EXAMINING VARYING LEVELS OF ACCESSIBILITY TO GREENWAYS BASED ON

SOCIO-DEMOGRAPHIC CHARACTERISTICS

A CASE STUDY OF SAN ANTONIO, TEXAS

A Thesis

by

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ABSTRACT

An important issue associated with the provision of urban green space is the distribution of the space and the resulting accessibility for communities across a city. As a public amenity, it is important to ensure every population group has access to urban green space. With recent efforts toward building greenway systems in many cities, it is critical to examine whether these greenways contribute to equal access to green space, especially for disadvantaged neighborhoods. This study explored the accessibility of greenway systems in San Antonio, Texas by measuring the network distance from each neighborhood to greenway entrances and number of greenway entrances within specific distances from neighborhoods. The study used GIS analyses of census data with demographic and socioeconomic variables and streets data of San Antonio. Statistical analyses, e.g., bivariate correlation, analysis of variance (ANOVA), and multiple regression, were also used to explore the relationship between the socioeconomic variables and the dependent variable representing the accessibility of greenway.

The results showed that lower socio-demographic groups enjoyed the same level or better access to greenways. The results also showed that urban areas have better access to greenways than suburban areas. Population density, black or African American, Hispanic or Latino, female, and unemployment rate had a statistically significant association with the accessibility of greenway as well. The spatial difference is related to the different distribution of socioeconomic characteristics. With the results, implications

for design or management of greenway trail systems to provide residents more accessibility to these systems are discussed.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Professor Dongying Li and Douglas Wunneburger of the Department of Landscape Architecture and Urban Planning and Professor Jamie Rae Walker of the Department of Recreation, Park, and Tourism Sciences.

All work conducted for the thesis was completed by the student independently.

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There is no funding for this study.

NOMENCLATURE

GIS	Geographic Information System
OLS	Ordinary Least Squares
ACS	American Community Survey
ZCTA	Zip Code Tabulation Area
ANOVA	Analysis of Variance

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CHAPTER 1

INTRODUCTION

The importance of urban green space for social, cultural and economic benefits has been highlighted in the literature (De Groot et al., 2010). While many cities have strived to provide greenspace for their citizens, greenway has risen as an urban amenity to provide diverse benefits to residents. Urban greenways provide linear green space and their vegetation positively impact on the area (Shafer et al., 2000). Larson et al. (2016) describe the greenway's effect that "the mere existence of urban greenways provides corridors of natural vegetation that affect wildlife habitat, air and water quality, flood mitigation, and a variety of other maintenance and regulatory ecosystem in cities" (Larson et al., 2016, 112). Additionally, greenway trail systems serve as an epicenter for cultural services such as recreational use. Greenways connect parks, neighborhoods, businesses, and other public spaces and strengthen the quality of residents' life through enhanced connectivity and outdoor recreation. Access to green space also has a significant impact on well-being and social interaction (Chiesura, 2004; Kazmierczak, 2013; Shafer et al., 2000).

Because of the advantages mentioned above, many cities in the United States have constructed greenways as linear park systems. Due to the trends, many researchers conducted studies related to the greenspace and greenway (Harris et al., 2018; Palardy et al., 2018; Weber et al., 2017). In order to understand how different access to greenways has an impact on residents' greenway use and subsequent health outcomes, it is critical to examine whether neighborhoods with different demographic and socioeconomic status have equal access to greenways. Lindsey et al. (2001) researched how different social groups have accessibility to urban greenways in Indianapolis, and La Rosa (2018) studied a planning framework to evaluate how different social groups have their demands and preferences related to accessibility of urban greenspaces. Many studies have measured the accessibility of green space in urban areas (La Rosa et al., 2018; Lindsey et al., 2001; Zlender & Thompson, 2017), but few studies, to the best of our knowledge, deal with greenway accessibility with recently constructed greenways.

This study focused on the greenway system in San Antonio, Texas, which has recently completed an extensive greenway system. The aim of the study is to examine the relationship between access to greenways and neighborhood sociodemographic factors in San Antonio. The study measures accessibility using network distances from each neighborhood to the nearest greenway entrances and the number of greenway entrances within specific distances. These findings can help planners and policymakers investigate the inequality in access to greenways and develop policy directions to enhance environmental equity.

CHAPTER 2

LITERATURE REVIEW

2.1. Greenway

Green space has long been regarded as necessary space for urban residents due to its various advantages such as cleaner lifestyle and health promotion. As a result, empirical research typically demonstrates the relationship among environment, behavior, and green space that affects our physical and mental health (Chiesura, 2004; Dallat et al., 2013). For example, research has analyzed the relationship of how green space plays a pivotal role in relieving ill health or fertility issues (Mitchell & Popham, 2008). Greenway is a type of green space with trails. The author of the *Greenways for America*, Charles Little, noted that a greenway is a linear open space constructed along a natural corridor and is a natural or landscaped course for pedestrian or bicycle passage (Little, 1990). Even though parks as a type of urban green space have received the majority of research attention, the linear landscape features of eco-friendly trails have been recognized as important ecological and recreational spaces (Fabos & Ahern 1996; Little, 1990). Some research shows that greenways have potential to serve most people by using personal-level surveys in which users reveal their satisfaction about greenway system in their areas (Gobster, 1995; Larson et al., 2016). Gobster (1995) claimed that Chicago greenway users preferred to use the greenway near their residences within at least 5 miles and that the greenway would be designed to meet their users' purpose such as recreation. Larson (2016), after surveying greenway users in Atlanta and San Antonio, highlighted the importance of ecosystem services that greenways can provide to residents.

Scholars have been studying the extent of the services provided by urban ecosystems (Gomez-Baggethun et al., 2013; Haase et al., 2014). Much of the research into the value of urban ecosystems has focused on measuring and quantifying biophysical properties and processes that bring about material benefits such as monetary benefits or making eco-friendly circumstances (Haase et al., 2014). Besides, other researchers have also studied the immaterial benefits of experiencing and appreciating natural environments (e.g., recreation and aesthetics), commonly referred to as cultural eco-systems (Martin-Lopez et al., 2012). In urban areas, such cultural services can be the most valuable contribution a green space has to offer (Chiesura, 2004; Gobster et al., 2007; Martin-Lopez et al., 2012). The study focused on greenways, an increasingly popular urban amenity that offers a variety of benefits (e.g., ecosystem services) to urban residents through a unique fusion of natural green spaces and built infrastructure (Benedict & McMahon, 2006; Fabos, 2004). Greenway also serves as the hub of cultural services based on human use. Greenways connect parks, neighbors, businesses, and other public spaces and improve quality of life through active outdoor recreation, thus influencing positive outdoor activity with social interaction, including educational activity for students (Kazmierczak, 2013; Lackstorm & Stroup, 2009; Shafer et al., 2000).

Many studies have focused on the positive influence of access to urban green spaces on the health and well-being of citizens. The proximity and use of urban parks and green spaces have shown a definite link between physical activity levels and physical health (Cohen et al., 2007; Godbey & Mowen, 2010). Cohen showed that most people who exercised in their local parks and the frequency of park use and exercise are associated with park accessibility. Godbey and Mowen mentioned that parks have the potential to improve people's physical activity and health benefits. Additionally, such parks have a positive effect on psychological health (Clark et al., 2014). Clark said that direct and indirect pathways from biodiversity change human health. For example, biodiversity loss has negative impacts upon human well-being and health, community attachment (Arneberger & Eder, 2012), cognitive functioning (Bratman et al., 2012), and other aspects of well-being (Larson et al., 2016). Arneberger and Eder said that the perceived supply and green space's quality improve community attachments. Bratman showed that the benefits of natural experiences are relevant to cognitive capacities such as attention, memory, and impulse inhibition; further, they have a negative effect on mood or stress.

2.2. Accessibility, Equity, and Greenway

As a result of the aforementioned positive effects of greenway trail systems, it is essential for a city to provide equal accessibility of greenways to citizens. The question of whether residents of a particular city have equal access to a greenway, which depends in part on how equity is defined, has a significant impact on the management of a greenway system. If some population groups have equal distance to live within a specified distance, it is clear that access to greenway trails is not equal, and the distribution of the benefits provided by the greenway is not equal (Lindsey et al., 2001).

According to a previous study, the term “accessibility” is generally understood as the ease with which one place can be reached from another. Bhat et al. (2000) said that accessibility deals with mobility, interaction of transport systems, and land-use patterns. Curtis and Scheurer (2010) introduced some of definitions of accessibility previous researchers represented. Geurs and van Eck (2001) describe accessibility as “the extent to which the land use-transport system enables individuals or goods to reach activities or destinations by means of a transport mode(s)” (Geurs and Van Eck, 2001, 36).
Whereas Bhat et al. (2000) noted the concept of accessibility as “A measure of the ease of an individual to pursue an activity of a desired type, at a desired location, by a desired mode, and at a desired time” (Bhat et al., 2000, 1). When considering urban service facilities, accessibility, meaning the distance from residents’ households to the facilities in regard to greenway as a recreational site and as a route to take during utilitarian travel, is important to consider. The degree of accessibility reduces daily barriers such as distance and time to reach a facility or space (Humpel et al., 2004).

It is not only important for urban service areas such as green space to consider accessibility for residents but also the equity of whether the service area is accessible equally to various residents based on socioeconomic characteristics or races. Wolch et al. (2014) concluded that the areas where a higher percentage of people with low-income, e.g., Latinos, African Americans, and Asian-Pacific Islanders have lower levels of accessibility to parks than Caucasian-dominated areas (Wolch et al., 2014). Also, Dai (2011) presented, via with GIS and OLS statistical methods, that African-dominated areas in Atlanta have lower accessibility to urban green space as well (Dai, 2011). Jones et al.

(2009) studied green space equity in the United Kingdom. The results showed that the deprived areas had better accessibility to green spaces, but those residents did not have better perceptions and did not use the green space that is easily accessed (Jones et al., 2009). Other British research said that Indian, Hindu, and Sikh groups have limited access to green space in the city (Comber et al., 2008).

As with the studies related to the access of greenways, some researches dealt with greenway access. Coutts and Miles (2011) said that greenways might facilitate racial comingling in urban public space (Coutts & Miles, 2011). However, Lindsey (2003) mentioned that disadvantaged residents should have disproportionate access because they have greater needs to reach the greenway easily (Lindsey, 2003). Thus, greenway research requires the consideration of accessibility and equity. The greenway location and its surrounding features affect how greenway trails are used (Bialeschki & Henderson, 1988; Coutts, 2008, 2009; Furuseth & Altman, 1991). In other words, an essential measure of Greenway's service to citizens is accessibility with each family (Giles-Corti & Donovan, 2002).

2.3. Measures and Approach

2.3.1. Place-based measures

Many researchers have used place-based accessibility measure methods. Place-based measures are used to investigate the accessibility to certain areas for residents' location or their workplaces (Miller, 2007; Neutens et al., 2010). When the distance to the nearest service area, the number of services within a designated unit (e.g., census tract or block group), or the gravity-based measure is necessary, the place-based measures are performed. (Neutens et al., 2010; Tsou et al., 2005). Even though empirical researches indicate that this method is insightful and easy to implement, it has also been criticized for its lack of consideration to the interconnectivity between an individual's activities and to the space-time constraints implied by the opening hours of facilities and an individual's involvement in mandatory activities (Hanson & Schwab, 1987; Kitamura et al, 2001; Weber, 2003). Distance measures and gravity-measures are included in this place-based measures category.

2.3.1.1 Distance-Based Measures

Most researchers investigating methods to measure accessibility have utilized the most common approaches to defining geographical accessibility, which are distance-based measures (Talen & Anselin, 1998). The measures are regarded as the most straightforward measure in place-based measures. The measurement methods can be used on individuals, blocks, or tracts. This method estimates the accessibility with a function of the spatial separation between places. For example, the higher separation investigated, the lower accessibility the places have. When the study uses these distance-based measures, researchers should consider how to identify the type of distance (Vale et al., 2016). The previous studies measured the accessibility for residents to access urban services and facilities such as healthcare services, recreational facilities, supermarkets, etc. (Allard et al., 2003; Hewko et al., 2002; Pearce et al., 2006; Smoyer-Tomic et al., 2004; Smoyer-Tomic et al., 2006; Witten & Exeter, 2003). The advantages of distance-based measures are that it is easy to operate and interpret the results. The measures do not require more data than other models such as gravity-based or individual-based measures (Geurs et al., 2004).

2.3.1.2 Gravity Models

Gravity models designate the attachment area by estimating travel impediment. The measures use the function of accessibility with opportunities in a specific zone to other zones to calculate accessibility. This method is frequently performed in public health and transportation planning (Miller, 2005). It is also used by taking a relative distance and considering how much travel time and cost commuters spend in reaching a specific service (Geurs & Van Wee, 2004). It has advantages that are easy to compute via transport or land-use data. However, this model has limitations, i.e., it is difficult to interpret and communicate with transports, land-use, and weighs opportunities and treats every traveler equally whether he or she is pedestrian or bicycle user (Baradaran & Ramjerdi, 2001; Geurs et al., 2004).

2.3.1.3. Floating Catchment Area Approach

To decide where to increase or decrease service provisions, the two-step floating catchment area (2SFCA) method, which combines many related types of information into a single, immediately meaningful, index, is being used. This method allows comparisons to be made across different locations. This method uses catchment areas of a particular size float on supply and demand points. The 2SFCA measure has been applied simply and practically to calculate accessibility for public services planning or establishing policies. For example, this method was used to estimate the accessibility of a medical service (Luo, 2004), elderly care facilities (Cheng et al., 2012), or grocery store (Dai & Wang, 2011). Thus, it can apply to the various service area of the service facilities (McGrail & Humphreys, 2009). However, because there are no clear criteria to determine the scope of supply and demand, it has a risk that it will present a different outcome from the reality of the public service facility location assessment process (Ahn et al., 2014).

2.3.2. Individual-based measures

Because of the increased computational power of geographical information systems (GIS) and availability of individual-level activity-travel data, it has become easier to move beyond place-based accessibility measure methods to people-based measures. Diverse people-based measures have been proposed and implemented that explicitly acknowledge an individual’s travel behavior and space-time environment (Kwan, 1998; Recker et al., 2001). This method includes space-time accessibility measures which show the gender differences in accessibility, while the place-based measures cannot articulate it (Kwan, 1998). The individual-based measures seem more appropriate to measure equity of public service delivery because they articulate interpersonal differences in accessibility and assess the level of equity (Neutens et al., 2010). The measures are a more sensitive method to calculate the accessibility and equity with individual variation data such as gender or racial differences (Geur et al., 2004).

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1. Study Area

San Antonio is located in Bexar County, Texas. The population of the city is 1,439,358, which makes it the state's the second-largest and Bexar County is the fourth-largest population County in Texas (2016 ACS 5-year estimates). The dominant race of the city is white (78.8%), and there are more Hispanic or Latinos (63.6%) than non-Hispanic or Latinos. The land area of San Antonio is 460.93 square miles.[1] According to the GIS data of San Antonio, total park area is 44.86 square miles without newly constructed greenways, and the length of all greenway routes is 353.93 miles.[2]

San Antonio constructed its greenway trail system from 2005 to 2018. The Howard W. Peak Greenway Trail System, which is named after the former mayor of San Antonio, is a growing network of approximately 65 miles of developed multi-use and accessible trails, which are made up of hike and bike trails along creeks around the city. The greenway trail system plan was approved in 2000, and the construction became gradual after 2005; now only two routes, Medina River and Apache Creek, are under development (City of San Antonio). Except for these routes, many San Antonio residents already use the greenway for walking, cycling, and so on (Larson et al., 2016). The greenway trails are constructed through natural landscapes along San Antonio's waterway, including

[1] http://www.census.gov/quickfacts
[2] https://www.sanantonio.gov/GIS/GISData

Salsado Creek, Leon Creek, Medina River, Westside Creeks, and Tributary Creeks. The greenways include dense riparian greenery along a creek-side floodplain, with limited development along the trail and its access points. The greenway routes are areas in the urban center. The access points were designated in some spots with parking lots, so users can access designated trailheads of each route. To measure the greenway trail system's accessibility, the study assigns the size of samples. Because the greenway trail system winds through San Antonio's boundaries, the block groups in Bexar County were selected for the research.

Figure 1 San Antonio Greenway Trails System Plan
(Source: https://www.sanantonio.gov/ParksAndRec/Parks-Facilities/Trails/Greenway-Trails)

3.2. Data Acquisition

The study requires data to estimate the accessibility and equity of the greenway trail system. To research the spatial relationship, GIS data were downloaded from the San Antonio Website[3]. The GIS data needed for the research included parks and recreation information, i.e., San Antonio streets, park boundaries, greenway trailheads, and greenway trails.

San Antonio streets data are composed of vector and line data. This street data were the main base for the network analysis in this study. Park boundaries data, i.e., polygon type data, show the parks of San Antonio. Greenway trails data, i.e., line data, display only greenways without the parks. These two data were not the primary source for the network analysis, but they show how the parks and greenways are distributed in San Antonio with maps. Greenway trailhead data are point-type data and display each trailhead of greenway routes in the city. These trailheads are the entrances of the routes, so this data and the San Antonio street data were mainly used for network analysis using the GIS ArcMap program. These data were projected as NAD 1983 StatePlane Texas South Central FIPS 4204 (U.S. Feet) which were frequently used for the GIS data with Texas spatial dataset.

Also, to study the relationship between the accessibility of greenway and socioeconomic factors in Bexar County, census data from the Social Explorer Website were required. For the study dealing with the latest data, American Community Survey

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[3] https://www.sanantonio.gov/GIS/GISData

data, ACS-2016 5-year data were used. In the various data, some socioeconomic data were chosen. The variables are below:

Table 1. Selected Census Data Variables

Variable Name	Mean	Std. Dev
Population Density (Per Sq. Mile)	5143.98	3236.13
Gender		
- Male	844.26 (49.25%)	550.54
- Female	870.41 (50.75%)	549.38
Age		
- 0-17	449.58	369.34
- 18-44	679.09	531.87
- 45-64	393.01	233.95
- 65 or more	192.99	127.23
Race		
- White alone	1344.70 (79.45%)	851.09
- Black or African American	130.09 (6.98%)	198.86
- Others (American Indian and Alaska Native, Asian, Native Hawaiian and other Pacific Islander, some other race alone, and two or more races)	240.32 (13.57%)	228.45
Hispanic or Latino		
- Not Hispanic or Latino	696.36 (37.77%)	716.43
- Hispanic or Latino	1021.48 (62.23%)	662.68
Educational Attainment for Population 25 Years and Over		
- High education (Bachelor, Master, Professional, and Ph.D. degree)	290.89 (23.87%)	350.62
Unemployment Rate for Civilian Population in labor force 16 years and Over	7.32 %	6.60 %
Median Household Income	$ 53028.53	$ 31454.18
Per Capita Income	$ 24543.32	$ 14631.83
Housing Units	626.66	370.54
Ratio of Income in to Poverty Level < 0.5	119.45	142.77

Table 1. Continued

Variable Name	Mean	Std. Dev
Housing Units by Vehicles Available		
- No Vehicle Available	43.06	56.06
- 1 Vehicle Available	207.15	164.06
- 2 Vehicles Available	218.85	174.00
- 3 Vehicles Available	75.41	68.61
- 4 Vehicles Available	23.58	31.01
- 5 Vehicles or more Available	6.96	13.33

Source: Social explorer

3.3. Measures

3.3.1. Network Distances

The ArcMap program is mainly used for the study, and Network Analyst is program extension. This extension is frequently used for dealing with network issues in the cities (Chen, 2017; Prabhakaren et al., 2017; Bazargan, 2018). This extension offers diverse network analysis tools such as route, service area, closest facility, origin-destination (OD) cost matrix, vehicle routing problem, and location-allocation. These tools have different functions that are helpful to solve different network problems. This study employed two of these tools, i.e., closest facility and service area. The closest facility analysis helps researchers to find the closest facility from certain points by using the distance, cost, or travel time data (Gorr & Kurland, 2013). This analysis makes the shortest or the least time-consuming route with a line drawn between two locations. In this study, each line from the analysis shows the shortest route from the centroid of each census block group to the closest greenway trailheads.

To measure accessibility, a set of parameters must be specified. The first parameter is the spatial unit of reference and aggregation methods. Choosing the proper spatial unit of analysis is significant for minimizing aggregation errors. When measuring accessibility using spatial data, aggregate errors are caused by the distribution of each spatial unit. The size of a spatial unit varies from a small area represented by a census block to a large area such as a census tract, and furthermore, a county and a state. For accuracy of the study, accessibility is a less aggregated error as it is measured for relatively smaller areas (Apparicio et al., 2008). Thus, the census block group was used as a parameter for the network analysis. The census block group is the smallest spatial data acquired on the dataset American cities provide. Also, to calculate the distance between the block group and each greenway trailhead, one of the GIS functions, Feature to Point, was used. This tool creates points generated from the locations of input features whatever they are multipoint, line, or polygons (ArcGIS). The input features in the study were the census block groups in Bexar County and the output points were shown at the center of the block groups, which were the polygon data.

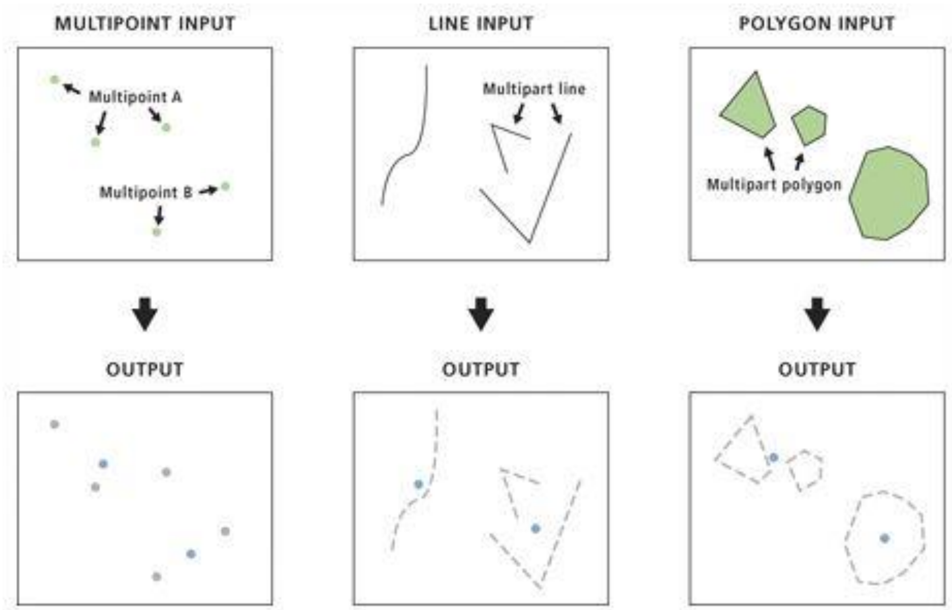

Figure 2. Illustration of the Feature to Point GIS Tool
(Source : desktop.arcgis.com/en/arcmap/10.5/tools)

To perform the closest facility analysis, the greenway trailheads data were added as facilities, which means the end-point, while the centroids of each block group were set as incidents, meaning start-point. The analysis settings were put to travel from centroids of block groups to the closest greenway trailheads. Additionally, the distance unit was set to miles to calculate the distance, and the U-turns at junctions setting was not allowed in this analysis. Apparicio et al., (2008) represented four types of distance which are generally used for calculating accessibility measures: “Euclidean distance (straight-line); Manhattan distance (distance along two sides of a right-angle triangle opposed to the hypotenuse); shortest network distance; and shortest network time” (Apparicio et al., 2008, 4). In this study, the distance was calculated using the shortest network distance because the data used for this study have no time data and the network distance is more realistic with the San Antonio street data than Euclidean distance and Manhattan distance.

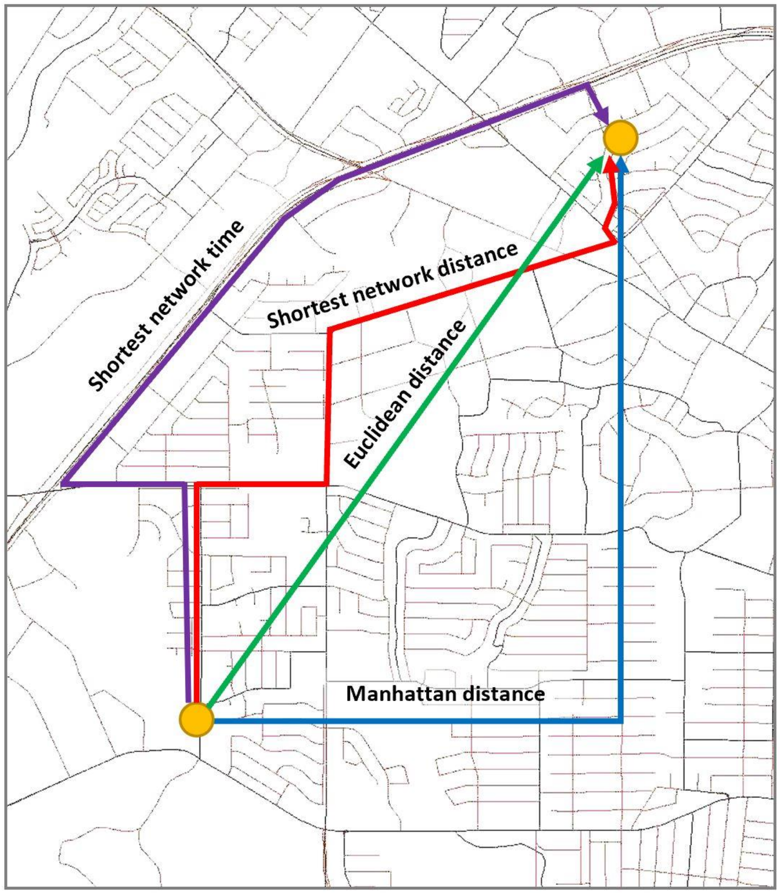

Figure 3 Several Types of Distances
(Reprinted with permission from Apparicio et al., 2008)

Also, calculating the number of services within meters or minutes is also frequently employed. After obtaining the closest distance from each centroid of a block group to the greenway entrances, the study measured how many entrances are accessible from each block group using the San Antonio street data. In this case, new service areas in the network analyst extension were employed. In the ArcMap program, all greenway trailheads data were added to the facilities and 1, 3, and 5 miles were set in the analysis settings. These certain distances are considered accessible distances with foot or vehicles from the block groups. Then, the study computed the service area and the number of the trailheads were calculated within 1, 3, and 5 miles from the centroid of the block groups.

3.3.2. Variable Coding

To estimate the relationship between socioeconomic and dependent variables, which are total distances from the centroids of the block groups to the greenway entrance and the number of access points within accessible distances to each block group, the statistical methods were operated by using the statistic program, Stata 15 IC. In the case of the independent variables, the percentage of the variable was used rather than the population of each variable because the census block groups have different sizes. This is because different block groups have different population bases, and using the percentage values allows us to consider this. The independent variables were divided as continuous variables and categorized variables. The three variables (i.e., high education attainment, median household income, and ZCTA) were categorized. High education attainment are categorized as low, medium, high level based on the percentage of people having Bachelor's degree and above. Median household income is divided to three categories. Medium level of median household income is set with the standard Pew research center reported.[4] Zip code tabulation area (ZCTA) is the urban/suburban/rural classification for zip code tabulation areas (The Census Bureau). In this case, only two block groups were

[4] Pew research center defines middle class as those who earn between 67 and 200 percent of the average median income. ($45,858)
(http://www.pewsocialtrends.org/2016/05/11/americas-shrinking-middle-class-a-close-look-at-changes-within-metropolitan-areas/)

classified as a rural area among 1,084 block groups, and it is too small to find the statistical relationship, so the two block groups were regarded as a suburban area in this study. Table 2 shows how the variables were categorized.

Table 2 Coding for the Categorized Variables

The Categorized Variables	Code
High Educational Attainment	1. Lower than 30% of population holding a bachelor's degree or above 2. Between 30% ~ 50% population holding a bachelor's degree or above 3. Larger than 50% population holding a bachelor's degree or above
Median Household Income	1. Low: \$0 ~ \$30724.86 2. Medium: \$30724.87 ~ \$91716 3. High: \$91717 ~ \$250001
ZCTA	0. Suburban (households per square mile < 2213.2) 1. Urban (households per square mile >= 2213.2)

3.4. Data Analysis

Based on the variables explained above, different statistical methods were used for this study. First, the choropleth maps were created by using the geographical information system program, which shows how the socioeconomic variables are distributed among the block groups in Bexar County. Second, the one-way analysis of variance (ANOVA) was used to assess whether the level of access to a greenway varies based on different socio-demographic conditions of the neighborhood. After obtaining the ANOVA analysis, pairwise comparison analysis was done because ANOVA test indicates that at least two groups differ but cannot determine which groups have a difference. The pairwise comparisons analysis evaluated which groups show a significant difference among the educational attainment, median household income, and ZCTA. Pairwise comparison is typically performed using the Tukey test and Newman-Keuls test. The latter test is generally used in psychology, while the Tukey test is used in other areas, so the Tukey test was performed in this study. Also, to measure the correlation between the socioeconomic variables and the dependent variables (i.e., distance, the number of greenway entrance within 1, 3, and 5 miles), correlation analysis was conducted. Pearson's product moment correlation is also used to obtain the correlation coefficients and p-values. Yule and Kendal (1950) showed that the smaller the spatial unit, the lower the correlation between the two variables by comparing the yields of wheat and potatoes. In this study, because the basic spatial unit is the census block group, the unit is smaller than the census tract or county level. This correlation analysis cannot show the causal relationship between the variables, so regression analysis is necessary. Therefore, the multiple regression analysis was conducted to understand how socioeconomic variables affect the network distance to the nearest greenway entrance and the number of greenway entrances within a specific distance. The important assumption, for when multiple regression is performed, is that there should be no correlation between the independent variables. If there is multicollinearity, the estimates and standard errors of the regression coefficients become inaccurate. Therefore, after the regression analysis, the study obtained the variance inflation factor (VIF), which is commonly used as a statistical index to diagnose collinearity. If the VIF value is lower than 10, we can say there is no multicollinearity (Hair et al., 2009; O'brien, 2007).

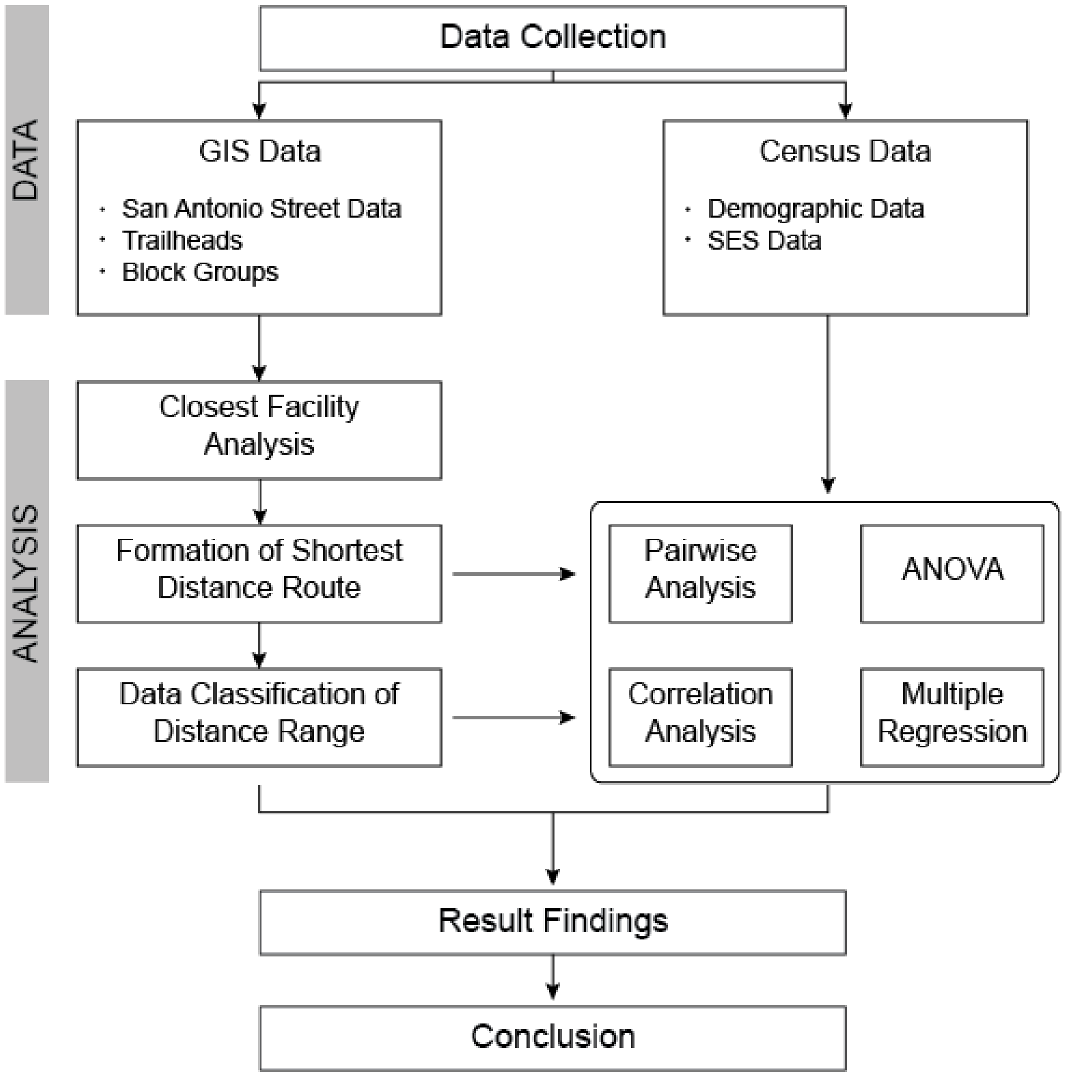

Figure 4 Flow Chart of Data Analysis

CHAPTER 4

RESULTS

4.1. Descriptive Statistics

Before measuring the statistical significance of the variables, population characteristics of Bexar County by block groups were mapped. The program showed the choropleth maps of the distribution of each of the sociodemographic variables. First, Figure 5 shows the distribution of the population density, female percentage, and the housing units. The city center of San Antonio has a denser population than the outer area. Most suburban areas in Bexar County did not have values larger than 7397.58 per square miles. However, the northern part of the county had a denser population than the southern part. The southern suburban area had a population density lower than 2372.32 per square mile. In the case of the gender distribution, there was no difference based on whether the block group was an urban area or suburban area with an irregular pattern. Figure 5 showed that there were most parts of the female percentage value from 43% to 59%, so this county displayed an overall balanced gender composition.

Figure 6 represented no particular pattern in residents' age, but those aged higher than 65 tended to live in suburban areas or north side of the city. Also, Figure 7 displayed that the north side of Bexar County had a more significant proportion of households whose household income and per capita income were higher than those of the south side. In the urban area, block groups in the northeast side of the city tended to have a larger percentage of people with higher household income and per capita income while the north side part of the suburban area of Bexar County tended to have a higher household income and per capita income (Fig. 7).

Figure 8 showed that block groups in the north side of the county have a larger percentage of people with higher educational attainment level than those on the south side of the county. Mainly, the city center has a higher percentage of people who have lower educational attainment, meaning no high school diploma, while the suburban area has a higher percentage of others.

In the race proportion maps, the suburban area had higher values in whites alone, and the east side of the county tended to have a higher percentage of blacks or African Americans. The proportion of other races had a higher value in the south side of the county (Fig. 9). On a Hispanic or Latino part, the southwest part of the city and south part of the county had a higher percentage of Hispanic or Latinos. The race distribution shows strong patterns of Hispanic population clustering in certain areas of the city (Fig. 10). Figure 10 also shows the number of housing units in the county; note that many housing units are aggregated in the suburban area rather than the city center. The north side of the suburban area had more housing units than in the south.

Figure 11 displays the unemployment rate of each census block group. There is no distinct pattern, but several block groups had a higher unemployment rate (23 to 51%). In regard to poverty-level, the south part of the county, especially suburban areas, had a higher percentage of poverty level under 0.5, which means that the income is less than half the poverty threshold, i.e., “severe poverty.” The value is the lowest category of poverty level the census bureau provides (The U.S. census bureau). Furthermore, people who have no vehicle tended to live in the city center (Fig. 12). With other maps showing one or two vehicles and 3 or more vehicles available for each household, we can say that the more vehicles households have, the farther they live from San Antonio's city center.

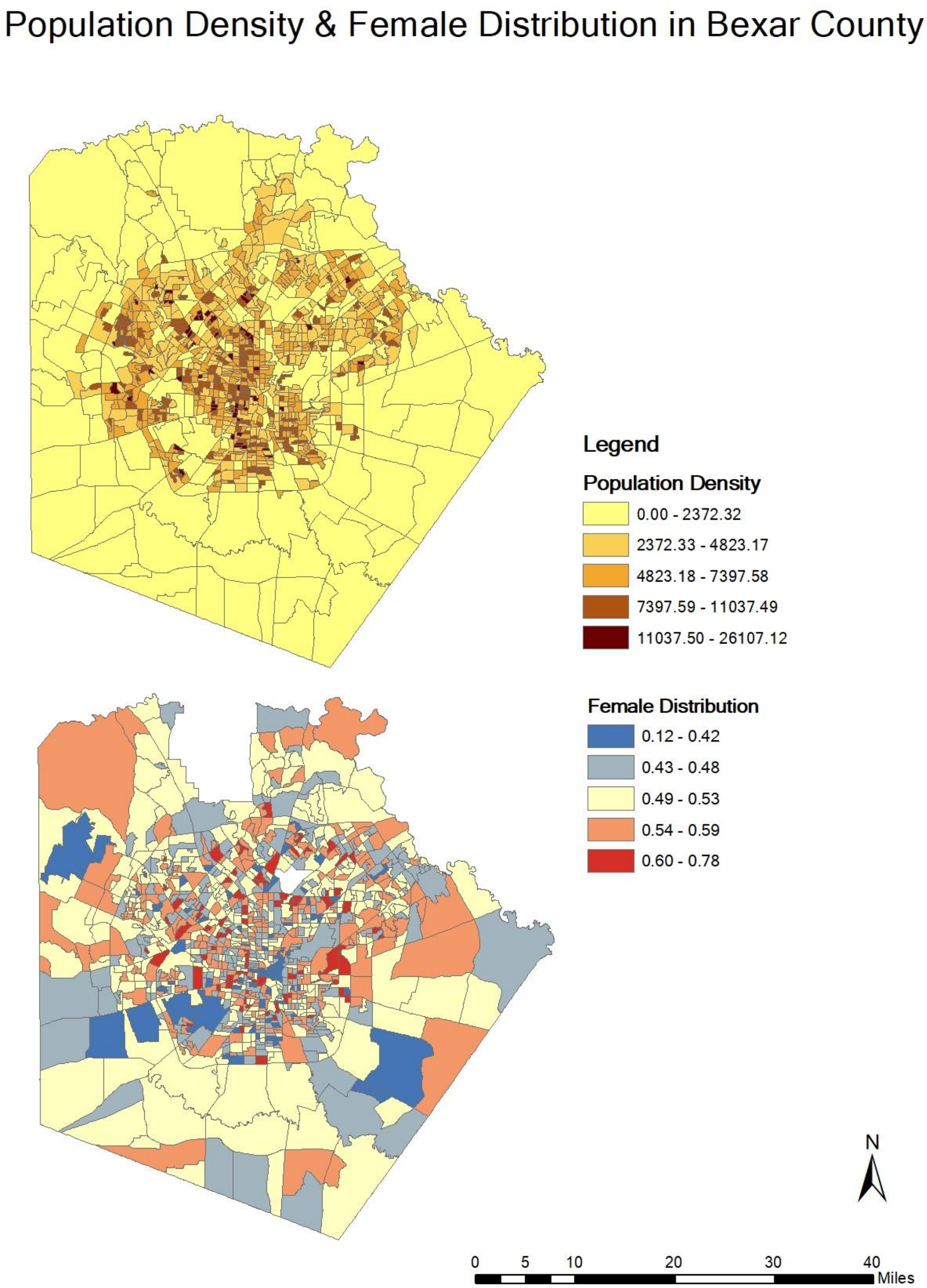

Figure 5. Maps of Population Density and Female Percentage in Bexar County

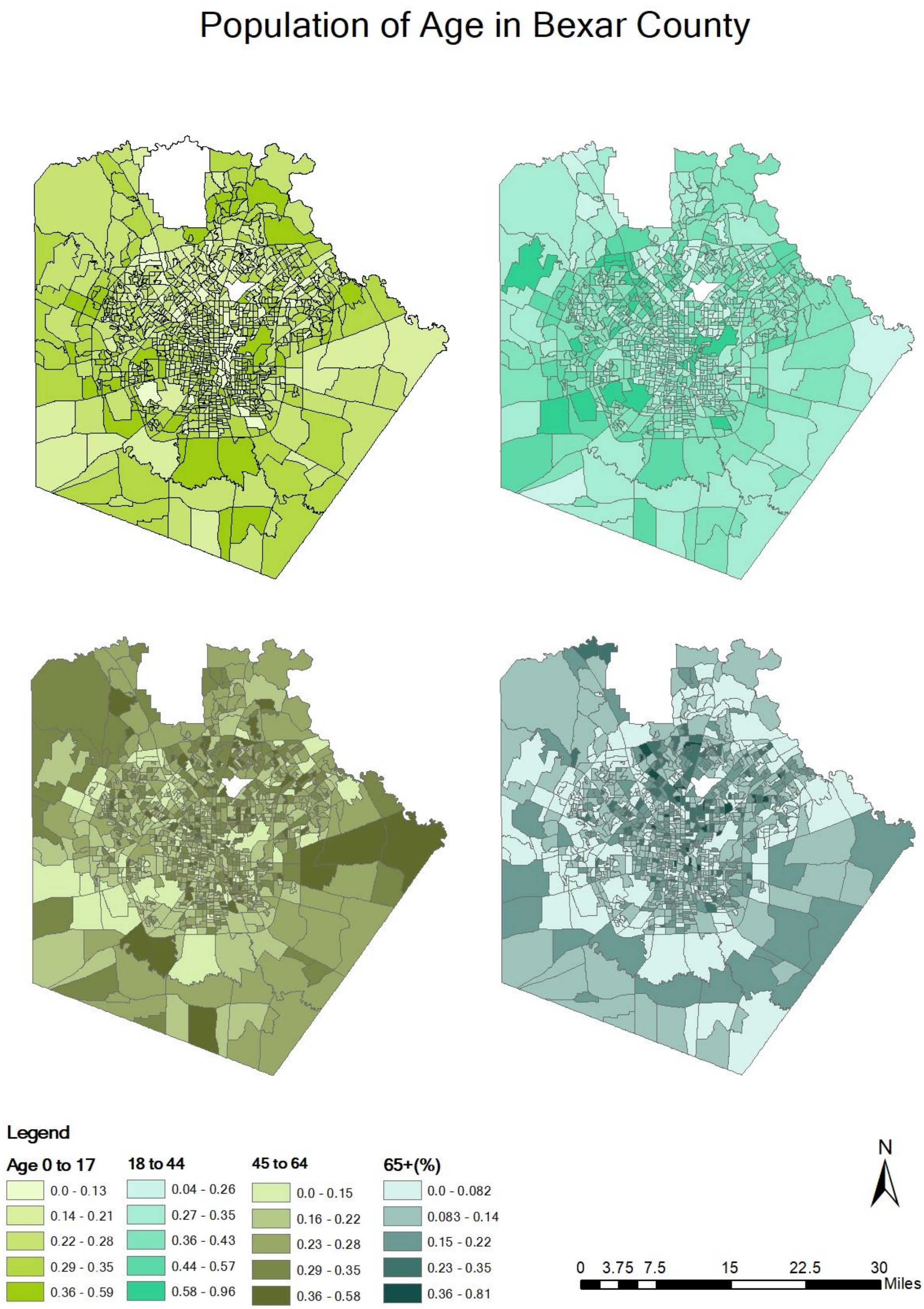

Figure 6. Maps of Age Distribution Percentage in Bexar County

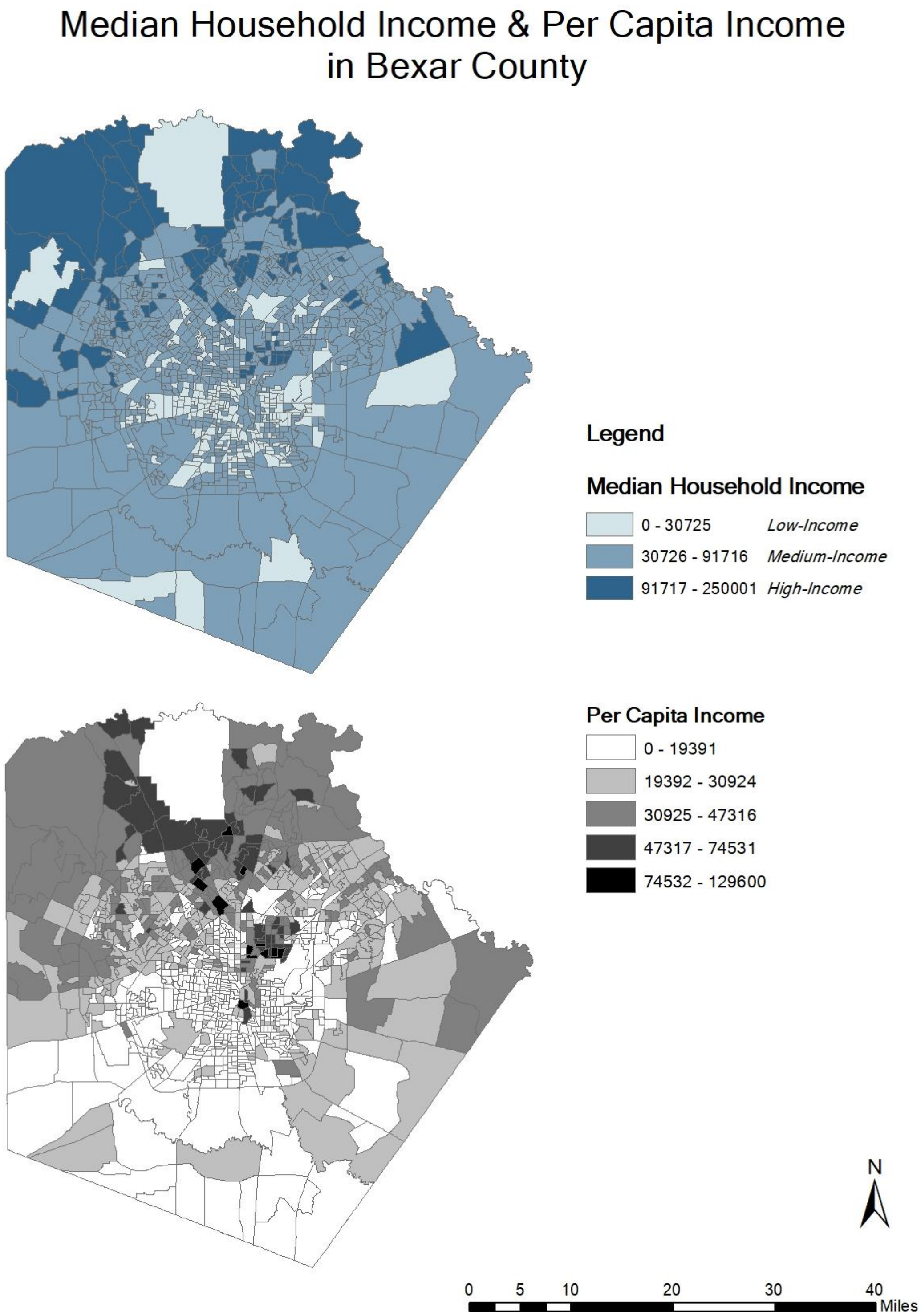

Figure 7. Median Household Income and Per Capita Income in Bexar County

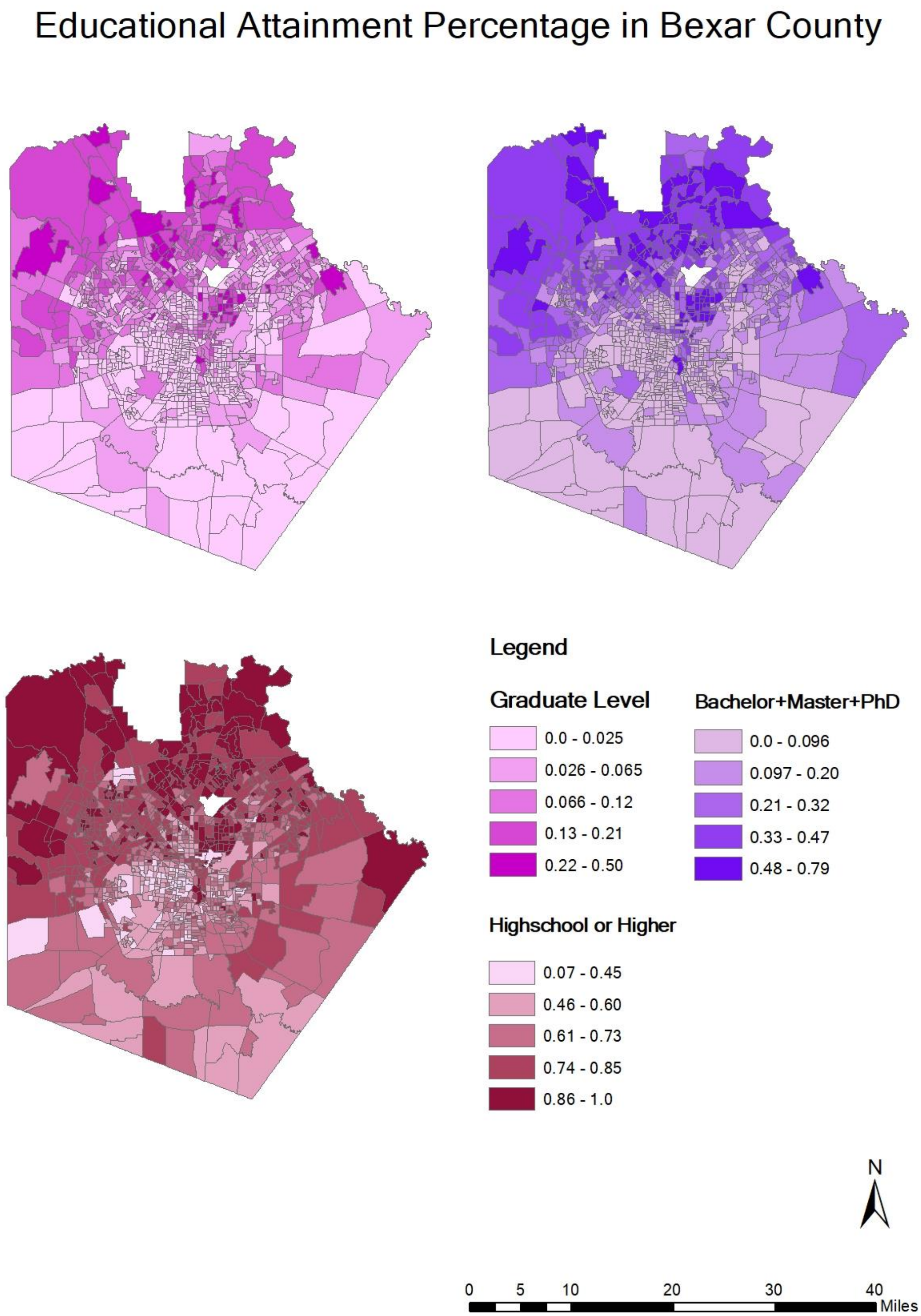

Figure 8. Educational Attainment Percentage in Bexar County

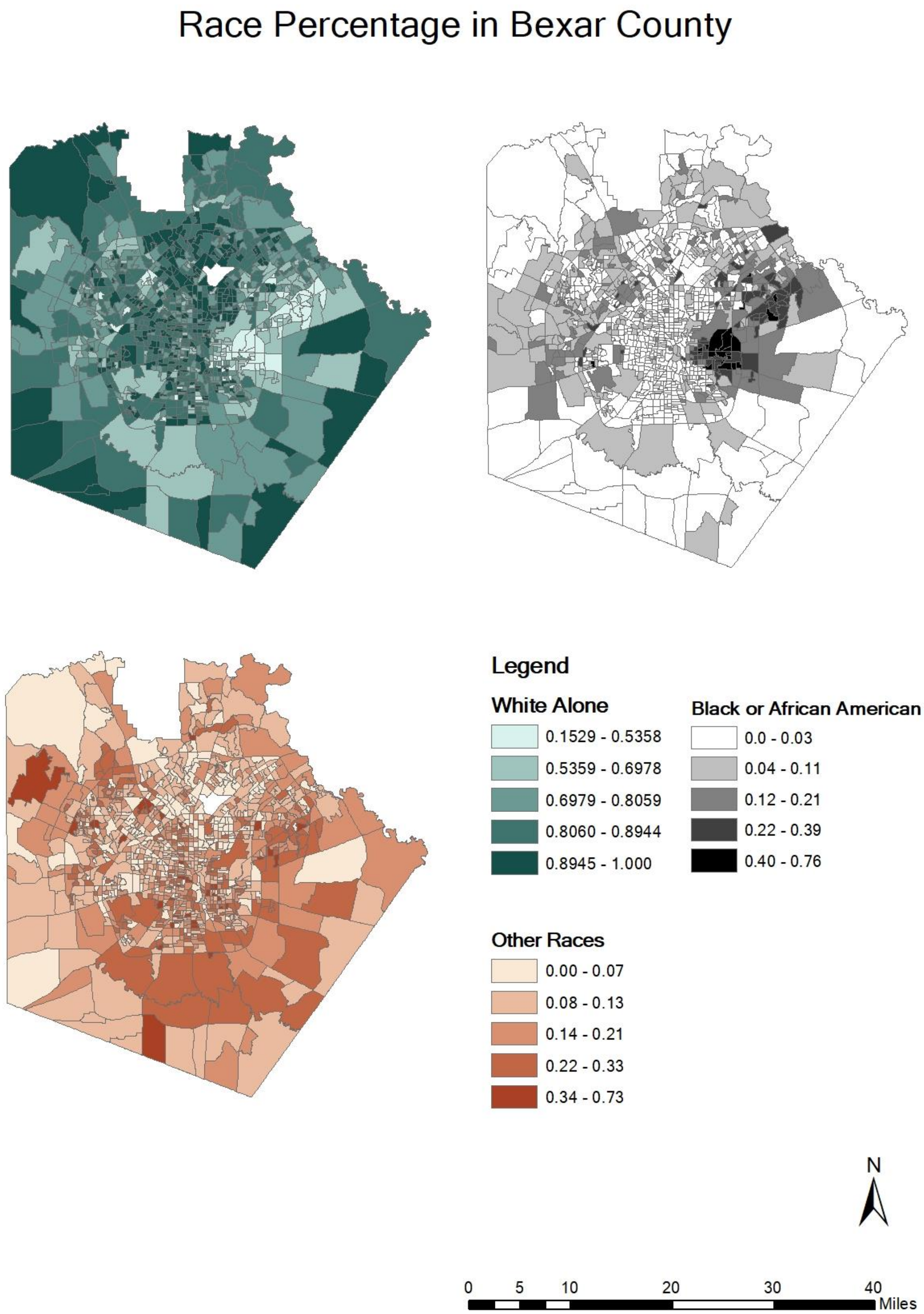

Figure 9. Race Percentage in Bexar County

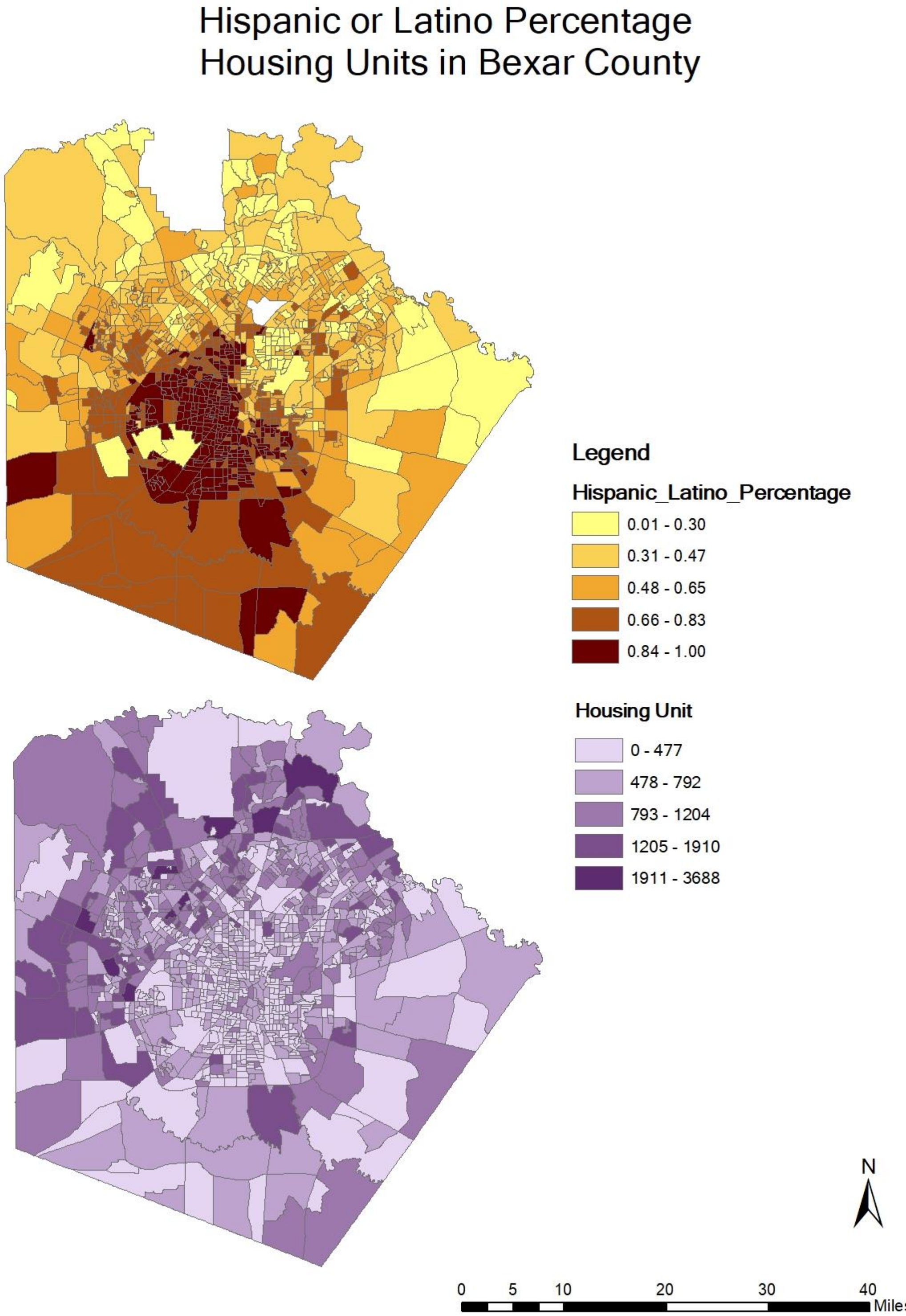

Figure 10. Hispanic or Latino Percentage and Housing Units in Bexar County

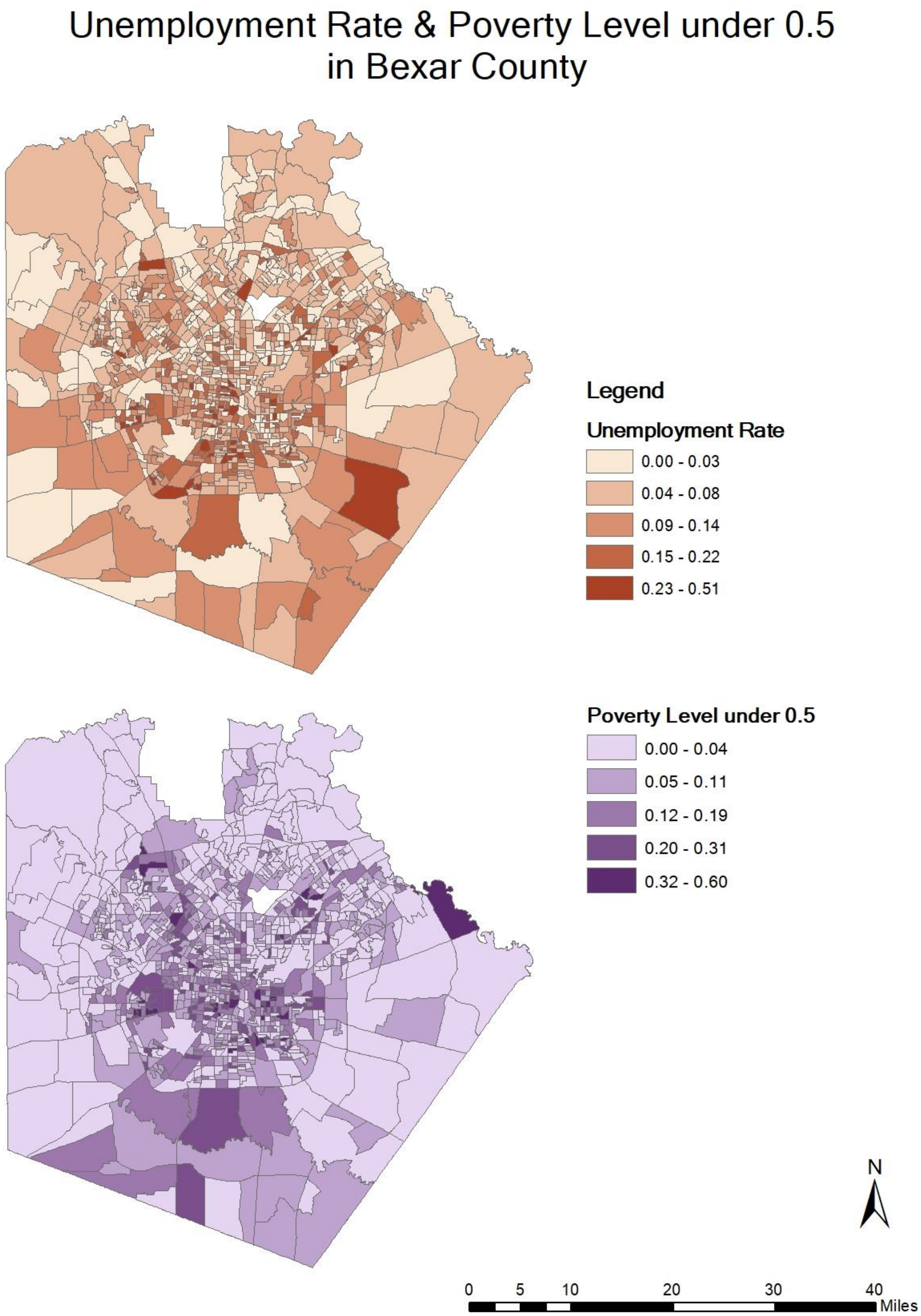

Figure 11. Unemployment Rate and Poverty Level under 0.5 Percentage in Bexar County

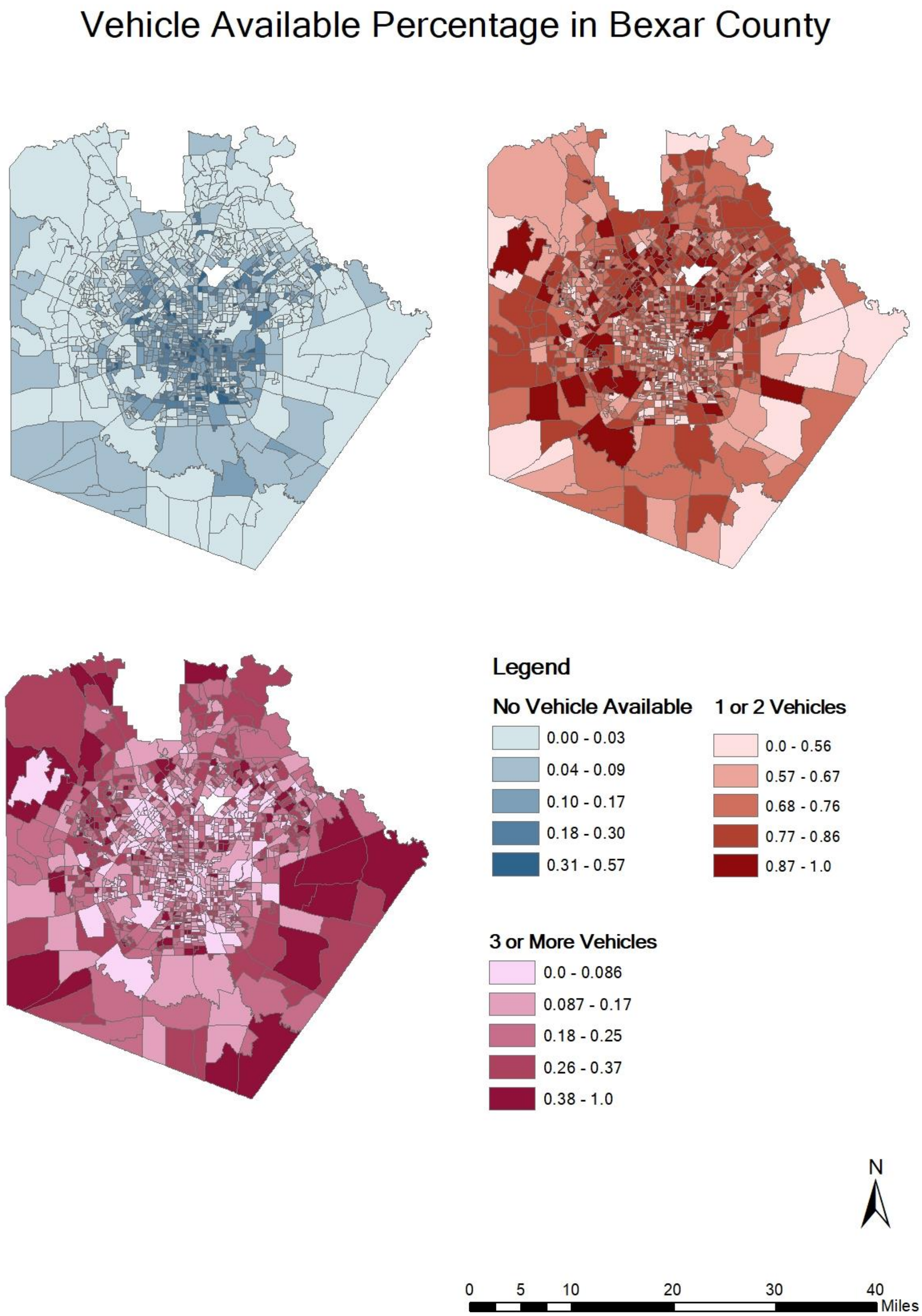

Figure 12. Vehicle Available Percentage in Bexar County

4.2. Access to Greenway

4.2.1. Network Distance

Table 3 shows the dependent variables used for statistical analysis. According to the result of the network analysis, the mean distance from the centroids of the census block groups to the greenway trailheads was 14845.9 feet (2.81 miles), and its standard deviation was 11547.89 feet. Service area analysis showed that the number of greenway entrances within 1 mile had a mean value with 0.1153, which means that most people do not have access to the greenway entrances within 1 mile of their households. However, they can access one or two greenway entrances within 3 miles and 5 or six greenway entrances within 5 miles according to Table 3.

Table 3. Average Number of Greenway Entrances

Variables	Obs	Mean	Std. Dev
Total Distance	1,078	14845.9	11547.89
Number of Greenway Entrances within 1 Mile	1,084	0.1153	0.3875
Number of Greenway Entrances within 3 Miles	1,084	1.8432	1.7391
Number of Greenway Entrances within 5 Miles	1,084	5.6716	3.5729

Figure 13 shows the distribution of distances from the centroids of block groups to the closest greenway trailheads. Most routes had values with lower than 20,000 feet (3.79 miles). Figure 14 shows that 1,073 of the 1,084 block groups had no greenway entrances within 1 mile from their centroids. Only 11 block groups can be accessible to the greenway entrances within 1 mile. Figure 15 shows that, except for 324 block groups, other block groups had at least one greenway entrance within 3 miles from their centroids.

Within 5 miles, 128 block groups had no accessible greenway entrances from their centroids (Figure 16).

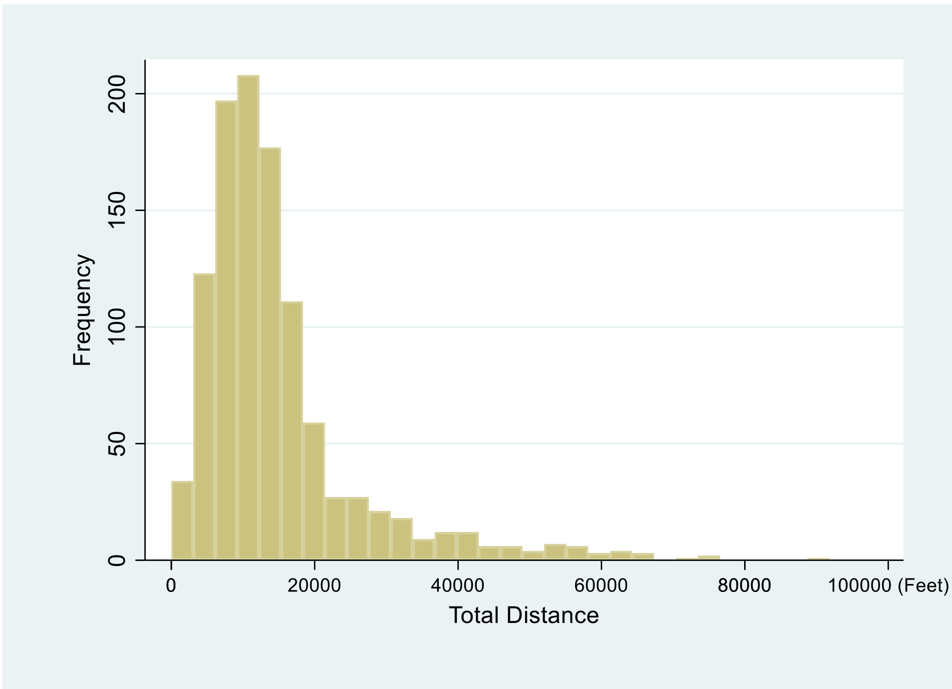

Figure 13. Total Distance Frequency Plot

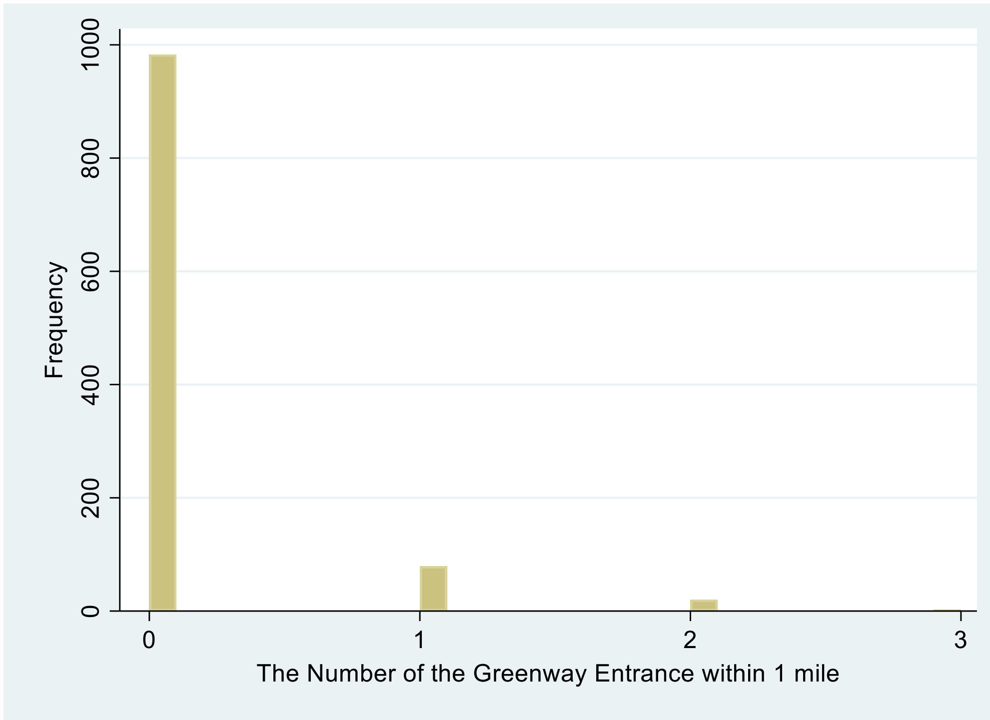

Figure 14. Number of Greenway Entrance within 1 Mile Frequency Plot

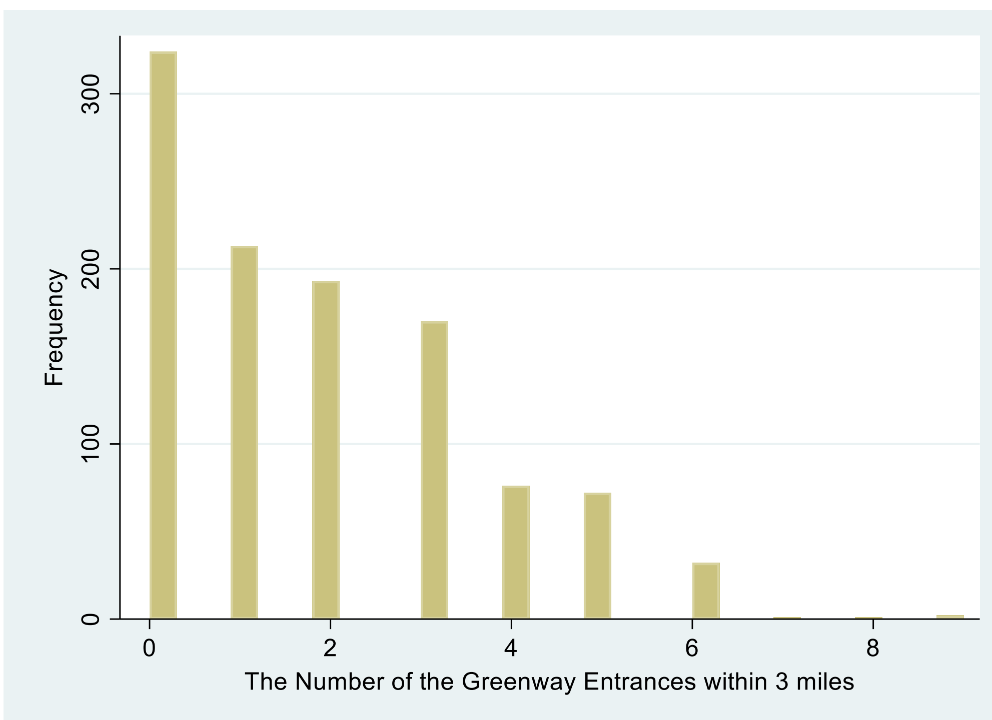

Figure 15. Number of Greenway Entrance within 3 Miles Frequency Plot

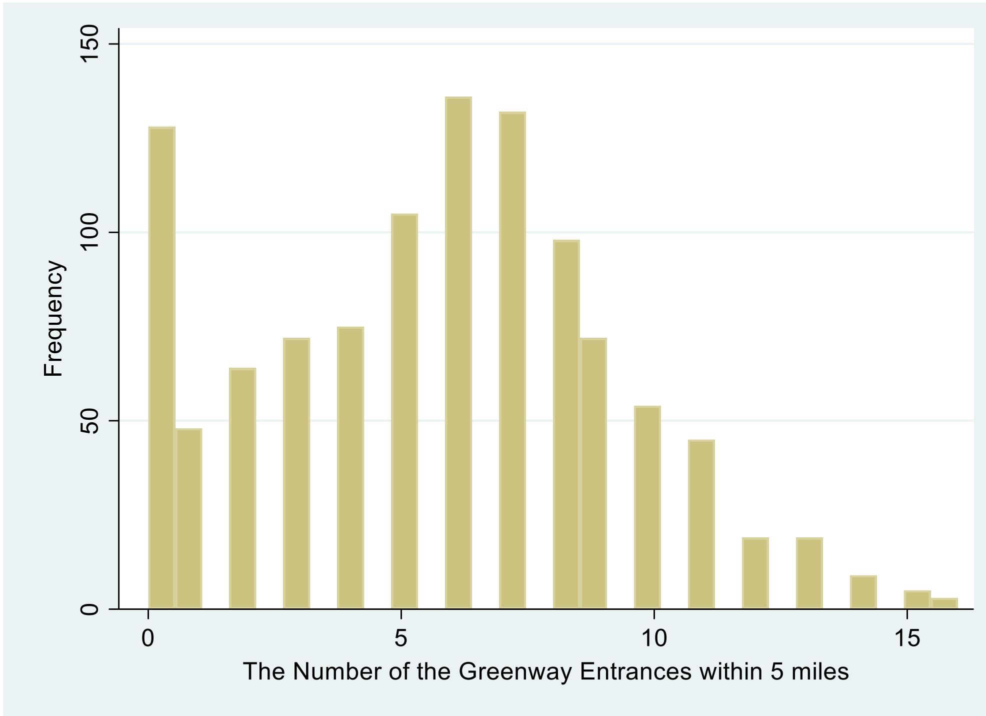

Figure 16. Number of Greenway Entrance within 5 Miles Frequency plot

Figure 17 displays a map showing the distance from each centroid to the closest greenway entrance in Bexar County. Most block groups in an urban area had the closest greenway entrances within 1 to 3 miles, while most suburban areas in Bexar County shows that the shortest distance to greenway entrances is greater than 5 miles. This map indicates that suburban areas have a lower chance to obtain a greenway system. Figure 18 shows the number of trailheads within 1 mile from each centroid of block groups in Bexar County. Only people living in the block groups show the color in the map was accessible to the greenway trailheads on their foot. Also, Figures 19 and 20 show the block groups with more than one value meaning the number of trailheads within 3 or 5 miles was located near the greenway routes. Even some block groups in urban areas had no greenway entrances within 3 miles, but they had at least one greenway entrance within 5 miles. The three maps had some block groups with no street data, so they had no color in the maps. Except for them, the figures generally show that the northwest, northeast, and southeast sections of San Antonio have many accessible greenway entrances for residents, while people living in suburban areas have no accessibility to the greenways.

Figure 17. Distance from Each Centroid to the Closest Greenway Entrance in Bexar County

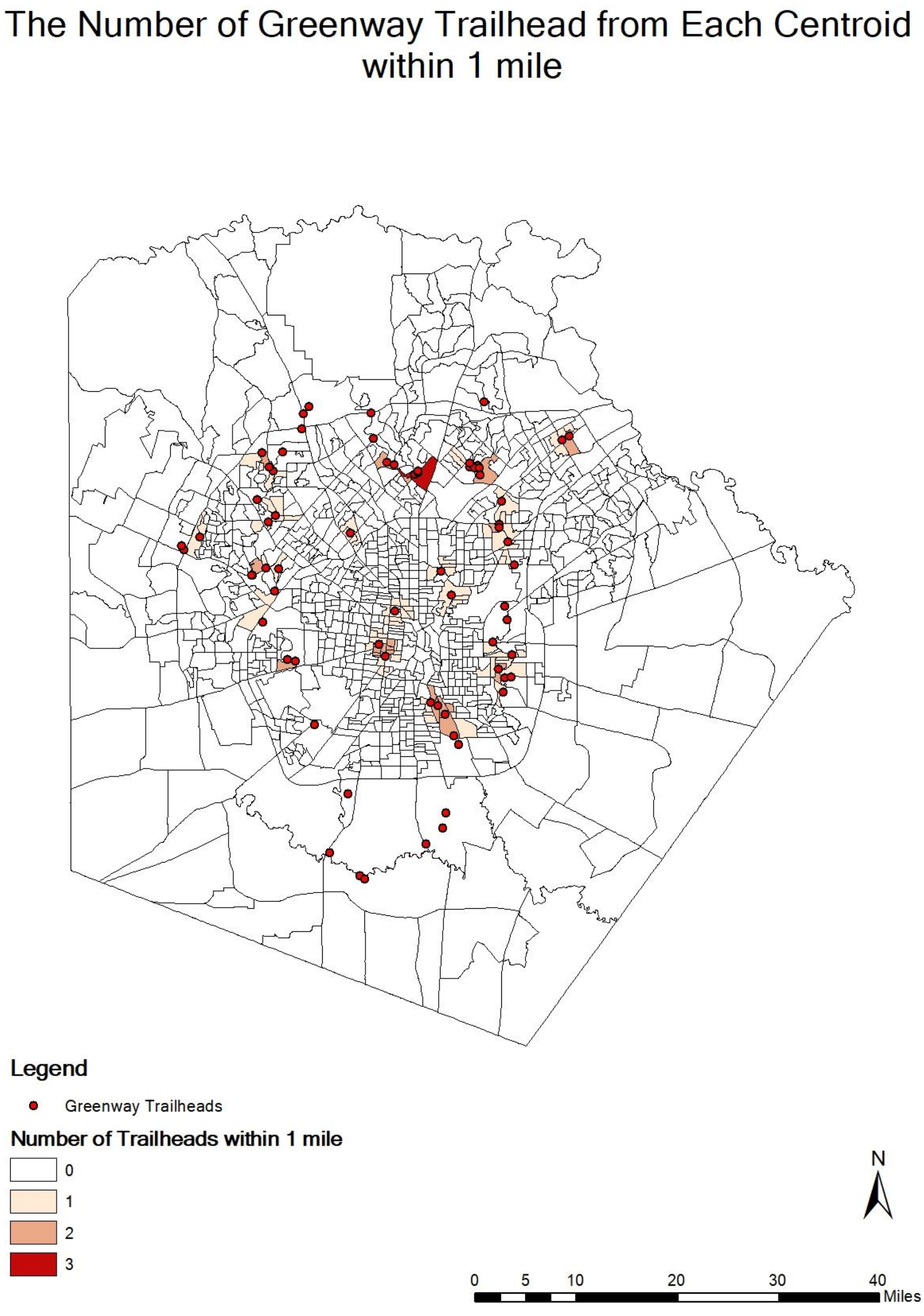

Figure 18. Number of Greenway Trailhead from Each Centroid within 1 Mile

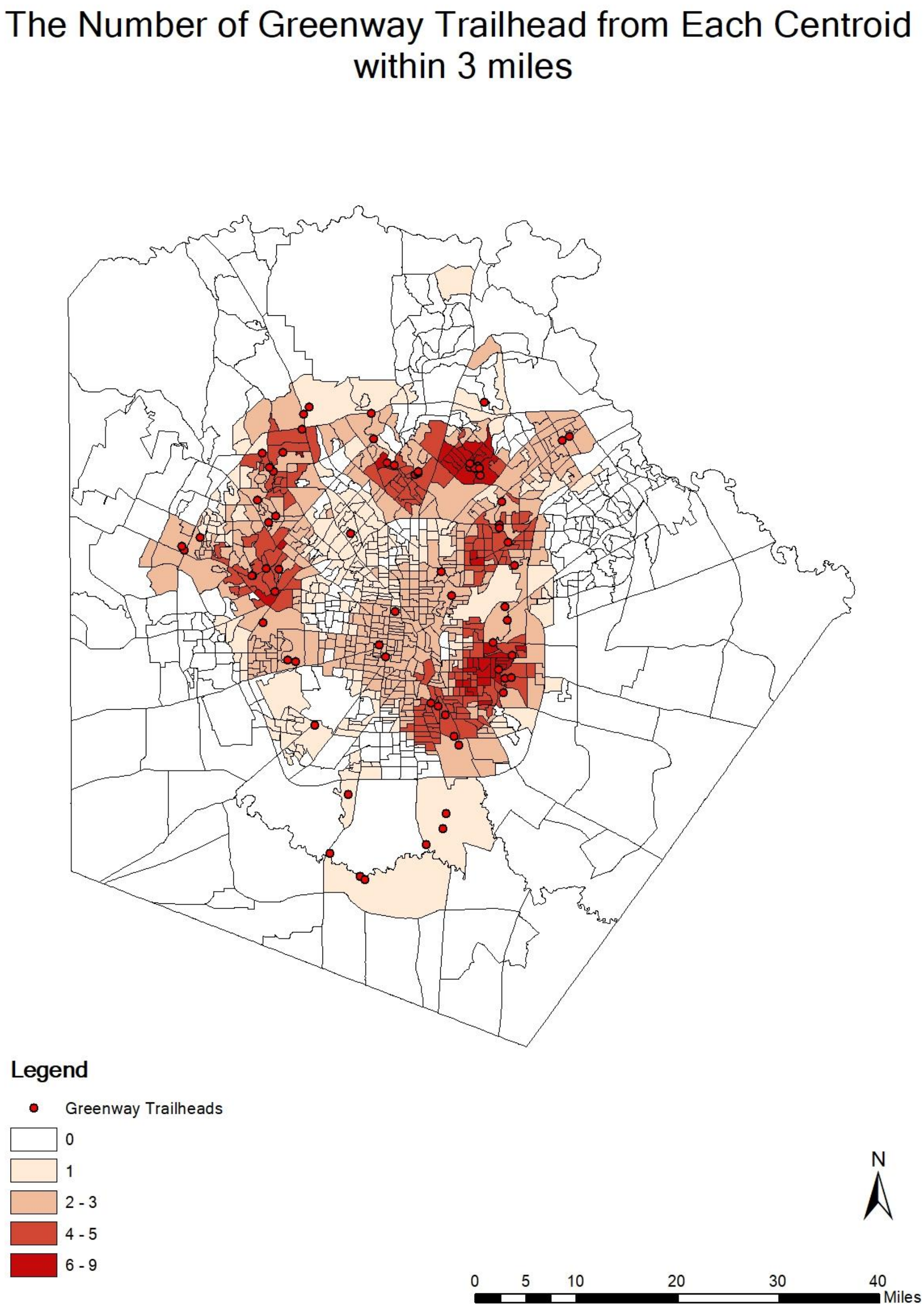

Figure 19. Number of Greenway Trailhead from Each Centroid within 3 Miles

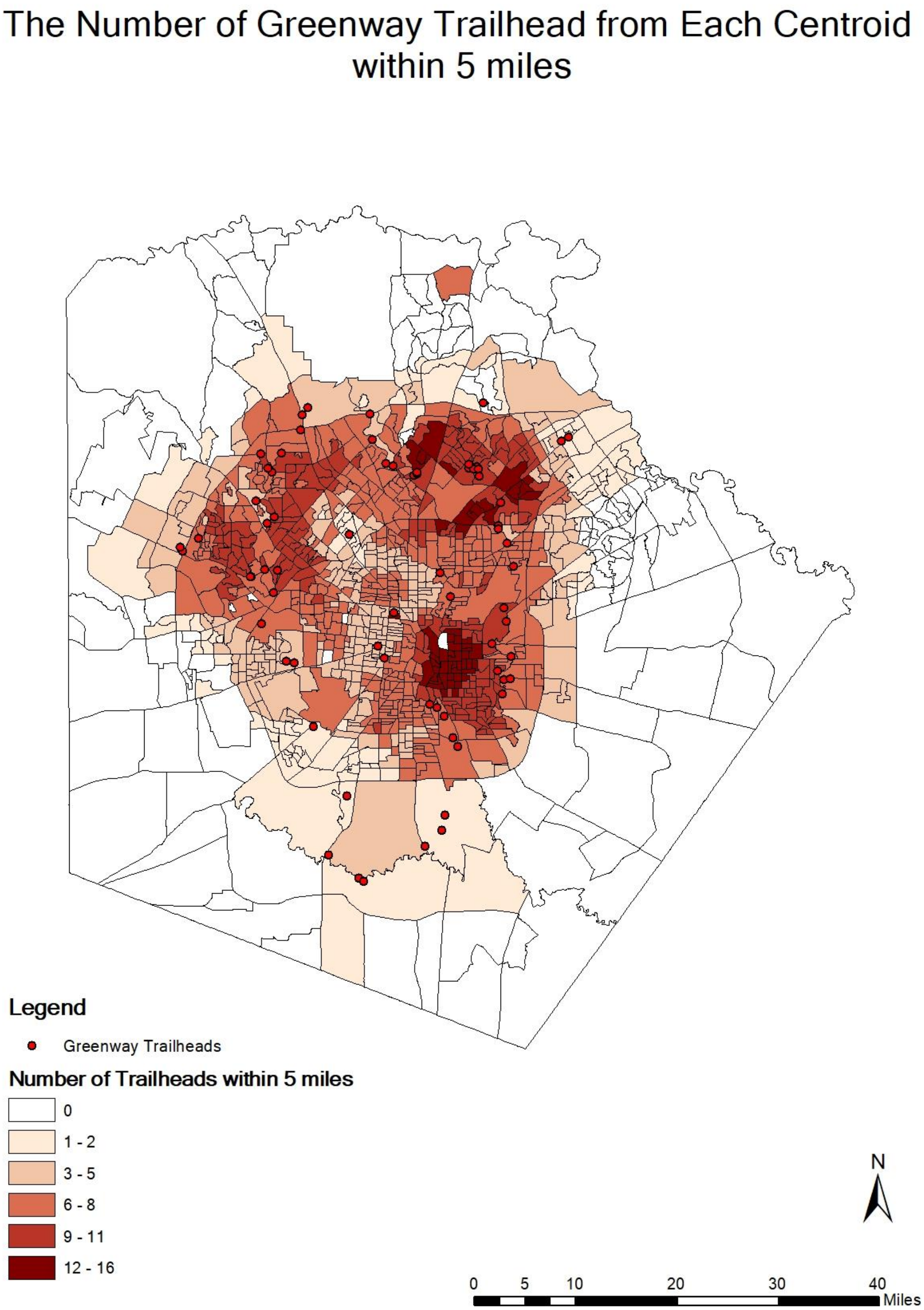

Figure 20. Number of Greenway Trailhead from Each Centroid within 5 Miles

4.2.2. Access to Greenway by SES

To examine whether access to greenways varies based on SES and location factors, the ANOVA statistical method was used. Educational attainment, median household income, and ZCTA that show whether each block group is an urban or suburban area was tested as a grouping factor in an ANOVA model. What stands out in Table 4 is the significant statistical difference in the mean network distance from each block group to the nearest greenway entrance between the different groups of the educational attainment ($F(2, 1075)$, p=0.001). To investigate how specific groups differ, the pairwise comparisons of means with equal variances result indicated a statistically significant difference in network distance only between the "high education" group and "low education" group. Also, there was a statistical significance in the mean network distance between the three groups of median household incomes in Bexar County ($F(2, 1075)$; p=0.0008). In the case of the pairwise comparisons, the output showed that a significant difference in access was found between the 'medium' and 'low' income groups (p=0.006), and the "high" and "low" income groups (p=0.002). Table 4 represents the two groups of the ZCTA in Bexar County, and the network distance shows a significant difference statistically ($F(1, 1076)$; p=0.000).

Table 5 shows, a significant difference ($F(1, 1082)$; p=0.012) between the number of greenway entrances within 1 mile from each centroid of block groups and the ZCTA, while "educational attainment" and "median household income" variables had no significance with their p-values higher than 0.05. Per the dependent variable, the service area ranges from within 1 to 3 miles; further, the median household income groups had a statistically significant difference between "medium" and "low" income block groups (p=

0.000) and “high” and “low”(p=0.000) income block groups. Also, the ZCTA had a significance statistically with the number of greenway entrances within 3 miles from the centroids of block groups to the greenway trail entrances ($F(1,1082)$; p=0.000). From the results of ANOVA showing the relationship between the number of greenway entrances and the categorized variables, i.e., “educational attainment,” “median household income,” and “ZCTA,” what is interesting about the data was that three variables had a statistically significant difference ($F(2,1081)$; p=0.008), ($F(2,1081)$; p=0.000), ($F(1,1082)$; p=0.022). Even though there was only one significant difference between the “medium” and “low” education level in the educational attainment variable (p=0.006), “median household income” and “ZCTA” showed there were statistically significant differences between all groups (p=0.022).

Table 4. ANOVA and Pairwise Comparison Results of Distance

Source	SS	Df	MS	*P*
Between groups (edu)	1.198	2	598955202	0.011
Within groups (edu)	1.424	1075	132487567	
Total (edu)	1.436	1077	133353802	
Between groups (income)	1.883	2	941586301	0.001
Within groups (income)	1.417	1075	131850114	
Total (income)	1.436	1077	133353802	
Between groups (ZCTA)	4.033	1	4.033	0.000
Within groups (ZCTA)	1.033	1076	95998317.1	
Total (ZCTA)	1.436	1077	133353802	

Distance	Contrast	Std. Err	T	*P*
Educational Attainment				
- Medium vs. Low	1618.24	923.329	1.75	0.186
- High vs. Low	2852.185*	1045.81	2.73	0.018
- High vs. Medium	1233.946	1259.457	0.98	0.590
Median Household Income				
- Medium vs. Low	2465.873**	856.234	3.09	0.006
- High vs. Low	4576.6***	1349.734	3.39	0.002
- High vs. Medium	1930.727	1202.886	1.61	0.244
ZCTA				
- Urban vs. Suburban	-25512.31***	1244.741	-20.50	0.000

*** *p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.005**

Table 5. ANOVA and Pairwise Comparison Results of the Greenway Entrance within 1 Mile

Source	SS	df	MS	*p*
Between groups (edu)	0.311	2	0.155	0.356
Within groups (edu)	162.275	1081	0.150	
Total (edu)	162.586	1083	0.150	
Between groups (income)	0.736	2	0.368	0.086
Within groups (income)	161.850	1081	0.150	
Total (income)	162.586	1083	0.150	
Between groups (ZCTA)	0.950	1	0.950	0.012
Within groups (ZCTA)	161.636	1082	0.149	
Total (ZCTA)	162.586	1083	0.150	

Greenway Entrances within 1 mile	Contrast	Std. Err	t	*p*
Educational Attainment				
- Medium vs. Low	-0.016	0.031	-0.52	0.860
- High vs. Low	-0.050	0.035	-1.41	0.334
- High vs. Medium	-0.034	0.042	-0.80	0.705
Median Household Income				
- Medium vs. Low	-0.051	0.029	-1.77	0.179
- High vs. Low	-0.092	0.046	-2.02	0.109
- High vs. Medium	-0.041	0.041	-1.00	0.575
ZCTA				
- Urban vs. Suburban	0.1229*	0.0487	2.52	0.012

*** *p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.005**

Table 6. ANOVA and Pairwise Comparison Results of the Greenway Entrance within 3 Miles

Source	SS	df	MS	*p*
Between groups (edu)	1.740	2	0.869	0.750
Within groups (edu)	3273.6	1081	3.028	
Total (edu)	3275.34	1083	3.024	
Between groups (income)	64.423	2	32.212	0.000
Within groups (income)	3210.917	1081	2.970	
Total (income)	3275.34	1083	3.024	
Between groups (ZCTA)	170.393	1	170.393	0.000
Within groups (ZCTA)	3104.946	1082	2.8696	
Total (ZCTA)	3275.34	1083	3.0243	

Greenway Entrances within 3 miles	Contrast	Std. Err	t	*p*
Educational Attainment				
- Medium vs. Low	-0.105	0.138	-0.76	0.730
- High vs. Low	-0.031	0.158	-0.20	0.979
- High vs. Medium	0.073	0.189	0.39	0.921
Median Household Income				
- Medium vs. Low	-0.538***	0.128	-4.20	0.000
- High vs. Low	-0.765***	0.203	-3.78	0.000
- High vs. Medium	-0.227	0.181	-1.26	0.419
ZCTA				
- Urban vs. Suburban	1.646***	0.214	7.71	0.000

*** *p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.005**

Table 7. ANOVA and Pairwise Comparison Results of the Greenway Entrance within 5 Miles

Source	SS	df	MS	*P*
Between groups (edu)	122.126	2	61.063	0.008
Within groups (edu)	13702.959	1081	12.676	
Total (edu)	13825.085	1083	12.766	
Between groups (income)	485.694	2	242.847	0.000
Within groups (income)	13339.391	1081	12.34	
Total (income)	13825.085	1083	12.766	
Between groups (ZCTA)	67.207	1	67.207	0.022
Within groups (ZCTA)	13757.878	1082	12.715	
Total (ZCTA)	13825.085	1083	12.766	

Greenway Entrances within 5 miles	Contrast	Std. Err	T	*p*
Educational Attainment				
- Medium vs. Low	-0.877**	0.283	-3.10	0.006
- High vs. Low	-0.237	0.323	-0.73	0.743
- High vs. Medium	0.64	0.387	1.65	0.223
Median Household Income				
- Medium vs. Low	-1.154***	0.261	-4.41	0.000
- High vs. Low	-2.487***	0.413	-6.03	0.000
- High vs. Medium	-1.334***	0.368	-3.63	0.001
ZCTA				
- Urban vs. Suburban	1.034*	0.45	2.30	0.022

*** *p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.005**

4.3 Sociodemographic Factors Predicting Access to Greenway

Before conducting multiple regression, correlation analysis was performed. Thus, the data, i.e., explanatory variables, were tested to discern whether there is a correlation between the independent variables and four dependent variables. The variables with a *p*-value lower than 0.05 are regarded as those with a correlation to the dependent variables.

In the case of correlation with the distance, the following variables were correlated with distance to the closest trailhead; per capita income, housing units, age 0-17, 2+ vehicles, high education, and median household income. The following variables were negatively correlated with distance to the closest trailhead; population density, below poverty<0.5%, age 65+, Hispanic or Latino, female, unemployed rate, no vehicle, one vehicle, and ZCTA.

On the service areas, population density (1, 3, and 5 miles), below poverty<0.5% (1, 3, and 5 miles), age 45-64 (3 and 5 miles), age 65+ (3 miles), unemployed rate (1 and 3 miles), no vehicle (3 and 5 miles), one vehicle (3 and 5 miles), and ZCTA (1, 3, and 5 miles) were the positively correlated. Seven variables which are per capita income (1 mile), age 0-17 (3 miles), age 18-44 (5 miles), race white (5 miles), race black (5 miles), 2+ vehicles (3 and 5 miles), and median household income (1, 3, and 5 miles) were correlated negatively.

Table 8. Correlation Analysis Results

	Distance	Service Area (1 mile)	Service Area (3 miles)	Service Area (5 miles)
Population Density (sq.mi)	-0.364***	0.092*	0.152***	0.066*
Per Capita Income	0.135***	-0.071*	-0.037	-0.047
Housing Units	0.167***	-0.059	-0.15***	-0.129***
Below Poverty<0.5 (%)	-0.106***	0.08**	0.091**	0.141***
Age 0-17 (%)	0.099**	0.038	-0.1**	-0.027
Age 18-44 (%)	-0.032	-0.028	-0.026	-0.062*
Age 45-64 (%)	0.012	0.028	0.065*	0.075*
Age 65+ (%)	-0.078*	-0.033	0.08**	0.038
Race White (%)	-0.013	-0.026	-0.007	-0.065*
Race Black (%)	-0.0002	0.034	-0.007	-0.065*
Race Other (%)	0.02	0.002	-0.047	0.012
Hispanic or Latino (%)	-0.248***	0.054	0.056	0.044
Female (%)	-0.064*	0.022	0.039	0.014
Unemployment Rate (%)	-0.107***	0.096**	0.064*	0.052
No Vehicle (%)	-0.13***	0.049	0.169***	0.232***
1 Vehicle (%)	-0.116***	0.043	0.115***	0.224***
2+ Vehicles (%)	0.159***	-0.06	-0.179***	-0.297***
High Education	0.091**	-0.043	-0.014	-0.054
Median Household Income	0.114***	-0.067*	-0.135***	-0.187***
ZCTA	-0.53***	0.076*	0.228***	0.07*

*** $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$**

From the correlation analyses, the majority of the sociodemographic variables were significantly related to access, when examined independently. However, a number of the sociodemographic variables are related to each other, and the analysis needs to be done in regard to controlling for the other variables. Thus, the multi-regression analysis was performed to investigate the relationship between the socio-economic variables and the four dependent variables. Table 9 represents the result of the multiple regression analysis using the shortest network distance between the centroids of each block group and the nearest entrance of greenway trail routes in Bexar County, Texas. This analysis is conducted four times for each dependent variable (Table 10, 11, 12), and additional analysis to obtain the VIF value (variation inflation factor) is done to check the multicollinearity among the independent variables. In the first regression analysis, we removed six variables, "percentage of white race," "percentage of age 0 to 17," "percentage of no vehicle available," "low level of high educational attainment," "low level of median household income," and "suburban area." The variables were omitted to avoid the dummy variable trap. With this change of independent variables, the result represents that there is no multicollinearity problem because the highest VIF value is lower than the criterion value 10. For the network distance from block groups to the nearest greenway entrance, the 12 explanatory variables show their statistically significant difference; housing units (β=4.309; p=0.000) is only positive association while others were negatively associated; population density (β=-0.495; p=0.000), age 18-44 (β=-249.458; p=0.000), age 45-64 (β=-145.434; p=0.002), age 65 or more (β=-235.243; p=0.000), black or African American (β=-111.914; p=0.001), Hispanic or Latino (β=-125.350; p=0.000), female (β=-121.35; p=0.011), unemployed rate (β=-88.935; p=0.049), medium educational attainment (β=-2578.825; p=0.005), high educational attainment (β=-3367.123; p=0.012), and urban area (β=-21185.04; p=0.000).

Table 9. Regression Results for Socioeconomic Variables Predicting Access to the Greenway

	Coef.	SE	*P*	VIF
Population Density (sq.mi)	-0.495***	0.104	0.000	1.47
Per Capita Income	-0.021	0.036	0.557	3.70
Housing Units	4.309***	0.859	0.000	1.33
Below Poverty<0.5 (%)	-29.732	38.911	0.445	1.42
Age 18-44 (%)	-249.458***	42.27	0.000	2.41
Age 45-64 (%)	-145.434***	47.685	0.002	1.75
Age 65 or more (%)	-235.243***	46.69	0.000	1.78
Race Black or African American (%)	-111.914***	34.739	0.001	1.62
Race Others (%)	49.622	31.356	0.114	1.12
Hispanic or Latino (%)	-125.35***	19.247	0.000	3.16
Female (%)	-121.35*	47.57	0.011	1.11
Unemployment Rate (%)	-88.935*	45.038	0.049	1.18
1 Vehicle (%)	-5.284	39.259	0.893	4.45
2+ Vehicles (%)	55.086	34.874	0.114	5.83
Educational Attainment: Medium	-2578.825**	911.759	0.005	1.65
Educational Attainment: High	-3367.123*	1330.078	0.012	2.74
Median Household Income: Medium	68.771	834.838	0.934	2.00
Median Household Income: High	-1042.439	1341.201	0.437	2.09
Urban area (ZCTA)	-21185.04***	1323.704	0.000	1.28
_cons	64216.24	5543.097	0.000	

Access to greenway measured using distance to closest greenway entrance (n=1,074)
*** $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$**

Table 10 represents the result of regression analysis between the independent variables and the number of greenway entrances within 1 mile. The result of the multiple regression analysis indicates that only one variable, i.e., “unemployment rate,” is positively statistically significant with the number of greenway entrances within 1 mile. However, the data in Table 11 reveal that the nine socioeconomic variables have statistically significant differences with the number of greenway entrances within 3 miles. The positively significant variables are population density, age 18-44, age 45-64, age 65 or more, black or African American, high educational attainment, and urban area. Two variables, housing units and two or more vehicles available, had negative significance. Also, as shown in Table 12, there are two independent variables, age 45-64 and black or African American, which were positively significant with the number of greenway entrances within 5 miles, while housing units and two or more vehicles available variables were negatively significant.

Table 10. Regression Results of Socioeconomic Variables Predicting Number of Greenway Entrances within 1 Mile

	Coef.	SE	*p*	VIF
Population Density (sq.mi)	8.11	4.39	0.065	1.46
Per Capita Income	-1.48	1.54	0.337	3.70
Housing Units	0.000	0.000	0.189	1.33
Below Poverty<0.5 (%)	0.002	0.002	0.160	1.42
Age 18-44 (%)	-0.002	0.002	0.364	2.43
Age 45-64 (%)	0.002	0.002	0.292	1.76
Age 65 or more (%)	-0.003	0.002	0.193	1.77
Race Black or African American (%)	0.001	0.002	0.474	1.61
Race Others (%)	-0.001	0.001	0.738	1.12
Hispanic or Latino (%)	0.000	0.001	0.879	3.16
Female (%)	0.001	0.002	0.611	1.12
Unemployment Rate (%)	0.004*	0.002	0.025	1.18
1 Vehicle (%)	0.000	0.002	0.792	4.46
2+ Vehicles (%)	0.000	0.002	0.935	5.83
Educational Attainment: Medium	0.049	0.039	0.209	1.67
Educational Attainment: High	0.045	0.057	0.434	2.75
Median Household Income: Medium	-0.015	0.036	0.675	1.99
Median Household Income: High	-0.028	0.057	0.631	2.08
Urban area (ZCTA)	0.074	0.056	0.192	1.29
_cons	-0.006	0.236	0.981	

Service area analysis measured using the number of greenway entrance within 1 mile (n=1,080).
*** $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$**

Table 11. Regression Results of Socio-Economic Variables Predicting Number of Greenway Entrances within 3 Miles

	Coef.	SE	p	VIF
Population Density (sq.mi)	0.000*	0.000	0.018	1.46
Per Capita Income	-1.30	6.56	0.843	3.70
Housing Units	-0.001***	0.000	0.000	1.33
Below Poverty<0.5 (%)	-0.003	0.007	0.690	1.42
Age 18-44 (%)	0.025***	0.008	0.001	2.43
Age 45-64 (%)	0.286***	0.009	0.001	1.76
Age 65 or more (%)	0.211*	0.009	0.013	1.77
Race Black or African American (%)	0.018***	0.006	0.004	1.61
Race Others (%)	-0.008	0.006	0.157	1.12
Hispanic or Latino (%)	0.005	0.004	0.139	3.16
Female (%)	0.013	0.009	0.132	1.12
Unemployment Rate (%)	0.01	0.008	0.231	1.18
1 Vehicle (%)	-0.012	0.007	0.107	4.46
2+ Vehicles (%)	-0.021***	0.006	0.001	5.83
Educational Attainment: Medium	0.286	0.165	0.083	1.67
Educational Attainment: High	0.504*	0.242	0.037	2.75
Median Household Income: Medium	-0.162	0.151	0.285	1.99
Median Household Income: High	-0.054	0.244	0.825	2.08
Urban area (ZCTA)	1.21***	0.24	0.000	1.29
_cons	-0.456	1.004	0.650	

Service area analysis measured using the number of greenway entrance within 3 miles (n=1,080).

*** *P* < 0.05; ** *p* < 0.01; *** *p* < 0.005**

Table 12. Regression Results of Socioeconomic Variables Predicting Number of Greenway Entrances within 5 Miles

	Coef.	SE	p	VIF
Population Density (sq.mi)	0.000	0.000	0.308	1.46
Per Capita Income	8.41	0.000	0.534	3.70
Housing Units	-0.001**	0.000	0.007	1.33
Below Poverty<0.5 (%)	-0.003	0.015	0.825	1.42
Age 18-44 (%)	0.013	0.016	0.418	2.43
Age 45-64 (%)	0.048**	0.018	0.007	1.76
Age 65 or more (%)	0.007	0.018	0.681	1.77
Race Black or African American (%)	0.041***	0.013	0.001	1.61
Race Others (%)	0.007	0.012	0.564	1.12
Hispanic or Latino (%)	0.007	0.007	0.305	3.16
Female (%)	0.005	0.018	0.782	1.12
Unemployement Rate (%)	0.007	0.017	0.691	1.18
1 Vehicle (%)	-0.026	0.015	0.075	4.46
2+ Vehicles (%)	-0.07***	0.013	0.000	5.83
Educational Attainment: Medium	-0.222	0.34	0.514	1.67
Educational Attainment: High	0.337	0.498	0.499	2.75
Median Household Income: Medium	0.006	0.312	0.985	1.99
Median Household Income: High	-0.136	0.502	0.786	2.08
Urban area (ZCTA)	0.573	0.493	0.246	1.29
_cons	7.223	2.069	0.001	

Service area analysis measured using the number of greenway entrance within 5 miles (n=1,080).

*** *P* < 0.05; ** *p* < 0.01; *** *p* < 0.005**

CHAPTER 5

DISCUSSION

5.1. Main Findings

In the results of ANOVA, ZCTA shows a statistically significant difference between the network distance and the number of service areas. Block groups in urban areas have shorter distances to the nearest greenway entrances and tend to have more greenway entrances within 1, 3, and 5 miles than in suburban areas. This means that the greenway trail system in San Antonio is focused on urban areas. It is not surprising because the greenway routes were planned by the city of San Antonio, wherein the planners focused on the city rather than the entire Bexar County. Two variables, i.e., educational attainment and median household income, also show a significant difference between some groups but only “high vs. low” in educational attainment and “medium vs. low” and “high vs. low” in median household income show their significant difference. Thus, we can say that block groups with higher percentage of residents who had low educational attainment had greater access to greenway entrances. Also, low median household income groups have shorter distances to greenway entrances than do medium or high groups. In the case of the service areas, no significant difference between educational attainment and median household income and the number of greenway entrances were shown within 1 mile from block groups. However, block groups with the higher percentage of residents who were low median household income groups have more greenway entrances within 3 miles from their residential areas. From the results, we can see that low education-level groups have more greenway entrances within 5 miles, and the lower their household income is, the more greenway entrances their block groups have as well.

The results of correlation analysis and multiple regression analysis revealed that when the population density, age, percentage of black or African American, Hispanic or Latino, female, high educational attainment, or unemployed rate of the block group increases, the distance between the block groups to the greenway entrances decreased, while with the more housing units in the block group, the distance increased. What is striking about the result was that block groups with more female had better access to greenways. Also, groups with higher percentage of all groups without the group having a higher percentage of people whose age is lower than 18 were closer to greenway entrances. As in the number of greenway entrances within 1 mile, there was no significant difference except for the unemployment rate which showed only a slight positive association. It may be possible to say that the greenway system was not designed for people to access on foot. However, the increase of housing units or the percentage of households with two or more vehicles was correlated with the decreasing the number of greenway entrance within 3 miles, while the increase of population density, the percentage of people whose age is higher than 18, the percentage of black or African American, or high educational attainment was associated with an increase in the number of greenway entrances within 3 miles. Finally, the data showed two variables, i.e., housing units and households having two or more vehicles, and their increase was correlated with the decrease in the number of greenway entrance within 5 miles from their block groups. However, the increase in the percentage of those whose age is higher than 45 and lower than 65 and that of black or African American was associated with the increase in the number of greenway entrances. Two variables, which are "below poverty < 0.5" and "1 vehicle available," had a correlation relationship with the dependent variables, but the regression analysis result showed the variables had no significance with the dependent variables, so we can conclude that the two variables were not significant with the distance and number of greenway entrances within a specific distance. The interesting point is that the area with more housing units had lower accessibility of the greenway system. The greenway system is aimed to improve citizens' health, but, ironically, the greenways were less accessible to residential areas. Also, the regression results that represented black or African Americans are more accessible to greenways, including distance and number of greenway entrances. This result is similar with some of previous studies showing that the African Americans live closer to parks than Caucasians (Boone et al., 2009; Rigolon, 2016; Wen et al., 2013; Zhou & Kim, 2013), while some studies showed that whites live near the parks (Dai, 2011; Rigolon & Flohr, 2014). There were different results of previous studies based on the site, where the city or town is.

The study focused on network distance and how many greenway entrances are located within a specific distance for households in Bexar County, while the previous study focused on the satisfaction of a specific route of greenway users in San Antonio. Also, the study is meaningful because the San Antonio's greenway system has been constructed recently, and the geographical data of the greenway system includes all of the data including the routes under construction. This point eased measuring the accessibility of the greenway system.

5.2 Policy Implication

Greenways in San Antonio have been developed mostly in urban areas. Although this would ensure access for inner-city residents who are more likely to lack access to green space otherwise, it raises the question about access for suburban communities. It is general status because urban areas typically have a high ratio of impervious surfaces and a lack of green space, while suburban areas have green space such as forest, woods, and rivers. However, the greenway is not only green space but also space where people can enjoy diverse activities such as biking, recreational activities, or other outdoor activities. If other big cities plan to construct greenway routes or change original routes, it is better to consider various transportation to these areas such as bus stops, subway stations, or walkways to support most residents living in the cities. The San Antonio greenway is the right place for people in which to walk or ride a bike, but entrances are only accessible by personal vehicles. San Antonio has built the greenway system well without a one-sided pattern, but if the city plans to improve the greenway trail system in the future, officials need to consider more block groups with higher percentage of people being relatively less accessible to the greenway now by making more accessible point to the routes.

Also, some studies indicate that Caucasians have a lower perception of the cultural benefits of greenways than other races (Larson et al., 2016). In this analysis, block groups with more African Americans have better access to greenways. This result supports the previous studies' result. However, it is necessary for planners and officers to consider that routes are provided equally to each resident area so that other minor races have access within 3 miles as blacks can do. The previous study noted that the greenway route of San Antonio intrigued a substantial number of minor races, i.e., more than whites with the value of the minor race users of Leon Creek Greenway at 55%. The result means planners should consider racial and income levels. The results show that more people with high educational attainment or older people tend to live near greenway entrances and urban areas are more accessible than suburban areas. It is different compared with that of previous studies that reveal that older people tend to live in suburban areas, while younger people prefer to live in the city center. Also, the choropleth map shows more residents who have high educational attainment live on the north side of San Antonio. This means that the greenway trail routes were constructed in the north area rather than south area. Planners should design greenway routes as accessible geographically as well.

5.3 Limitations & Future Research Direction

The study results indicate that those areas having a higher percentage of lower levels in educational attainment and median household income tend to live in areas farther from greenway entrances. However, this study was based on a distance-based approach, but low SES groups face more challenges in accessing greenways than distance alone. For example, they tend to have less vehicle access and less free time to allocate than the others; thus, even if they are within walking or short driving distances to greenways, they may not be able to use it. In future studies, more temporal and social barriers that the low SES groups face should be taken into consideration. Also, although this study controlled for urbanity in the regression models, location still has an impact on the results. The areas in the periphery of the city are areas with certain socio-demographic characteristics. For example, two households, regarded as same location category such as suburban area, may have different characteristics when one household located at boundary of Bexar County and another household located at the area near the city of San Antonio. Additionally, this study did not consider individual preferences. Future research should include individual purposes or preferred transportation systems. Besides, this study looked at one-time point, and did not consider green gentrification or the impacts of greenways on communities over time. Also, this study only examined trailheads with parking lots as access points in the study area. However, there are other access points along the greenways in addition to the trailheads. If researchers do a similar study focusing on the other greenways in different cities, the network analysis method should be changed so people can access greenways through not only entrances but other spots as well. For future research, it is necessary to obtain more accurate updated data. If the city of San Antonio updates its greenway system such as through adding more accessible places, accessibility should be reconsidered again but with different methods. Also, this study obtained network distances with only street data and the centroids of block groups. However, the data used in this study has no travel time information; thus, researchers need to consider using street data and travel time with diverse travel ways to obtain more accurate results. This study is a correlational study and does not imply causation.

CHAPTER 6

CONCLUSIONS

Overall, this report introduced accessibility routes between various groups with selected socioeconomic variables. The greenway routes of San Antonio extend circularly with linear roads, but the access points are only entrances near parking lots. By measuring network distance from the block groups to the nearest greenway entrance, the study can physically measure greenway accessibility. Greenway routes were designed with much consideration by planners and city officials, so the routes appear to be equally provided to most residential areas. However, different groups live in different areas with regular or irregular patterns. The result of analyses indicates groups with socioeconomic variables are not provided equal greenway accessibility. As the results also showed, future planners and city officials should consider equal accessibility of greenways or other urban facilities to provide urban services.

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