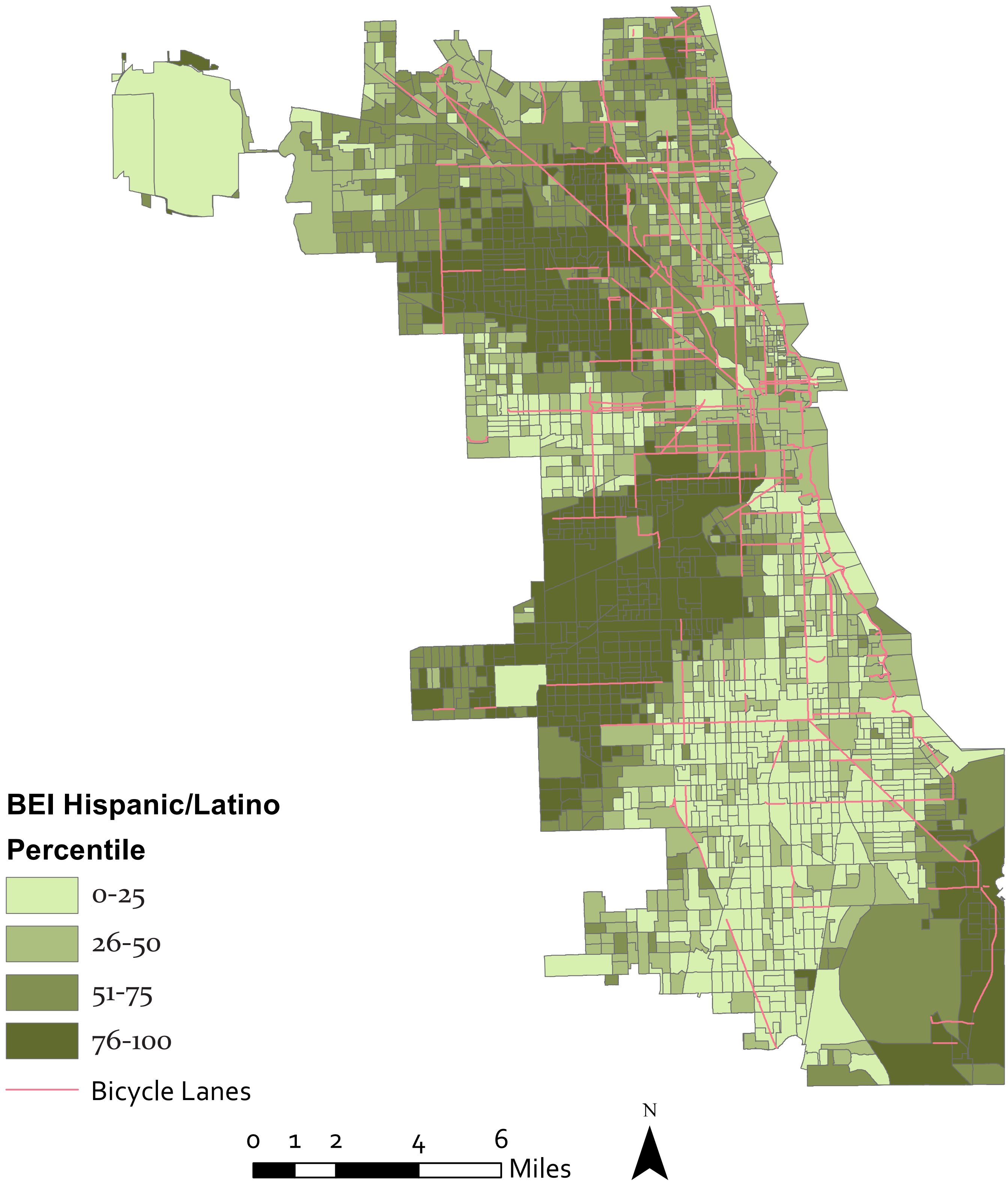
Chicago:Bicycle Equity Index



Chicago: BEI African American Population Breakout



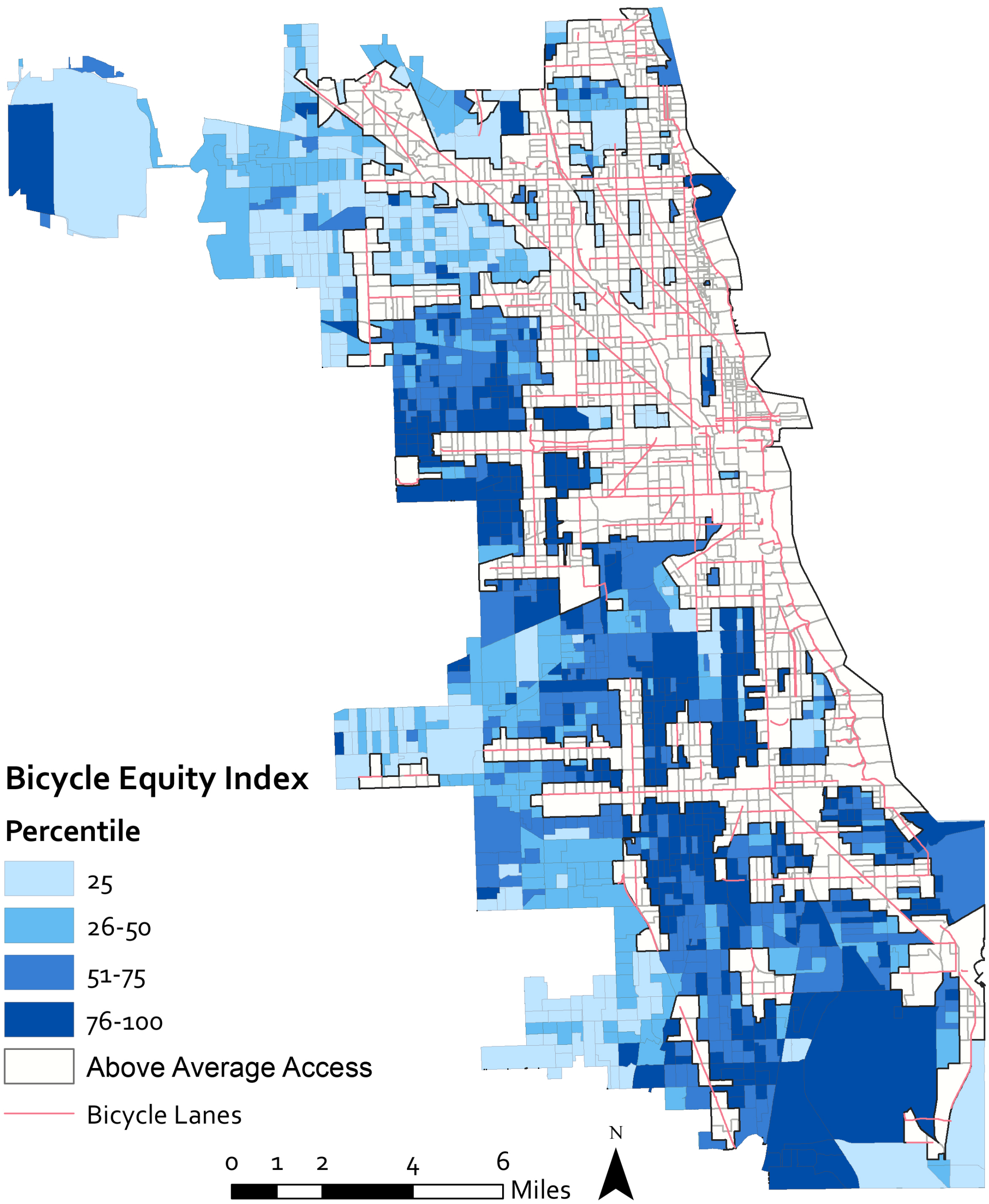
Chicago: BEI Hispanic/Latino Population Breakout



Access Coverage BEI Overlay

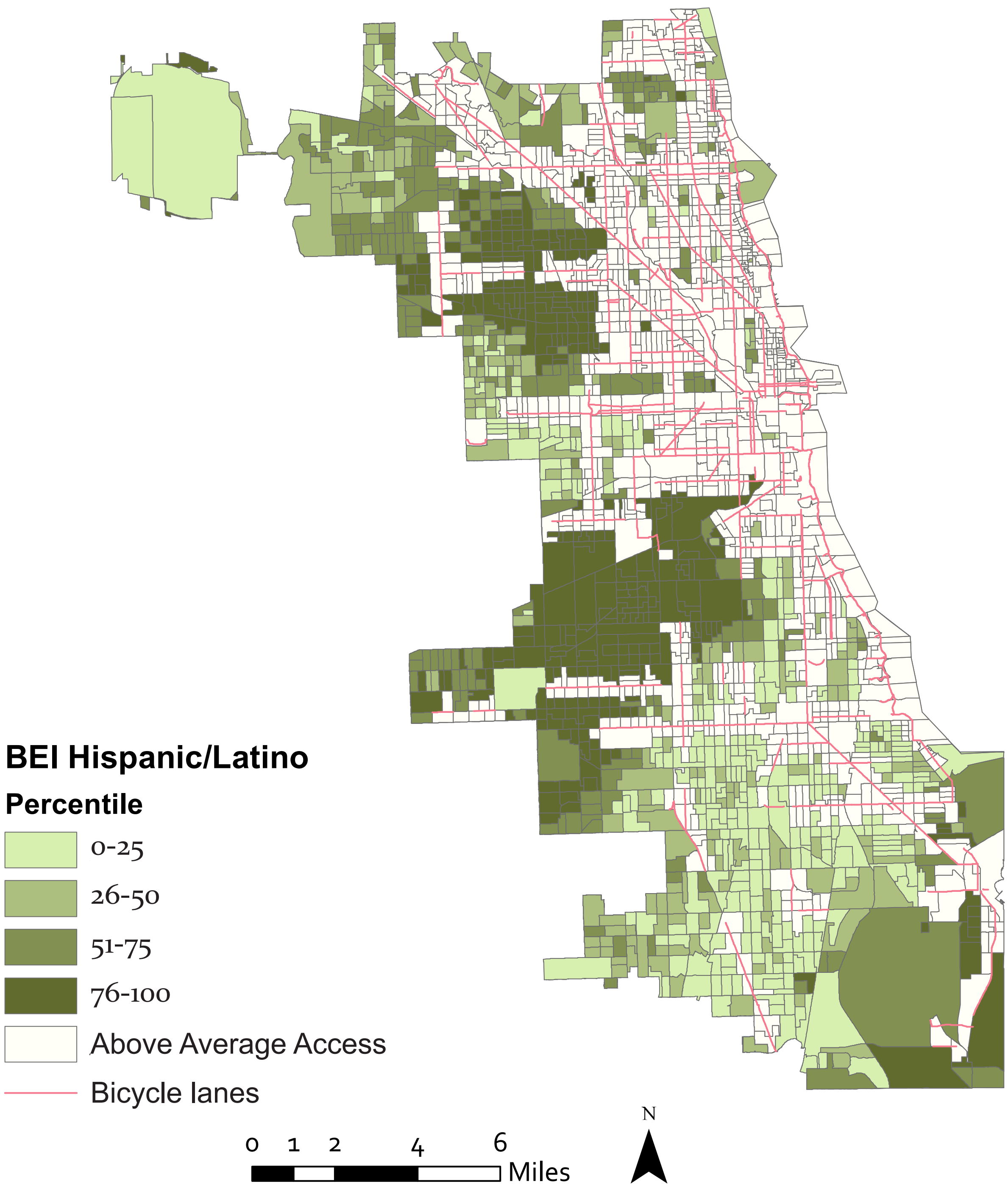
When areas of below average access are compared to the BEI, one can see that a large proportion of Chicago's underserved neighborhoods coincide with disadvantage populations identified through the BEI, notably residents living in the West Side and the Far Southeast Side neighborhoods. Furthermore, when demographic groups are examined individually, one can see a strong relationship between large pockets of minority populations and areas of below average bicycle access.

Chicago: Above Average Access Overlay



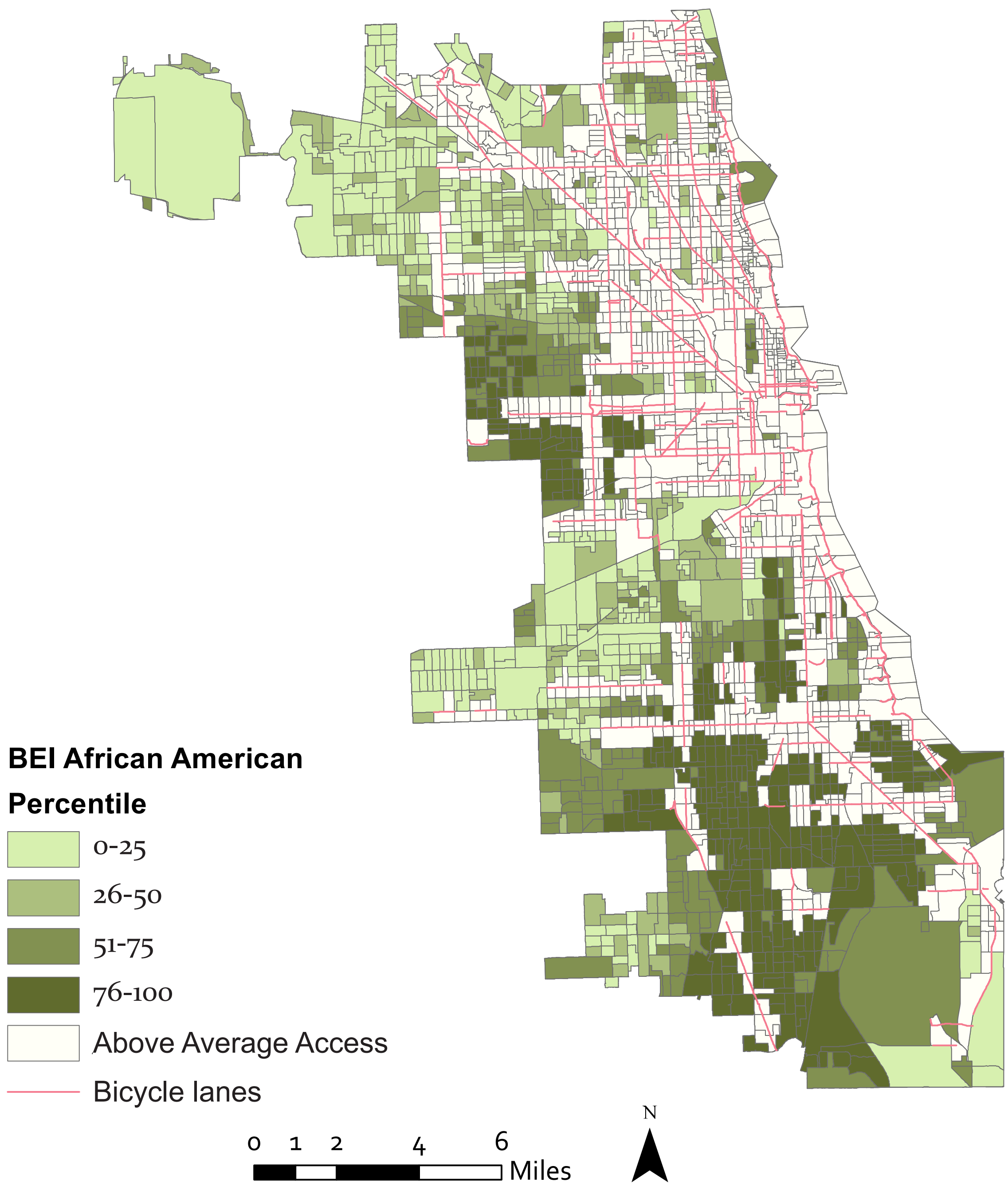
There are several significant Hispanic/Latino communities that coincide with areas of below average access in North Side, Northwest Side, and Southwest Side neighborhoods. While the Hispanic/Latino demographic accounts for 28% Chicago's overall population, they comprise 32% of the population living in neighborhoods with below average access. As a results, 57% of Chicago's Hispanic/Latino population being underserved by its bicycle network compared to 50% of the total population.

Chicago: Access Overlay Hispanic/Latino Population



Similarly, several African American communities coincide with areas of below average access in the Far Southwest Side and Far Southeast Side neighborhoods. Once again this minority population accounts for a higher proportion of the population living in underserved regions compared to the average distribution. While the African American demographic accounts for 31% of Chicago's overall population, they comprise 35% of the population living in areas with below average access. This leaves 57% of Chicago's African American population underserved by its bicycle network.

Chicago: Access Overlay African American Population

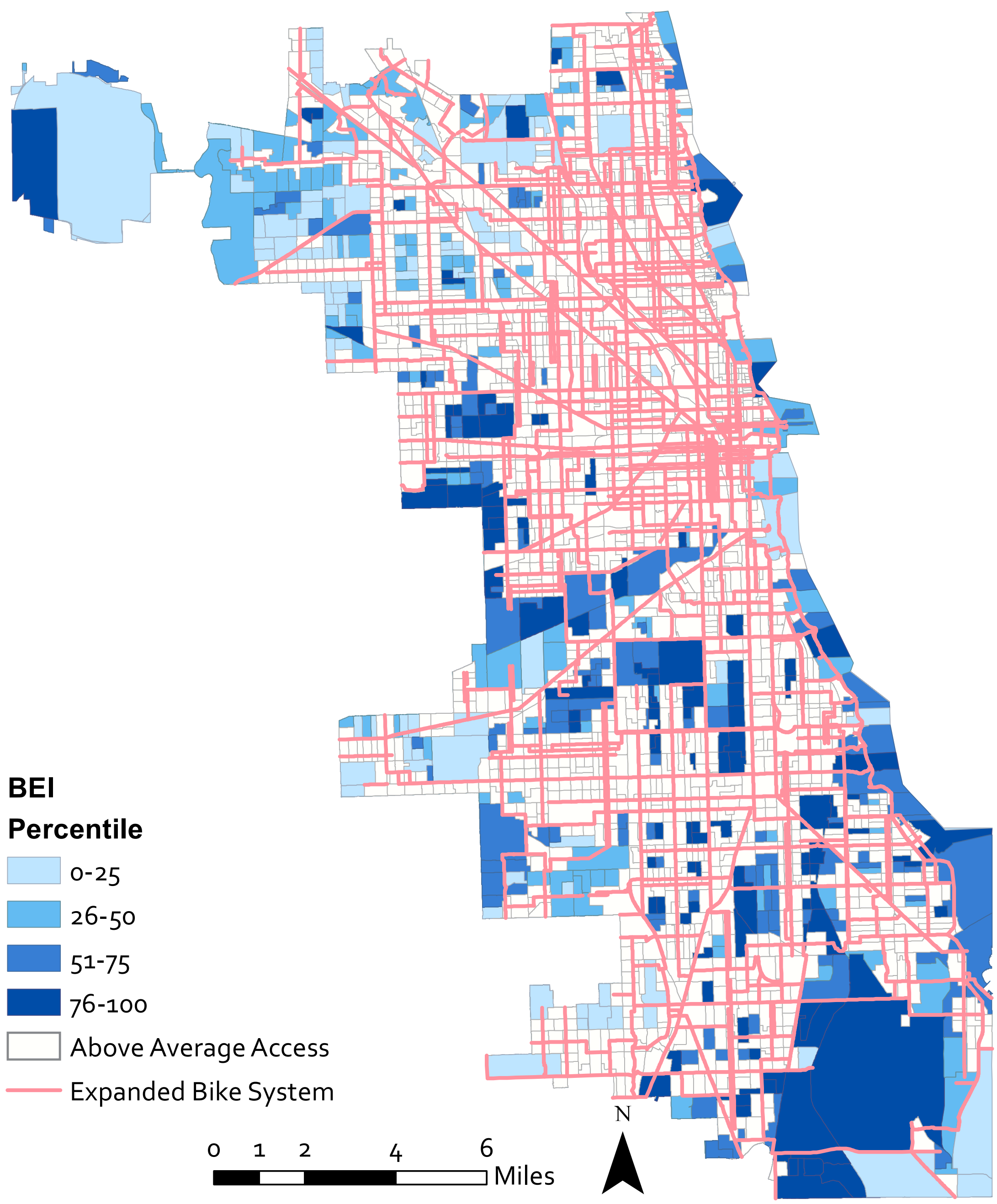


Full Build Network[II]

Changes to Chicago's bicycle network through the implementation of The Streets for Cycling Plan 2020 proposed bikeways would result in increased average or above average access to bicycle facilities for 27% of Chicago's population. Upon full implementation, 77% of Chicago's block groups would enjoy average or above average access to bicycle facilities versus the 49% that are currently provided average or above average access.

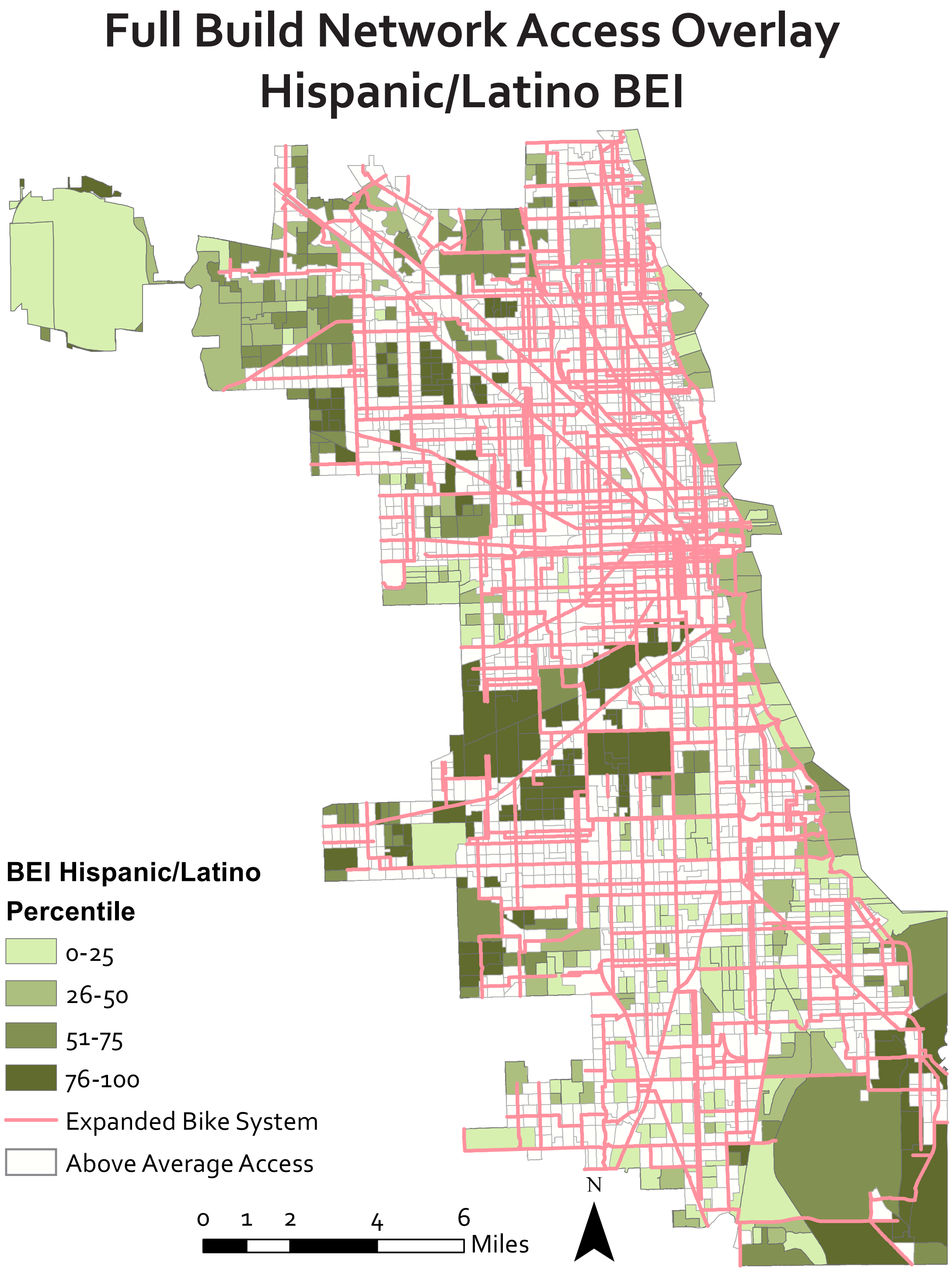
II The full build network used in this analysis consists of existing bike lanes/trails, in addition to bike routes identified in the Streets for Cycling Plan 2020. While these routes are intended for future bicycle facilities, "specific bike accommodations will be determined through the design and implementation stages of the plan" - Streets for Cycling Plan 2020 pg. 26

Full Build Network Access Overlay BEI



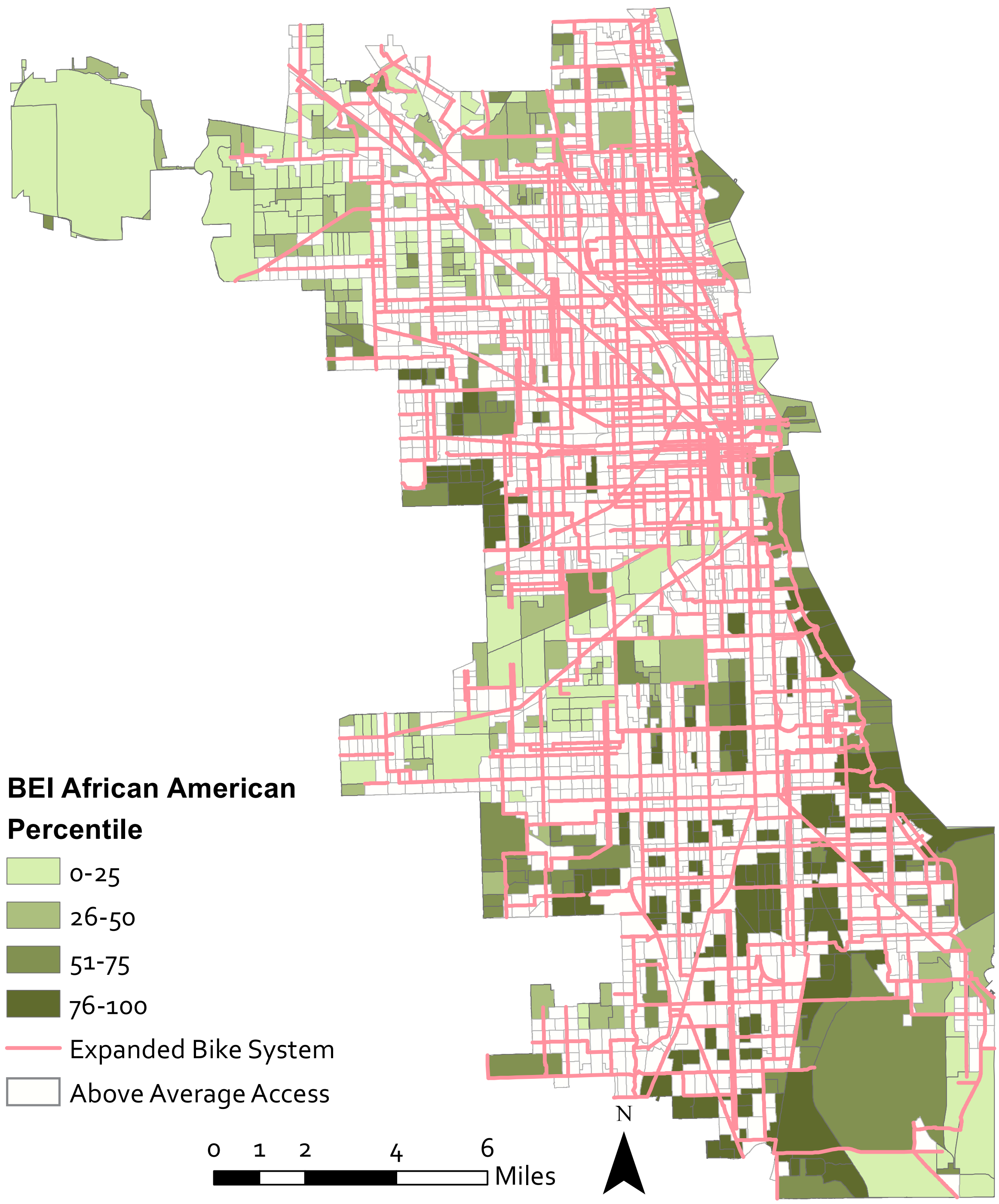
The full build bicycle network would greatly increase access for Chicago's Hispanic/Latino community by providing 32% more of its population with access to bicycle facilities. Considering that the Census Bureau has found that Hispanic/Latino's have the highest rate of biking to work of any racial or ethnic group, this increased access to bicycle facilities would go a long way towards providing healthy and safe travel options for this community. [12]

12 *https://www.census.gov/prod/2014pubs/acs-25.pdf (p. 13).*



The implementation of the full build bicycle network would similarly improve access for the African American community by providing 32% more of the population with access to bicycle facilities. Furthermore, the implementation of the full build network would reduce the proportion of the African American population living in underserved areas. Where they currently account for 35% of the population in underserved areas under the full build network they would only account for 32% of the underserved demographic.

Full Build Network Access Overlay
African American BEI



CASE STUDY CONCLUSION

By utilizing the BEI this analysis is able to provide additional context for planners and may serve as the basis for future community discussions related to current and future planning efforts. Strategic investment in underserved neighborhoods holds promise for increasing travel options, access to jobs and opportunities, increased health benefits, and the equitable distribution of infrastructure.

This case study should not be viewed as an indictment of Chicago's current or planned network, but rather one example of a pattern that may exist throughout current and planned bicycle networks where more resourced neighborhoods and communities receive the majority of current and/or future facilities. It is important that every community making transportation investments, including bicycling and walking investments, understand the potential inequities that may result from those investments and uses that understanding to ensure more equitable processes and outcomes.

METHODOLOGY

The method for investigating the equity of access to bicycle infrastructure involves the construction of a Bicycle Equity Index (BEI), mapping of the BEI to identify disadvantaged communities, and the mapping and analysis of bicycle facilities to identify access-deprived areas.

Bicycle Equity Index Indicators

The first step in the equity analysis is to identify the composition of the community living within the study area. This is accomplished by identifying the demographic and travel characteristics for the community in question. The aim is to identify communities that may benefit from the provision of bicycle infrastructure and/or are underserved by the current network. While low income and minority populations are more likely to rely on non-motorized transportation[13], those demographic indicators may not fully encompass the entire bicycle dependent population. Therefore, the Bicycle Equity Index is constructed using 5 indicators, which can be categorized into two groups, 1) Transit dependent indicators and 2) Environmental Justice indicators.

Transit Dependent Indicators

Transit dependent populations include those without cars or the ability to drive often. These people find mobility within their communities challenging and often rely on public transit and/or non-motorized transportation to gain access to their daily needs. Therefore, they have a greater need for infrastructure that provides them a safe, accessible mode of travel.

Three groups comprise this category:

- Elderly (Over 65)
- Youth (Under 18)
- Zero-Car Households

Environmental Justice Indicators

Environmental Justice is an equity framework that suggests that environmental goods are not evenly distributed in society and that access to environmental goods are stratified by race, ethnicity, and social class. Low-income and minority populations are less likely to own cars and more often rely on non-motorized forms of transportation. These groups are important to consider as they may possess a greater need of affordable modes of transportation and should be a priority for bicycle infrastructure investment.

- Minority (Non-white and/or Hispanic)
- Poverty (100% poverty level for the region)

Bicycle Equity Index Methodology

To combine several indicators into a single Bicycle Equity Index measurement, values for each indicator are standardized. Standardizing indicator variables is done by finding their z-score statistic. The z-score statistic represents how many standard deviations from the mean the value is for a particular area.

Z-score Statistic $$z = \frac{x - \mu}{\sigma}$$

A z-score of zero represents the mean or average,

13 *McConville, Megan. (2013). Creating Equitable, Healthy, and Sustainable Communities: Strategies for Advancing Smart Growth, Environmental Justice, and Equitable Development. U.S. Environmental Protection Agency's Office of Sustainable Communities. Web.*

anything greater than a zero represents values higher than the mean and anything less than a zero represents values lower than the mean. For this analysis, a positive z-score represents a higher proportion of the indicator in regards to the regional mean. To calculate the BEI, the z-scores from all 5 indicators were added together. However, only positive z-scores are used in the index construction and negative scores are converted to zero. See appendix for details about how to derive indicator z-scores.

Indicator Data Source

Census data needed for this analysis is provided by the American Community Survey (ACS). The ACS replaced the long form of the Decennial Census in 2010 and is now the source of detailed information relating to socio-economic, housing, and travel characteristics for any place in the U.S. The ACS is conducted annually; however, in order to obtain the most recent data at the largest geographic resolution available, block groups, the 5-year estimates of the ACS were used. The analyses in this report used the latest dataset available, 2009-2013, found at the Census Bureau's FactFinder website.[14]

Listed below are the data tables used to obtain the BEI indicators. Note that the data for these indicators can sometimes be found using other ACS tables.

- ACS Tables:
- ACS: B01001 Sex By Age
- ACS: B25045 Tenure by Vehicles Available By Age of Householder
- ACS: B03002 Hispanic or Latino By Race
- ACS: C17002 Ratio of Income In 2013 to Poverty Level in the Past 12 Months

Data Management

Once ACS tables are downloaded in csv format, they required data management before they are ready to be used in ArcGIS. Management entails labeling column headers, calculating the percentages of indicators per block group, calculating the mean values for the study area, calculating the standard deviation for the region, and calculating z-scores for each indicator per block group.

To calculate the indicator percentages, their raw totals are first found; this entails adding multiple columns together to create an aggregate value for each indicator. To calculate the z-score for each block group, the mean and standard deviation for all block groups in the study area must be found.

The z-score statistic was calculated using the formula: $z = (x - \mu) / \sigma$

where x is the percentage of the indicator, μ is the mean, and σ is the standard deviation.

The result of this data management process yields individual z-scores for each block group's elderly population (65 or older), youth population (under 18), zero-car household population, minority population (non-white and/or Hispanic), and low-income population (below the poverty line).

The mean was the average of all the block group indicator percentages in the data set; therefore only one value needs to be calculated. Similarly, the standard deviation is one value for the entire data set and is derived from the Block Group indicator percentages.

The z-scores from all 5 indicators are then added together to create the BEI. However, only positive z-scores are used in the index construction and negative scores are converted to zero. This eliminates indicators with negative z-scores (below average values) from diminishing the effect of other indicators. If a negative z-score is used in the index construction it would decrease the overall BEI value, making it appear less disadvantaged. For example, one would not want a low percentage of elderly population to decrease the effects of a large low-income population.

Furthermore, all indicators are given equal weight, meaning that no one indicator was thought to be more important to determining equity than another. However, the index construction may be adapted to a community's unique goals towards equity. For example, if a community thought access to bicycle infrastructure was especially important for their youth they could calculate their BEI in such a manner that block groups with a high percentage of youth would carry more weight in identifying communities in greater need of bicycle infrastructure.

14 *http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml*

Equity Index Formula

BEI = Gi+ Yi + Ci + Mi + Li

- Gi = Percent elderly z-score for Block Group i.
- Yi = Percent youth z-score for Block Group i.
- Ci = Percent zero-car household z-score for Block Group i.
- Mi = Percent minority z-score for Block Group i.
- Li = Percent low-income z-score for Block Group i.

Census Geography

In order to visualize the index in ArcGIS, census geography data is obtained and joined with the BEI. Census Block Group shapefiles, referred to as TIGER®/Line Shapefiles, can be downloaded from the U.S. Census website.[15] Users should be cognizant of the fact that block group geography changes every 10 years and that data from the ACS should match the vintage of the TIGER®/Line Shapefiles.

Note that two main problems can arise when using TIGER®/Line Shapefiles. First, using the Block Group shapefile for the entire state might lead to data processing instability. Second, using city or county boundaries obtained from other sources for the purpose of clipping the tiger shapefile down to the region could result in "slivers" and distorted geographic information because these boundaries may not match the census boundaries perfectly.

COUNTYFP is the FIPS code (Federal Information Processing Standard) and is used to uniquely identify every county in the U.S. Users can use this code to identify which county/counties are relevant to their own analysis.

Block group shapefiles are only available for the entire state. Therefore, knowing the "COUNTYFP" or block groups for the study in question is necessary in order to select only data associated with the communities analyzed. These block groups are then exported to create a "study area" shapefile for the analyses.

Bicycle Facility Data Source

GIS bicycle facility shapefiles are often available through city or county GIS portal websites. In some cases this may not be free information and requires purchase from the municipality. The quality of the shapefiles can also vary widely because there is no standard on the number of attributes attached to the shapefile. Some shapefiles may simply have ID numbers while others may specify facility type, year built, road type located on, or other attributes that may allow for a more detailed analysis. For example, shapefiles that specify facility type and/or road type located may provide an opportunity to conduct further investigation into the safety and comfort of bicycle facilities.

Most bicycle facility shapefiles require data management before they are ready to use because often these shapefiles contain both existing and proposed lanes. While, these proposed lanes are useful if one wants to look into who future development benefits, users should first determine the equity of the existing network. It is recommended that the existing lanes be selected and exported to a new shapefile to be true to the present conditions and the communities they affect.

Bicycle Facility GIS Methodology

Measuring access to bicycle infrastructure involves five operations; 1) Buffering the bicycle facilities shapefile, 2) Calculating both the area of the block groups and the area of the block group contained in the buffer, 3) Calculating areas of zero-coverage, 4) Standardizing the percentage zero-coverage in each block group to the regional average, and 5) Standardizing the percentage of the area covered by the buffer in each block group to the regional average.

Bicycle facility datasets are buffered ¼ mile; the portion of the block groups that intersected the buffer is the portion of the block group that was within a ¼ mile of a bicycle lane, and had access to the bicycle network. This buffer layer is used as an input layer to clip the "study area" shapefile, resulting in a layer in which the area of the buffer could be calculated for each block group. A separate "study area" shapefile is used to calculate the overall area for each block group and to provide a layer on which to join the clipped buffer layer to. It is important to note that the clipped buffer layer only had information for block groups that the

15 *https://www.census.gov/geo/maps-data/data/tiger-line.html*

buffer intersected. Therefore, when this layer is joined to the "study area" layer all of the block groups that did not intersect the facilities buffer are given <Null> values. In reality these null values should be represented by "0" sq. mi., however, this information can't be changed in ArcGIS. Instead, the attribute table is exported to excel to fix these <Null> values, calculate the percentage of non-coverage, and to calculate z-scores.

Z-scores are once again used to standardize the measure of access, which allows for comparison among block groups. Since these z-scores can be combined with the BEI to create a composite map, areas of non-coverage are calculated. Just as with the BEI, we would not want to add negative z-scores to the index. If areas of coverage or "access" are used to calculate z-scores, areas with below average scores would be negative. Therefore, areas of non-access are used to retain consistency of positive z-scores representing disadvantaged areas.

As with the equity indicators, the mean value for all block groups' percentages of non-coverage is found, as well as the standard deviation. Lastly the z-scores for each block group are calculated. These scores represent how much access the block group had in relation to the region as a whole. A z-score of zero represents the mean, anything greater than a zero represents areas with below average access while negative scores represents areas with above average access.

For mapping, overlay, and visualization purposes, block groups with negative z-scores are exported to create a new shapefile for areas with average or above average access. This layer represents neighborhoods that already have above average access. Since we want to easily see the areas with poor access, we can change this layer's symbology to white and simply overlay this layer on top of the BEI. This will in essence block out the block groups with average or above average access and reveal the BEI of block groups with below average access.

CONCLUSION

This analysis leaves the user with several maps that may be simply overlaid to elucidate areas in need of priority investment. However, these maps contain data that could be used for more sophisticated statistical analyses if one so chooses.

Also as there is no single best way to measure access and equity, communities may choose to apply different criteria to creating their own understanding of equity of access.

This may be done through the selection of different equity indicators, attributing weighted values to indicators, and/or the use of different buffer distances.

APPENDIX: TUTORIAL

This tutorial provides details on how to use the methods described above. While its content will cover the "how to" of using American Community Survey data, users will need a basic understanding of ArcGIS and Excel. Please ensure that all your shapefiles are projected correctly before performing the analysis in ArcGIS.

Downloading ACS Tables

While downloading the ACS data, one should note that the column fields will need to be re-labeled and the data managed before it is ready to bring into ArcGIS. ACS tables contain estimates and margins of error for each column header. Although, the margin of error is useful information is not used in this analysis and therefore was removed from the dataset. Removing the margin of error columns and any other excess data may help reduce the file size and aid its import into ArcGIS.

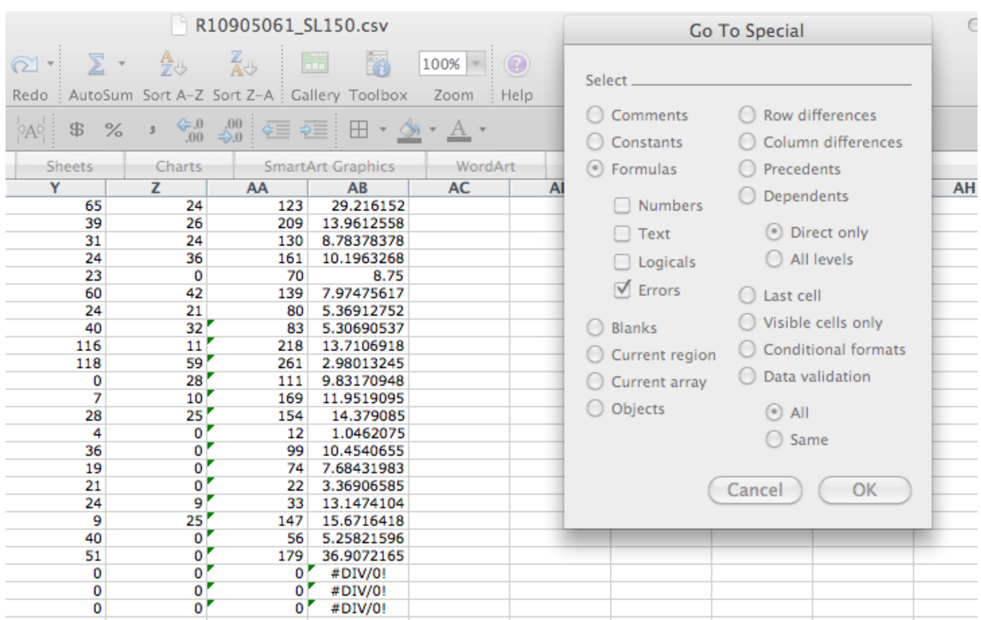
The next step in managing ACS data is to re-label column headers. Although you may choose to download data with annotation, these tables can't be brought into GIS because ArcGIS doesn't support certain special characters, spaces between words or long labels descriptions. Therefore, rename columns in a concise manner without any blank spaces.

Calculating Indicator Percentages

To calculate the percentage of these indicators we must first find their raw totals. For example, to calculate the total number of elderly and youth we will first combine genders for each age group since we are not interested in looking at males and females individually. Next we will sum pertinent fields to find the raw totals for each indicator. For example, all fields 65 yrs and older to derive total number of elderly in each block group. This operation can be preformed once in the top row and copied in the remaining cells in the column by double clicking on the lower right corner of the top cell.

Next we can calculate the percentage of elderly by dividing the number of elderly by the total population and multiplying by 100. Percentages need to be found for every block group, so once again double click on the lower right hand corner of the first cell you calculated to populate all the other cells in the column.

Before we move on, please be aware that some block groups might have a zero population. This will lead to an error when percentages are calculated and will cause a problem for further calculations. Therefore, we must first find these #DIV/0! errors and replace them with a "0" value. Highlight the indicator's percentage column you are working on and press the F5 key to open the Go To dialogue box. Click the Special button to get to the dialogue box, check the Formula and Errors options. All the cells that contain a #DIV/0! Error will now be highlighted. To replace these values enter 0 and press Ctrl + Enter, this will automatically replace all the errors with a "0" value.



Calculating Indicator Mean and Standard Deviations

In order to calculate the z-score of individual block groups we must first calculate the mean and standard deviation of all the block groups in the study area. To find the mean we will use the AVERAGE function and select all the cells within column (percent > 65 yrs). Take this value, copy and paste it into the rest of the cells into a new column you have created for (>65 mean).

Z	AA	AB	AC	AD
>85	>65yrs	percent_>65	>65_mean	
0	0	0	=AVERAGE(AB2:AB3994)	
0	231	9.40553746		
10	53	2.54074784		
14	59	3.29608939		
20	213	4.53095086		
0	19	2.3030303		
62	304	23.5658915		
7	17	1.31477185		
16	123	13.9455782		
228	547	25.524965		
85	282	20.3463203		
0	17	1.02781137		
9	134	9.31849791		
27	41	4.29319372		
13	106	4.60669274		
0	47	4.34782609		

To find the standard deviation we will use the STDEVA function, once again select all the cells in the column (percent > 65 yrs). Just as you did with the mean, take the value you derived for the standard deviation, copy and paste it into the rest of the cells in the new column you created for (>65 standard deviation).

AA	AB	AC	AD	AE	AF
>65yrs	percent_>65	>65_mean	>65_stddev		
0	0	12.7606662	=STDEVA(AB2:AB3994)		
231	9.40553746	12.7606662			
53	2.54074784	12.7606662			
59	3.29608939	12.7606662			
213	4.53095086	12.7606662			
19	2.3030303	12.7606662			
304	23.5658915	12.7606662			
17	1.31477185	12.7606662			
123	13.9455782	12.7606662			
547	25.524965	12.7606662			
282	20.3463203	12.7606662			

Calculating Indicator Z-score Statistic

Finally, we are ready to calculate the z-scores for all the block groups. The z-score statistic is calculated using the formula $z = (x - \mu) / \sigma$ where x is the value of the indicator (e.g. percent >65), m is the mean, and s is the standard deviation. In excel we will use the STANDARDIZE function: =STANDARDIZE(x, mean, st_deviation). To copy this formula and calculate the z-scores for the remaining cells in the column, double click on the lower right corner of the cell.

AA	AB	AC	AD	AE	AF	AG
>65yrs	percent_>65	>65_mean	>65_stddev	>65_zscore		
0	0	12.7606662	8.63150317	=(AB2-AC2)/AD2		
231	9.40553746	12.7606662	8.63150317			
53	2.54074784	12.7606662	8.63150317			
59	3.29608939	12.7606662	8.63150317			
213	4.53095086	12.7606662	8.63150317			
19	2.3030303	12.7606662	8.63150317			
304	23.5658915	12.7606662	8.63150317			
17	1.31477185	12.7606662	8.63150317			
123	13.9455782	12.7606662	8.63150317			
547	25.524965	12.7606662	8.63150317			
282	20.3463203	12.7606662	8.63150317			
17	1.02781137	12.7606662	8.63150317			

Combining Indicator Tables

Once these steps have been completed for each indicator (youth, elderly, 0-car households, poverty, and minorities), their z-scores are ready to be combined in one excel spreadsheet to calculate the BEI. To calculate the BEI we only need the z-scores, however, having the indicator percentages all in one spreadsheet may be convenient for the user if they want to look at other measures in GIS.

Creating Bicycle Equity Index

To calculate the BEI the z-scores from all 5 indicators will be added together. However, only positive z-scores are used in the index construction and negative scores are converted to zero. Therefore, we must replace all the negative z-scores with a "0" value. To do this we will use the formula: =IF(A2>0,A2,0) where A2 = the column of the indicator you are working on. For this demonstration A2 = AH2. Note, the find and replace function will not work for this operation. It will replace the negative value with a "0" but retain its original value during other calculations. For example, if one used this method to replace a "-3" with a "0", when they add the "0" to a "2" it will equate to "-1" instead of "2" because excel still recognized its original value.

AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
nonwhite_zscc	0_car_zscore	per>65_z	per<18_z	pov_z	no_0_nonwhit	no_0_0_car_z	no_0_>65_z	no_0_<18_z	no_0_pov_z
0.05596994	1.88496254	-1.4783828	-1.3128987	0.18348611	=IF(AH2>0,AH2,0)				
0.93724512	2.91243541	-0.3887073	1.70580176	1.56766453					
-0.4804275	0.5382582	-1.1840253	-0.7153904	-0.0394886					
0.60612376	0.28461585	-1.0965155	-0.3510676	0.75110335					
0.76550354	-0.1718364	-0.953451	1.01374422	1.1462936					
-0.0944739	0.14019705	-1.211566	-0.9446182	0.65474786					
0.11873065	1.83570451	1.25183587	-1.2545893	0.79379826					
0.19284292	0.92047968	-1.3260604	0.26369434	0.70131141					
-0.4274449	1.08684793	0.1372776	-0.9199886	-0.0873601					
-0.0509656	1.09272059	1.4788037	-0.3117068	1.73498402					
-0.4430013	1.45998122	0.8788335	-1.9302383	-0.1246934					

To populate the other cells grab the bottom right corner of the cell you calculated and drag it to the right 4 columns for the remaining 4 indicators. This will copy for the function for the columns to the right of the cell used in the formula (AH2), so ensure that the 4 other indicators are to the right of this column. You will see that after this function all the negative z-scores were converted to "0". Finally, to calculate the equity index use the formula:

BEI = Gi+ Yi + Ci + Mi + Li
Gi = Percent elderly z-score
Yi = Percent youth z-score
Ci = Percent zero-car household z-score
Mi = Percent minority z-score
Li = Percent low-income z-score

Sheets	Charts	SmartArt Graphics	WordArt				
	AM	AN	AO	AP	AQ	AR	AS
	no_0_nonwhit	no_0_0_car_z	no_0_>65_z	no_0_<18_z	no_0_pov_z	Equity_Index	
1	0.05596994	1.88496254	0	0	0.18348611	=sum(AM2:AQ2)	
3	0.93724512	2.91243541	0	1.70580176	1.56766453		
6	0	0.5382582	0	0	0		
5	0.60612376	0.28461585	0	0	0.75110335		
6	0.76550354	0	0	1.01374422	1.1462936		
6	0	0.14019705	0	0	0.65474786		
6	0.11873065	1.83570451	1.25183587	0	0.79379826		
1	0.19284292	0.92047968	0	0.26369434	0.70131141		
1	0	1.08684793	0.1372776	0	0		
2	0	1.09272059	1.4788037	0	1.73498402		
4	0	1.45998122	0.8788335	0	0		

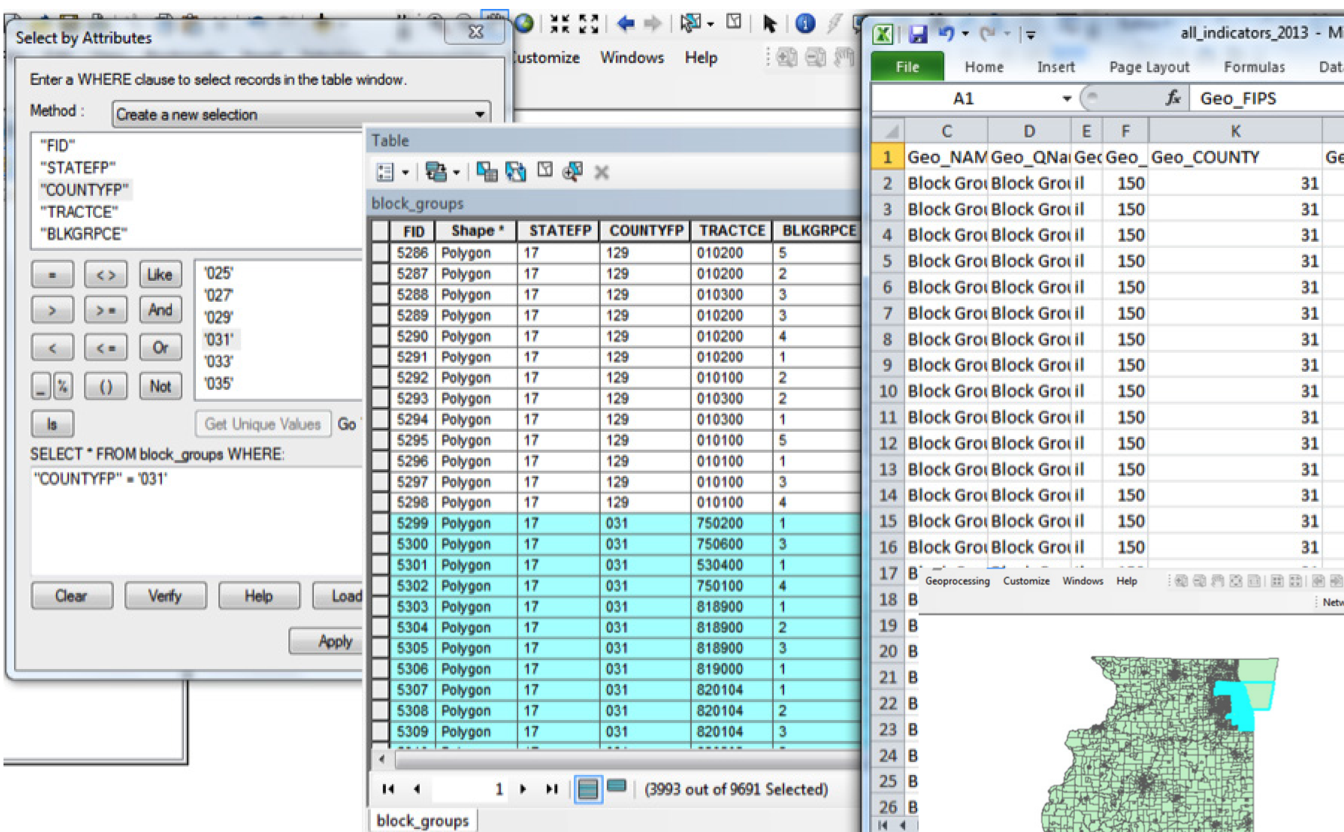
Once you have completed this step the BEI is ready to be visualized in GIS. Make sure to save the file as a csv.

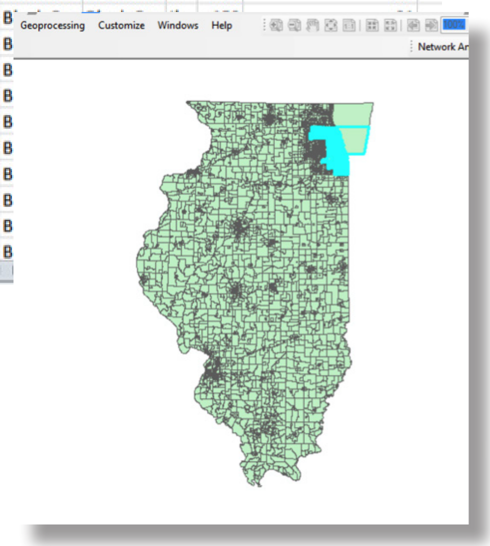
Census Geography

In order to visualize the BEI in ArcGIS, census geography data must be obtained and joined with the calculated BEI for a given location. Census block group shapefiles, referred to as TIGER®/Line Shapefiles, can be downloaded from the U.S. Census website, https://www.census.gov/geo/maps-data/data/tiger-line.html.

Users should be aware that block group geography changes every ten years and that data from the ACS should match the vintage of the TIGER/Line Shapefiles. Block Group shapefiles are only available for the entire state. Therefore, knowing the "COUNTYFP" for the study will be necessary in order to select data associated with the community being analyzed. The COUNTYFP is the FIPS code (Federal Information Processing Standard) and is used to uniquely identify every county in the U.S. Users can identify which county is relevant to their own analysis. You can find this information by referencing any of the ACS tables you downloaded to create the BEI. Please note that this county code will be under the heading Geo_County as opposed to COUNTYFP in your ACS tables.

Next we will create a new layer with only the block groups we are interested in for this analysis. To do so open the attribute table for your TIGER®/Line shapefile, in the upper left corner open the Table Options drop down box, open Select By Attributes and enter the formula: "COUNTYFP" = 'xx' where "xx" is the county code you're interested in. Notice that now only the county you're interested in is highlighted in blue.





To create a new layer with only this county's shapefiles, right-click on the layer and select Data, Export Data. Select 'Yes' when ArcMap asks if you want to add the exported data to the map as a new layer. You may turn off the original TIGER®/Line Shapefile or remove it from your map now that we have a new layer with only the region we're interested in.

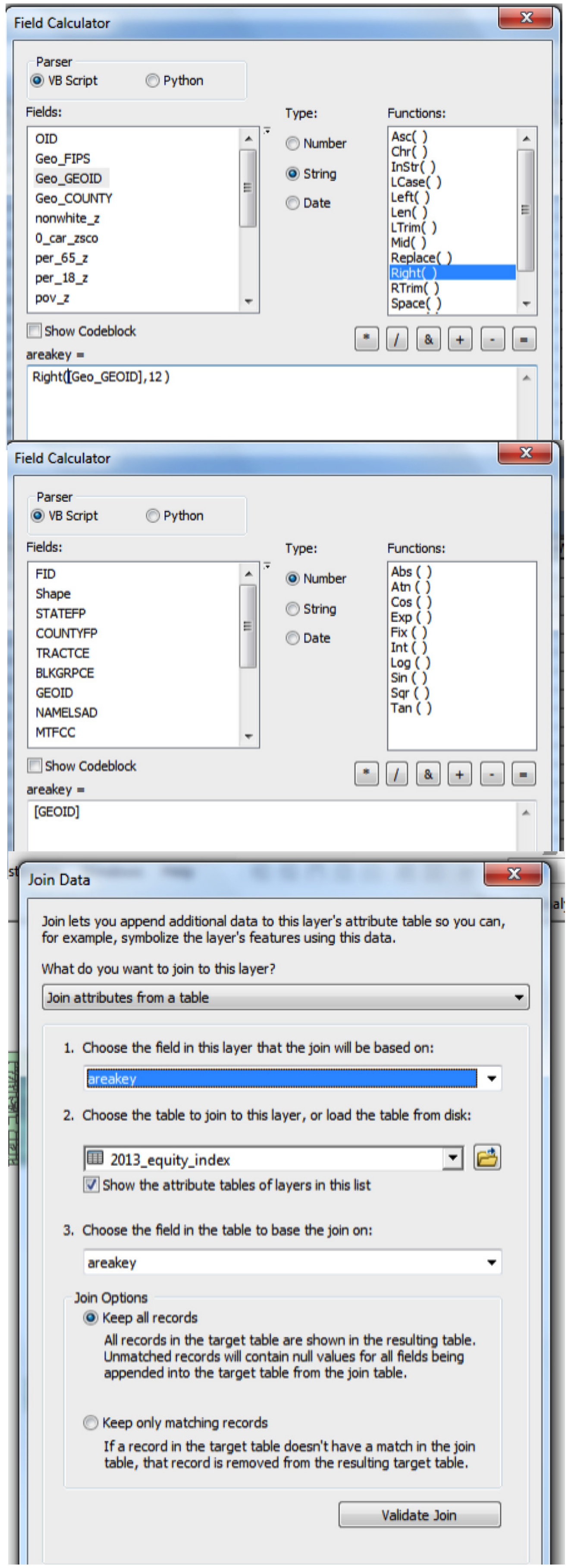
Joining the Bicycle Equity Index to Census Geography

Now we can add the BEI csv into ArcMap, but before we can move on we must export this format to a database. Right-click on the BEI csv, go to Data and Export. Name the file whatever you like and save it as a dBase Table. Allow ArcMap to add it to the current map.

To join the BEI to the block group shapefile we must create a common field to base the join upon. Open the attribute table of the BEI dBase table you just created. We will be creating a field that tells ArcMap how to join together our census data with the census geography. This will be based off of the GeoID, a unique indicator for each block group. If you open the attribute tables for the census geography and the ACS data you will notice that these GeoIDs do not contain the same number of characters, the GeoID for ACS data has 8 extra leading characters. We need to select out the last 11 characters to join to the census geography shapefile. In the BEI dBase's attribute table, open the Table Options drop down box, and choose Add Field. Note that you can't name this new field the same name as the existing Geo_GEOID. Choose text under Type and rename this new field, this tutorial uses the field name areakey. To populate this new field, right click on the areakey column header and go to Field Calculator. We will be using the string function Right ( ). Use the formula: areakey= Right([Geo_GEOID],12).

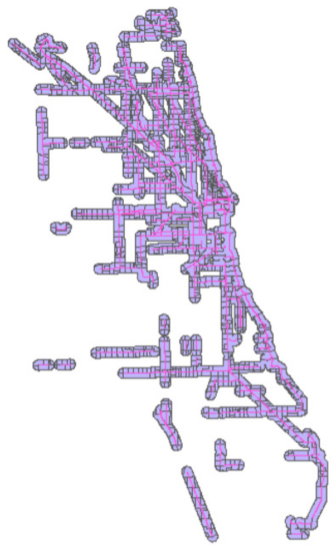
Create a new areakey field for the Block Group geometry using the method above. To calculate this field however, use the formula: areakey= [Geo_GEOID].

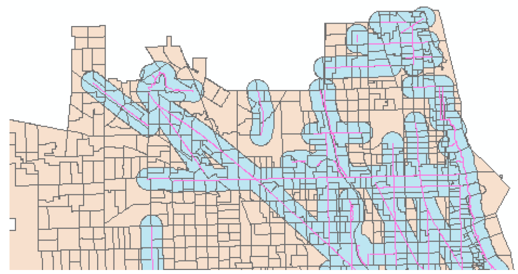
Next right-click on the block group shapefile, go to Joins and Relates, and select Join. Choose areakey as the field the join will be based on. Make sure that your BEI dbase is the layer you are joining and click ok. If you open the attribute table of the block group geometry you will now see all the information from your BEI.



Calculating Bicycle Facility Buffer Area

Once existing bicycle facilities have been buffered ¼ mile, we will calculate the proportion of each block group that lies within the buffer. To do this we will clip our block group shapefile with the bicycle facilities buffer. It is recommended to use a shapefile without information joined to it, so that the attribute table doesn't have excess burdensome information. You will now have a layer that looks similar to this.



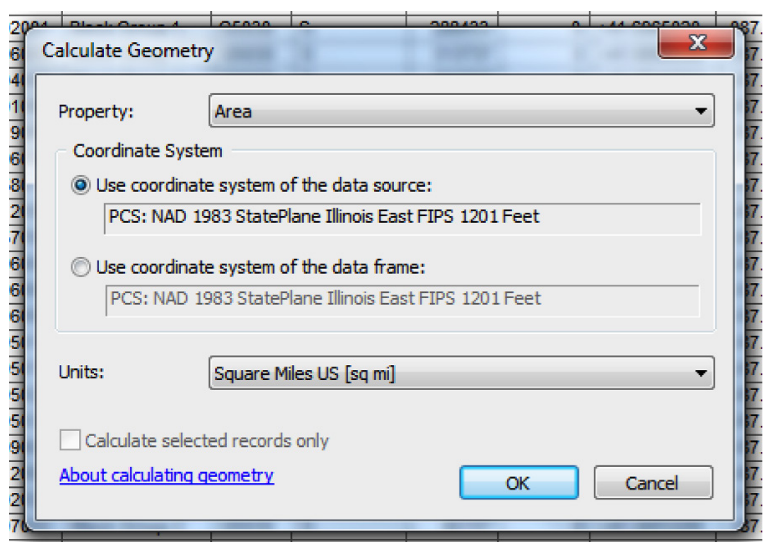


Notice that some of the buffer falls outside our site boundary. If we calculated the area within the buffer based on this layer we would end up with calculations for some block groups on the perimeter where the buffer area is greater than the actual area of the block group. Therefore we need to take this layer and clip it once more to our block group shapefile.

We will be joining this layer to our block group shapefile, but first calculate the area of each block group. Create a new field in its attribute table called area and make the field type Double. Right-click on the column header "area" and go to Calculate Geometry. Leave the property as Area and choose Square Miles US as the unit. Use the same operation to calculate the area of the clipped buffer layer. Now join the clipped buffer to the block group shapefile.

When you open the block group attribute table you will notice a bunch of <Null> values. This is because the clipped buffer layer only had information for block groups that the buffer intersected. These null values should really be represented by "0 " sq. mi. However, we can't change this information in ArcGIS, therefore we will need to export this information to excel to change.

Please note that some cities may have bicycle network so comprehensive that the bicycle facilitates buffer intersects all of the block groups. If so, you would not have any <Null> values and would not need to export the attribute table.



Calculating Access Coverage

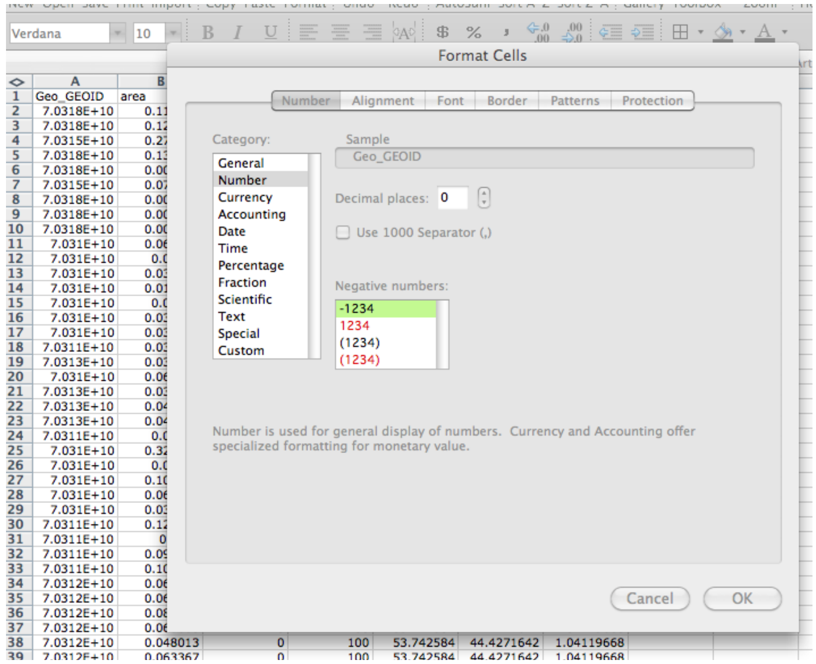
To export the attribute table data right click on the upper left hand box next to FID 0 and press command + A to select all the fields, right-click and select Copy Selected. Open a new excel spreadsheet and paste the selection, making sure to use paste special and text. Take a look at your Geo_GEOID, the field is condensing the GeoID. If we save the file with it like this it will not load back into ArcGIS with the correct GeoID. To fix this right click on the top of the field and select Format Cells, choose Number and change the decimal places to 0.

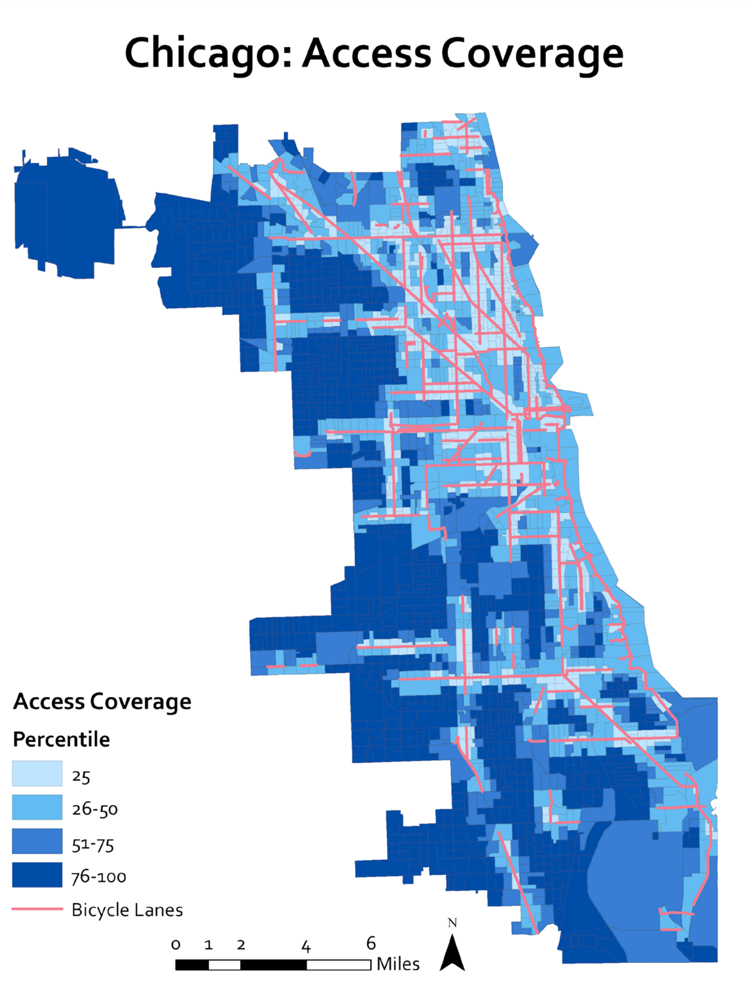
Next, use the Find & Replace function to replace all of the <Null> values with a “0”. Now we can calculate the percentage of the block group that falls within the clipped buffer, the areas that have access to bicycle facilities.

Since we are interested in combining this layer with the BEI, z-scores were once again used to standardize the measure of access. Additionally, since positive z-scores were used to indicate areas of disadvantage in the BEI we need positive z-scores of the access coverage to similarly indicate areas of disadvantage. In order to do so we will calculate the percentage of non-coverage block groups rather than their percentage of coverage.

As with the equity indicators, the mean value for all block groups’ percentages of non-coverage was found, as well as the standard deviation. Lastly the z-scores for each block group were calculated. These scores represent how much access the block group had in relation to the region as a whole. A z-score of zero represents the mean, anything greater than a zero represents areas with below average access while negative scores represents areas with above average access.

Since we will be combining the non-coverage z-scores with the BEI later we once again need to convert any negative z-scores to zero. To do so refer to the methods used when creating the BEI. Lastly, save this excel file as a csv, imports into ArcGIS and join to a block group shapefile.



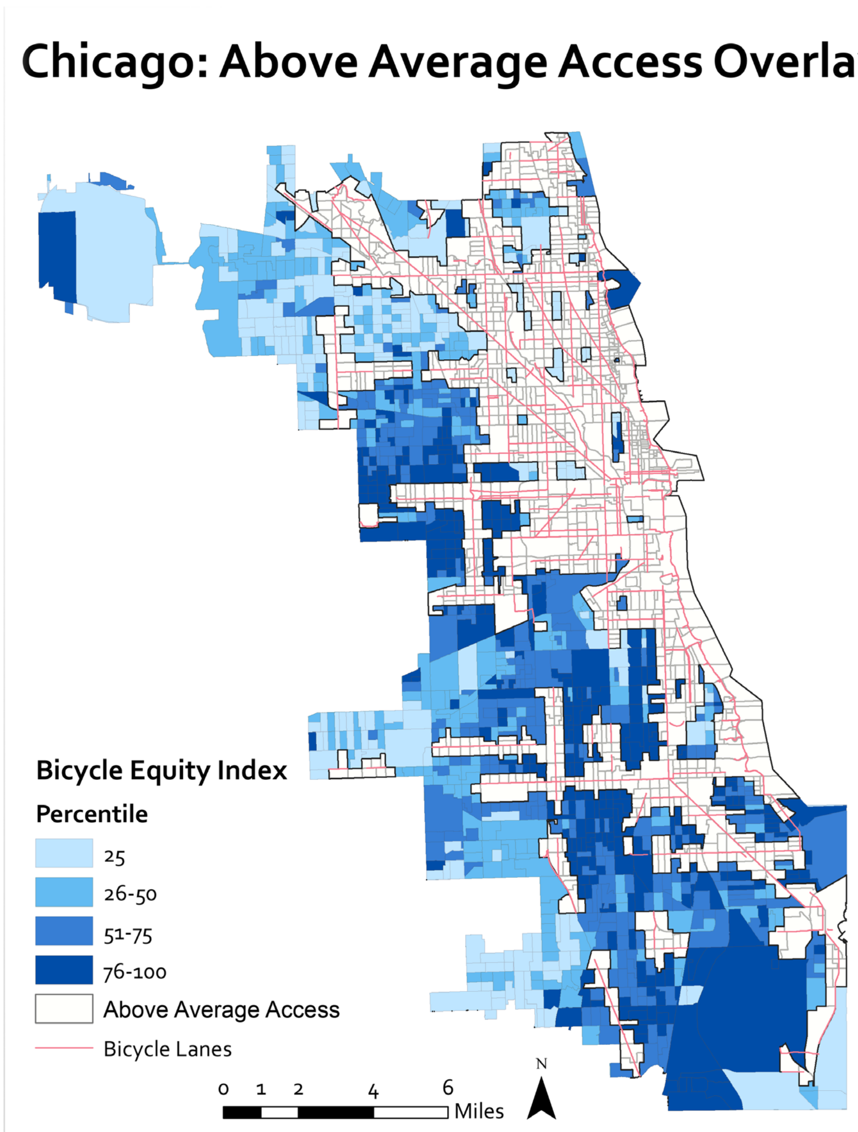


Mapping BEI & Access Coverage

In order to elucidate areas with both below average access and high disadvantage we will exports block groups with average and/or above average access to overlay onto the BEI. When the symbology of this layer is changed it will in essence block areas that have average or above average access and reveal the BEI of areas with below average access.

To create this above average layer, open the attribute table of the block group layer the non-access z-scores were joined to. In the upper left corner open the Table Options drop down box, open Select By Attributes and enter the formula: "non_access_z" = '0.' Note, "non_access_z" is the name of my non-access z-score heading, it will be unique to what you labeled it in excel. Notice that now only the z-scores with a zero value are high lighted in blue. Next, close the attribute table, right-click on the layer and select Data, Export Data. Select 'Yes' when ArcMap asks if you want to add the exported data to the map as a new layer.

Turn off the block group layer with the all the non-access z-scores and turn on the BEI layer. Make sure that the above average access layer is above the BEI layer in the table of contents. Change the symbology however you like. You now should have something similar to the map below.



QUESTIONS ABOUT THIS REPORT?

If you have any questions about this report and its contents, please contact the League at hamzat@bikeleague.org and/or ken@bikeleague.org.

If you have any questions about the technical aspects of this report, you can contact author Rachel Prelog at rprelog@gmail.com.

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