SPATIAL EQUITY ANALYSIS IN THE

ATLANTA 10-COUNTY REGION

by

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ABSTRACT

Spatial equity plays an important role in the planning process. Whether or not a city can provide relative equity in term of accessibility to its residents influences its development. Prior research focusing on housing distribution and the accessibility of households to public facilities shows an accessibility gap between different socioeconomic groups, with the low-income and minority groups being disadvantaged in terms of access to public goods and services. Since accessibility is closely related to mobility, access to public transportation has also been taken into consideration to examine the equity status of places. This thesis analyzed the spatial equity status of the Atlanta 10-County Region. The equity status of four household groups including White households with cars, White households without cars, African American households with cars, and African American households without cars are compared. Eight types of public facilities were chosen to analyze the accessibility of household groups traveling by public transportation system and by car. The results showed that households traveling by car have more accessibility than households without cars traveling by public transportation. Also, though there was a similar level of spatial equity between the two racial groups with the same transportation mode, when the two different transportation modes are considered, a high level of spatial inequity existed between two racial groups. White households had more accessibility than African Americans.

LIST OF ABBREVIATIONS AND SYMBOLS

ADA	Americans with Disabilities Act
ARC	Atlanta Regional Commission
MARTA	Metropolitan Atlanta Rapid Transit Authority
CCT	Cobb County Transportation
GCT	Gwinnett County Transit
GRTA	Georgia Regional Transportation Authority
LISA	Local Index of Spatial Autocorrelation
IEI	Integrated Equity Index
RA	Relative Accessibility
MAUP	Modifiable Areal Unit Problem
MTFCC	MAF/TIGER Feature Class Code

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CHAPTER 1

INRODUCTION

The purpose of this thesis is to analyze spatial equity status by public transit and automobile in the Atlanta 10-county metro area. The Relative Accessibility (RA) of households to public facilities will be used to measure the degree of spatial equity in the Atlanta region. This region is located in north Georgia and includes 10 counties around the city of Atlanta. According to the Atlanta Regional Commission (ARC), these counties are: Cherokee, Clayton, Cobb, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry, and Rockdale. The city of Atlanta is a transportation hub with an international airport and three major interstate highways (I-75, I-20, and I-85), and also serves as the economic capital of the American South. Besides its advanced street network, the Atlanta region has a convenient public transportation system using both bus and rail modes.

This area is in the range of the low foothills of the Appalachian Mountains and the piedmont, with an average elevation of 1,000 feet. It has many streams and creeks and is in the main basin of the Chattahoochee River. The Atlanta 10-county area has a population of approximately 3.5 million with 1.6 million households in the year 2000. Among the population about 30% is African American, 8 percent Hispanic and 4 percent Asian or other (Metro Atlanta Chamber, 2009). It has already become an international city with people from many countries, and with a variety of ethnic groups. A recent survey reports that there are over 500,000 foreign-born residents in metro Atlanta, which is about 10.3 percent of the population (Schemmel and Hurst, 2008). However, the rapid economic development in recent years triggered an increase in socio-economic inequality in Atlanta, and it is among the most segregated cities in the United States (Keating, 2001). According to Berube et al. (2003), there are dramatic social differences in education, work and income, especially for the black population, with one third living below the poverty line. Social inequity has sharpened the demographic characteristics of the region.

Spatial inequity is not a new topic. It appeared early in history; and is related to the evolution of cities and metropolitan areas. The spatial evolution of cities is related to the development of transportation, so it is also a transportation topic. According to Adams (1970), the development of urban transportation and land use can be divided into four eras: the walking-horsecar era (1800-1890), electric streetcar era (1890-1920), recreational automobile era (1920-1945) and freeway era (1945-present).

In the first era, land use in urban areas was mixed. People worked where they lived, and were in walking distance of essential services. Only rich people could manage to live outside of the central city and get to it with their horse-drawn carriages. Because of intensified industrialization, urbanization became unavoidable from 1850. Cities were filled with a wide variety of people, and came to be regarded as centers of corruption and social inequalities (Pucher, 2004).The affluent could afford to move to the outside of the city and enjoy the high-amenity environment of the periphery, but for the mass middle and working class, access to the periphery was limited.

In the second era, the urban area expanded, which was triggered by the evolution of transit technology – the appearance of electric streetcars. Residential land use was separated from the workplace, and street cars were used for commuting. The middle-class had more mobility with the help of an improved urban transportation system. Public transportation bloomed until automobiles appeared and became widespread in the United States.

The rapid increase in automobiles and development of roads and highways provided more mobility for people to get around. The rich had more choices as to where to live. Distance to work did not limit residential mobility for others. New urban fringe areas were opened up, and more and more members of middle-class moved outwards, leaving the low-income groups remaining in the old central city. Spatial inequity became more apparent.

In the third era, the development of automobiles brought not only the greater freedom of movement, but also a reduced market share for public transportation. As people became more and more reliant on automobiles, residential development expanded in the suburbs, outer periphery, and even the countryside. When the suburbs became crowed, people moved from the city. This process triggered the degradation of the central city and older suburbs, and also placed much pressure on the provision of public facilities. This processed continued during the fourth era and remains ongoing today.

Despite reliance on automobiles, public transportation is importation in urban transportation system for two reasons (Jönson, 2005). From the standpoint of the environment, public transportation can provide great help in reducing congestion and energy consumption, as well as adverse effects on the environment by vehicles. One of the most important roles of public transportation is that it can greatly improve the accessibility of those without automobiles, which plays a vital role in improving overall spatial equity. The thesis will examine this topic.

CHAPTER 2

LITERATURE REVIEW

Spatial equity

The problem of spatial inequity can be regarded as a product of urban development. Immigrants from Western Europe, Africa and Asia contributed to the variety of cultures in American society. However, along with these immigration trends, congestion, corruption and crime increased in the central city. The rich relocated to in the periphery or the countryside. With automobiles, they could enjoy the amenity of the fringes. Low land prices and taxes in the urban fringe, and the outwards movement of residents also triggered the moving of major business activities to the fringe. Over time, the central city deteriorated. Only the have-nots remained, lacking access to job opportunities and a high-amenity environment because of a lack of mobility.

Since the 1980s, there has been much research focusing on the analysis of equity (Jones & Kirby, 1982; Kirby, Knox, & Pinch, 1983; Hay, 1995; Talen & Anselin, 1998). The concept of equity is broad and different research has had different understandings of equity. Dworkin (1981) stated that equity was related to the free choices of resource utilization. According to Le Grand (1991), equity meant that all members of a population, regardless of where they live, should have the same choice sets. Hay (1995) related the concept of equity to geographical distributions and access across space. If some residents have more difficulties or need to bear more costs in access across space than others, the extent of which the equity is achieved would be limited. He also argued that though in some cases there can be a good match between distribution of population and public provision, inequity can also happen. For instance, even if there were a large amount of medical service provision in an area with many elderly people, the requirement of equity would not necessarily be satisfied because whether medical provision is proper and available for elderly people or not remains a question. Recent research by Tsou et al. (2005) used spatial equity to refer to the equal-treatment of all residents. In general, the notion of equity is about the distribution of income, goods or services (Murray, 2001).

Income difference and housing distribution are the two most important aspects in the studies of social inequity. Income difference in the inter-region level classified by race has long been a concern of planning. According to Mieszkowaki (1979), the percent of low-income people among minority groups is significantly different between regions. Smith and Welch (1979) also analyzed the problem of income difference between races. Evidence shows that compared to their White contemporaries, minority groups experience disadvantages in workplaces, education and access to essential services (Couch & Daly, 2002; Andrews, 2003). Study by Yu and Zhang (2005) showed that the average income of African Americans were about 37% lower than that of White residents at the end of 2001.

Prior research in spatial equity also focused on the housing distribution of the minority groups. According to Eunice and Grier (1968), segregation of different races is a major contribution to social inequity. One of the consequences of discrimination is housing segregation, which are associated with educational deficiencies, low employment rates and social disorders in the minority groups. Social inequity is also related to unequal distribution of resources between the central city and suburb, the middle-class groups and the low-income groups. The middle-class groups enjoy more than their share of resources, while the low-income minority groups have less than their share. In the planning process, the problems of spatial equity should be taken seriously (Eunice and Grier, 1968).

Although the issue of spatial equity has existed for a long time, not until recently has research on spatial equity of public facilities been conducted (Tsou et al., 2005). Though public services should be provided equitably, the complexity of residential territories within jurisdictions makes the equity goal hard to achieve (Knox and Pinch, 2000). In urban planning, spatial equity in access to public facilities is one of the vital factors of sustainable development. However, research has revealed that equity status remains to be improved (Talen, 1997; Nicholls, 2001; Tsou et al., 2005; Wolch et al., 2005; Kawabata and Shen, 2007).

Frieden and Morris (1968) discussed the problem of inequity in urban areas. They pointed out that the most important planning issue was to extend equal opportunities to the minority groups, and in particular to increase access to better education resources, health programs, recreation facilities, and cultural resources. In their opinion, the character of places mattered a lot. Even in the same metropolitan area, different places provided different quantities and qualities of public goods and services (Frieden and Morris, 1968). Therefore, questions of where the minority groups lived partly determined what levels of public services they could receive. Another factor which influenced access to opportunities was freedom of movement, which was a prerequisite for access to better housing. They argued that lack of residential mobility could be a serious problem for the minority groups, because they might be restricted within certain locations without good access to public services, which in turn reduced their social mobility and opportunities to live a better life.

Prior research on the distribution of public goods and services examined whether or not they are equally distributed among residents or residential groups (Talen, 1997; Rosero-Bixby, 2004; Byrne and Wolch, 2009; Gibson et al., 2010). Among this research, many focused on spatial distribution of one specific type of public services, e.g., schools, health care facilities, parks and green spaces, grocery stores.

In one type of research, social factors such as race, ethnicity, and socio-economic status were taken into account, and equity was examined based on the access of different groups of people to public facilities. For example, Stoll (2005) studied spatial mismatch between black people and jobs. This study showed that for metropolitan areas in 2000, there was a greater spatial mismatch between jobs and black residents, and blacks were more isolated from jobs in job-sprawl areas. Wolch et al. (2002) found that minority groups may lack access to parks. Helling and Sawicki (2003) calculated the accessibility to shopping and services and found differences in residential access by race.

In another type of research, the type of facility was considered, and equity was examined based on the demand and supply of that type of facility. For example, there are two articles that analyzed equity from the standpoint of needs and supply. Rosero-Bixby (2004) analyzed the supply and demand of health services and revealed the geographic characteristic of access inequity. The study found that around 14% of population was underserved in Costa Rica based on the selected indicators. Murray (2001) evaluated the distribution equity of transportation services by identifying people who may need public transport services but do not have sufficient opportunities (i.e., potential mismatch between demand and supply). The application in Queensland showed that the provision of public transportation was not always consistent with the need for the services, such as in some areas of substantial employment in need of public transportation that were transportation disadvantaged.

Accessibility and spatial equity

According to Fainstein and Fainstein (2009), social inequity especially income inequity has been growing in the past several decades. They also indicate that it is important to be aware that even though the distribution of services is equal, or that poor areas may even enjoy a disproportionate advantage in access to public goods and services, social inequity cannot be easily overcome. Most low-income people are concentrated in the central city, which is near to public services, while the high/middle income groups in the fringe area could be farther from these facilities. However, spatial equity is more complex than just proximity to public services. Other factors also matter a great deal in spatial equity, such as the different quality of public goods and services and the choices among a variety of facilities. Taking these factors into account, the examination of distribution of public goods and services could be complex. The concept of spatial equity is therefore tightly related to accessibility to public goods and services, and the analysis of equity relies on the measure of accessibility. ‘Accessibility’ was made a part of the Americans with Disabilities Act of 1990 (ADA) to describe the ways in which a building or a site is physically reachable for all people with disabilities. It is also commonly defined as the ease with which activities can be reached from a certain place given the mode of transport (Lotfi and Koohsari, 2009). As it is critical to the economic productivity of property, accessibility has been a concern for many years (Andrews, 1962). The analysis of accessibility is tightly related to the issue of equity. For example, taking into account social factors, Shen (2005) evaluated the location of manufactured housing and its accessibility to community services; Song and Sohn (2007) measured spatial accessibility to retailing of single family housing.

Although little research has focused on spatial equity related to access to multiple public facilities, there has been much research that has studied accessibility of different types of public goods and services. Among them, considerable research has focused on the provision of parks, while others focused on the distribution of health care facilities. For example, Moore et al. (2008), Lotfi and Koohsari (2009) studied the accessibility of parks and its distribution among different socio-economic classes in different cities. Both of the studies found that there were spatial disparities in the distribution of parks. Smoyer-Tomic et al. (2004) and Comber et al. (2008) also paid attention to the supply of greenspace and playgrounds. The study by Comber et al. (2008) found that access to urban greenspace was unevenly distributed among different ethnic groups of society, and Indian, Hindu, and Sikh groups had limited access to the greenspace in the city. There is also much research focusing on accessibility to health centers (Seymour et al., 2006; Hare and Barcus, 2007; Ohta et al., 2007; Loh et al., 2009). For example, Gibson et al. (2010) studied the accessibility and the equity of health centers to households in rural China.

Other types of public facilities analyzed include the access to grocery stores or retail stores with a focus on equity in food, such as Wang and Lo's (2005) research on grocery-shopping behavior and Song and Sohn's (2007) research on spatial accessibility to retailing. Prior research also evaluated the equity of job opportunities (Shen, 1998; Wang and Minor, 2002). A study by Shen (1998) evaluated location characteristics and employment accessibility of low-income workers in Boston's inner-city neighborhoods. Results revealed that because of a low ownership rate of automobiles, low-income workers had limited employment accessibility. Similarly, a study by Wang (2005) also showed that low-wage workers had the lowest job accessibility among various wage groups, as a result of limited transport mobility.

Deka (2004) summarized the importance of accessibility in different types of public facilities and resources. For access to health care facilities, many studies show that even though hospitals are located close to the low-income households and minority groups, those populations always have low access to health care because of lack of mobility (Ginzberg, 1991; Malgren et.al, 1996;

Hanson and Giuliano, 2004). He pointed out that good access to health care was absolutely essential. Even if other activities can be accessed through public transit, trips to hospitals might not be accomplished only by public transportation in some emergency situations. He then discussed access to recreational resources. He concluded that there were clear social-economic differences in access to types of recreational activities (Floyd et.al, 1994), as low-income households and the minority groups have lower access to suburban recreational activities. Access to grocery stores was also important from the standpoint of social justice. Because people get fresh food and similar necessities from grocery stores, access to grocery stores plays a vital role in daily life of the consumers. Because of the suburbanization of supermarkets and large grocery stores, the low-income households and the minority groups living in the central city had to go further to get to the markets where they pay more for their purchases than did white households (Finke et al, 1997; Chung and Myers, 1999).

Though many studies measured accessibility to a single type of public service, few focused on provisions of different types of public facilities. For example, Shen (2005) studied the accessibility of manufactured housing to several types of community services, Apparicio and Seguin (2006) studied the accessibility of public housing to different services and facilities. Nevertheless, Tsou et al. (2005) found that the relationship of access to different types of public facilities mattered a lot because residents had different preference toward different types of public facilities.

In this thesis, the concept of equity as access between residents and public provision of facilities across space will be used to examine equity status for households in the Atlanta 10-county area. As to the problem of specification of demand and supply, a specific model of accessibility will be applied to measure the degree of equity.

Public transportation

Urban development has been related to the evolution of transportation technology and the development of transportation systems. Prior research has studied the influences of transportation systems on different aspects of urban form. Meyer and Miller (2001) discussed the impacts of transportation systems. They pointed out that transportation systems had several major influences: land use, economic activity and social/cultural aspects.

Firstly, surveys implied that the level of accessibility provided by the transportation system could influence the pattern of land use, which could then lead to changes in the spatial distribution of activities in a region. For example, Muller (1995) summarized that the highway system was a major cause of urban sprawl and turned the cities inside out. Also, there are many studies showed that transportation system development triggered dispersed urban development and investment of public transportation would also increase potential development along the transit stops and stations (Jackson, 1985; Boarnet & Haughwout, 2000; Richard, 1993; Landis, J. et al., 1995).

Secondly, transportation system could be an economic resource to a region by providing huge opportunities to jobs, industrial productivity and so on. Meyer and Miller (2001) gave the example that in 1997, 11% of U.S. gross domestic product was from the transportation-related sector.

Thirdly, the transportation system has impacts on the social or cultural aspects of urban life. The transportation system is a determining factor in quality of life as it provides access to other activities, such as employment, education, recreation and cultural resources (Meyer & Miller, 2001). Because of these impacts on society, inequity in transportation could lead to inequity among different groups (Hodge, 1995; Bullard & Johnson, 1997). Also, though the transportation system provides mobility and accessibility, the level of mobility depends on car ownership. Since many urban activities are distributed along highway networks, accessibility could be much lower for people without cars (Pucher et al., 1998). Access to public transportation can help a lot in increasing the accessibility of people without cars, especially for the elderly, people with disabilities, low-income households and minorities.

According to Pucher (2004), public transportation use in the United States was a total of 45,100 million passenger-miles, and 8,720 million trips in 2000. Bus usage made up 58 percent of transit passengers. Public transportation usage has great geographic variations: usage in large cities was much more than that in smaller ones and that in central cities were more than in suburbs. For example, 43 percent of all transit trips took place in New York, Pennsylvania, and New Jersey (Hanson and Giuliano, 2004).

Table 1 Spatial Variation in Public Transportation's Market Share

Metropolitan area population size	1995			2001
	Central city	Suburb	Total	Total
3 million+	9.74	1.62	3.77	3.41
1.00-2.99 million	3.10	0.61	1.01	1.08
0.50-0.99 million	2.71	0.64	0.88	0.63
0.25-0.49 million	/	0.39	0.48	0.58
All metro areas	8.26	1.16	1.81	1.69

Source: Pucher and Renne (2003, Table 9)

Pucher also presented the importance of public transportation: relieving congestion and saving energy, reducing the pressure on the environment and increasing mobility for the disadvantaged population (Hanson and Giuliano, 2004). In large cities, public transit took up a large amount of transport market share. With the capacity for carrying a large number of passengers with little cost per passenger, public transit can greatly relieve congestion in large cities at a relative low cost. At present, the low-income groups and the minority people rely more heavily on public transportation than affluent households.

Table 2 Transit use in 2001 (percentage of trips in each racial/ethnic group)

Mode of transportation	Race/ethnicity			
	African American	Asian	White	Hispanic
Total transit	5.3	3.2	0.9	2.4

Source: Pucher and Renne (2003)

Public transportation and Accessibility

Many studies focused on the accessibility of transit system to measure mobility. According to Cahill (2010), mobility describes the capacity of moving freely from one place to another. It plays a vital role in daily life not only because it helps us enjoy relationships with others, but also because disadvantages in mobility can lead to further disadvantages. While populations with automobiles will have more mobility than population without automobiles, and therefore tend to have more accessibility to public facilities, public transportation is provided in some cities in order to improve accessibilities for population without their own automobiles. Whether the provision of public transportation can provide sufficient accessibility for those without automobiles, and to what extent public transportation improves spatial equity needs to be analyzed.

There are mainly two different types of research related to the accessibility of transit systems: the first type deals with measuring access to the transit system, and the second one deals with measuring access to destinations through a transit system.

Shaw (1991) took the Tri-Rail system in Florida as a case study and analyzed urban transit accessibility using GIS. He first selected bus routes and then did buffer analysis to measure the accessibility of the transit system. Results showed that cars were the major access mode when considering the accessibility to the origin stations of transit system, which in turn meant that people who have no cars had low access to these stations.

Studies by Lee (2005) measured transit accessibility to destinations. Lee discussed first the complicated characteristics of analyzing accessibility through public transit and then came up with a procedure for calculating accessibility through public transportation to destinations. Many factors contribute to the analysis procedure in calculating accessibility through transit to desired destinations, such as waiting time and the numbers of transfers. Also, since transit stops and stations are not necessarily located at trip origins and destinations, travel distance between trip origins/destinations to transit stations needs to be considered. In his study, Lee first identified all stops in a certain range of each destination and calculated walking time from each stop, then identified all parcels within a certain range of each origin and calculated walking time from each origin. By adding in-vehicle travel time and waiting time, he got more precise travel time from origins to destinations through transit system. The shortest travel time was then selected to calculate accessibility to destinations.

Research carried out by Kwok and Yeh (2004) revealed an accessibility gap between public transportation and private transportation by calculating accessibility to a variety of public services and facilities. They pointed that sustainability was related to the usage of public transit and the level of accessibility that public transit provided. In the case study of Hong Kong, they measured the accessibility gap between public transport and private transport in the year 1991 and 1996, and observed a decrease in the accessibility gap. Since the accessibility by public transportation was in the numerator, higher gaps meant more accessibility was provided by public transport and thus more sustainable development. Such result revealed Hong Kong experienced a decrease of sustainable transportation development during the study period (Kwok and Yeh, 2004). The method they came up with is not only useful for transportation planning, but also the development of a more sustainable society.

Considering the types of destinations, there are many studies focusing on travel between home and work travels through public transit. Since public transportation can be an important mode to provide accessibility to job locations, many people get employed with the help of transit systems (Horner and Mefford, 2005). Spatial mismatch between housing locations and job locations has long been given much attention (Kain, 1992; Preston and McLafferty, 1998; Sultana, 2002). Studies by Horner and Mefford (2005) examined employment accessibility through bus transit in Austin, Texas and revealed that the minority and low-income groups had low employment accessibility. They argued that equity should be given more consideration in public transportation.

CHAPTER 3

DATA AND METHODOLOGY

DATA

Figure 1 shows the location of the Atlanta 10-County Region in the Georgia State. *Figure 2* shows the location of households with and without cars in the Atlanta Region.

Figure 1 the Atlanta 10-County Region in Georgia

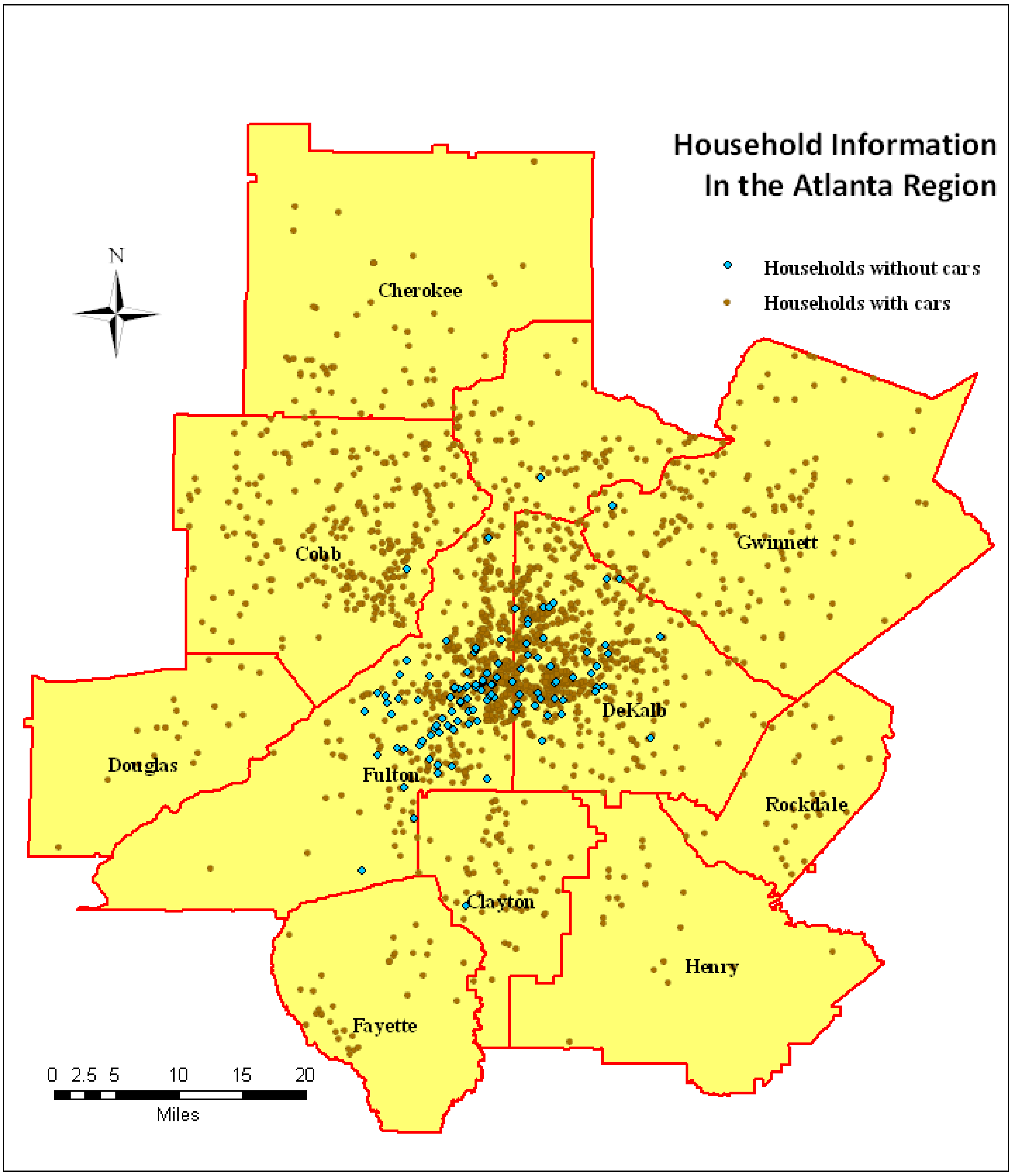

Figure 2 Households' Location in the Atlanta 10-County Region

There are three basic factors in the accessibility calculation: the origin, the destination and the network connecting the origin and the destination. In order to do accessibility analysis, several types of data are needed. First of all, households' information as the origin points, public facilities information as the destination points, and street network as links from the origins to the destinations. The Atlanta Region census data, containing information for the Metropolitan areas (10-county area) by counties and population information, was created by US Census Bureau in 2000 and developed by the Atlanta Regional Research Division. Some of these variables are shown in Table 3.

Table 3 Variables in Atlanta Region Census Database

Variable	Data Type	Definition
FIPSSTCO	String	Code of County
COUNTY	String	Name of County
POP00	Double	Population in 2000
DEN00	Double	Population density in each census tract

Second is the Atlanta Street Network shapefile, created by the U.S. Census Bureau. Some of the characteristics of variable in the shapefile are shown in Table 4.

Table 4 Variables in Atlanta Street Network

Variable	Data Type	Definition
COUNTYFP	String	Current county FIPS code
MTFCC	String	Class code of primary feature of streets
FULLNAME	String	Full name of streets

Third is the Atlanta household survey data at a disaggregated level, containing information on household location, income, vehicle number, ethnicity, race, and language. Data is from the Metropolitan Travel Survey Archive. The survey was conducted by the Atlanta Regional Commission in 2001 to get information about travel behavior of households in the Atlanta region.

There are a total of 2048 households recorded in the survey, of which 1985 households are located within the Atlanta 10-County Region. Among them, 1872 households owned at least 1 car, including 1393 white households and 338 African American households who have valid locations. 113 households have no cars, including 75 white households and 23 African American households who have valid locations. Aspects of these variables are shown in Table 5.

Table 5 Variables in the Atlanta Household Survey

Variable	Measurement level	Definition
SAMPN	Scale	Household ID number
TOTVEH	Ordinal	Total household vehicles
ETHN	Ordinal	Ethnicity
OETHN	Nominal	Other ethnicity
HHSIZE	Ordinal	Household size
COUNTY	Ordinal	Household county

In the table, ETHN has 6 values: 1, 2, 3, 4, 5, 7. Among them, 1 represents ‘Black/African American,’ 2 represents ‘Latino, Hispanic, Spanish,’ 3 represents ‘Asian/Pacific Islander,’ 4 represents ‘Native American,’ 5 represents ‘White/Caucasian,’7 represents ‘Other’.

Fourth is public facility data in different categories. Data is from the Atlanta Regional Commission and the Metropolitan Travel Survey Archive. Considering facilities that people would frequently use in daily life, several types of public facilities are selected for this thesis analysis:

1) Parks, containing information of park size and type. Polygon
2) Community facilities containing information about public facilities, which include elementary schools and libraries. Points

3) Activity centers, containing information of different types of centers: city center, regional center, station community, and town center. Points
4) Others: grocery stores, supermarkets, banks, post offices. Points

Table 6 Facility Categories

	EDUCATION	HEALTH	RECREATION	DAILY LIFE
Category/type	Elementary school	Pharmacy	Park	Bank
	Library		Activity center	Post office
				Supermarket

Fifth is transit data, which is from the Atlanta Regional Commission, including current transit data, which constitutes information of bus routes, bus stops, subway routes and subway stations.

METHODOLOGY

Measures of Accessibility

Based on different characteristics of study objects and various criteria of access, different methods have been used to measure accessibility (Lotfi, Koohsari, 2009).

The coverage model is used to calculate the number of facilities within a certain distance. A study by Talen (1997) used the coverage model to calculate the accessibility to parks, according to the idea that park distribution standards are based on specified amounts of park acreage within certain distances of residential areas. Comber et al. (2008) also used the coverage model to determine urban greenspace accessibility for different ethnic and religious groups. According to the guidelines for greenspace access provision, they examined access to different sizes of natural greenspace. Distance used in these studies was defined on the basis of street network distance.

The coverage model can be useful when examining overall equity status among neighborhoods, and it can be easily handled in ArcGIS. However, it has a major disadvantage. It not only neglects spatial distributions of public facilities within study areas, but also assumes that all individuals within a neighborhood have the same set of opportunities for choosing public facilities (Church and Marston, 2003). Toward this drawback, several studies measured accessibility using more specific methods, i.e., the minimum distance model, gravity-based model, and the Huff model.

The minimum distance model measures the distance from an origin to the nearest facility (Apparicio and Seguin, 2006). It takes into consideration that for some types of public facilities, such as emergency services or health care facilities, the distance to the closest one matters more than the total amount of facilities that can be reached. Shen (2005) and Apparicio and Seguin (2006) used minimum distance models to measure the accessibility of community services and facilities for different types of housing respectively. According to Shen, the minimum distance can be regarded as the best or worst accessibility for a home, according to the positive or negative nature of the facility.

When dealing with the proximity of public facilities, using street network as distance measure, minimum distance model can be a proper choice. However, it is based on the assumption that residents will go to the nearest facilities when they have choices. Several studies on health centers found that people did not necessarily go to the nearest facilities, partly because of the characteristics of the facilities (Church and Marston, 2003; Hare and Barcus, 2007). Therefore, some research has used a gravity-based model or the Huff model to measure accessibility.

The gravity-based model takes the attractiveness of facilities into account, which can be represented as below:

$$A_i = \sum_j S_j \cdot g_{ij}^{-\beta}$$

Where A_i is the accessibility of origin i, S_j is the attractiveness of facility j, $g_{ij}^{-\beta}$ represents transportation impedance;g_{ij} is travel distance, time or cost between i and j, $-\beta$ is distance decay parameter.

The gravity-based model can also be called a potential model. It relates characteristics of facilities and the distance between residents and facilities to measure the accessibility. It assumes that the higher the attractiveness of the facility, the closer the distance, and the higher the gross accessibility. Potential models have been used in various research, such as measuring accessibility to health care facilities (Rosero-Bixby, 2004; Hare and Barcus, 2007), grocery stores (Wang and Lo, 2007), shopping and services (Helling and Sawicki, 2003), and so on. Characteristics of facilities, such as size, treatment available, were taken into consideration to represent the demand of facilities.

Though the potential model considers the attractiveness of facilities and sums up all possible opportunities in a limited space, it is unlikely that residents can or would want to visit all of the possible facilities (Church and Marston, 2003). In other words, people make choices when they visit facilities. The Huff model takes into account individual preferences. It is based on the idea that the possibility of an individual going to a particular facility is related to the attractiveness of, and the distance to that particular facility and its competitors (Loh et al., 2009). It can be represented as below:

$$P_{ij} = \frac{S_j^{\alpha} g_{ij}^{-\beta}}{\sum_{j=1}^{n} S_j^{\alpha} g_{ij}^{-\beta}}$$

$$\sum P_{ij} = 1$$

Where P_{ij} is the possibility that the individual i will visit a particular facility j, S_j is attractiveness of the particular facility j, n is the total of facilities of certain type, α is the attractiveness parameter. Then accessibility based on this possibility can be represented as below:

$$A_{ij} = \sum_{j} P_{ij} g_{ij}$$

It considers people's choices when they need travel to somewhere, while the nearest facilities may not be their best choices. Church and Marston (2003) discussed that people would make a choice of which activity site to visit. Loh et al. (2009) used the Huff model to measure the accessibility to hospital services considering the number of beds in the hospital as the attractiveness factor. It can also be considered as a destination (supply) competition constraint in a potential model. Wang (2003) and Song and Sohn (2006) used a similar model but with demand competition to measure accessibility. Zhang et al. (2011) integrated a population-weighted distance with the Huff Model and examined the accessibility to parks in different geographic levels. Using travel distance to local neighborhood parks as the index of accessibility, the results revealed great differences in access to parks among different neighborhood wealth groups, racial groups, and different urbanizations levels in the United States.

Distance Measurements

Several types of distance can be used to measure accessibility: Euclidian distance, network distance, and travel time or cost.

Some research used the Euclidian distance method to measure accessibility; this calculates the Euclidian distance from the origin to the destination, and sums up the total distance from the origin to all of the destinations to get the accessibility of the origin. Though it can provide the relative accessibility of different origins, the result is by no means precise for two reasons. First, the distance from one place to another place is not always straight, and one need to go through street networks to get from one place to another. Second, when different modes of transportation are taken into account, the relative distance in travel cost or time from one place to another is much different from the straight distance. While in many cases, travel cost or time makes more sense than a straight-line distance, methods taking travel time or cost into account should be used to get accurate accessibility.

Towards the first factor, some researchers have made a comparison of straight-line distances and network distances. For instance, Gibson et al. (2010) found that road distances produce measures of accessibility that are nearly twice as great as straight-line distances. Many studies used network distance to do accessibility analysis. Apparicio and Seguin (2006) used travel distance through street networks to calculate accessibility of services and facilities for residents of public housing. Towards the second factor, there is research using travel time as a measure of accessibility (Hare and Barcus, 2007; Seymour et al., 2006; Wang and Lo, 2007). Travel time can be more accurate and rational in urban areas than travel distance because it can take speed limit and congestion into account when calculating accessibility. Chang and Lee (2008) used detailed transportation impedance (generalized cost of travel for different transport modes) to measure accessibility of Korean high-speed rail. Factors including access time to destinations, waiting time at stops, transfer time consumed, fares and terminal costs were taken into account, in order to get accurate transportation impedance.

Measure of Equity

Talen (1997) used the Local Index of Spatial Autocorrelation (LISA) to map the social equity of urban service distribution. LISA measures the distribution pattern of local phenomena, and the relationship between distribution in one zone and distributions in nearby zones. It represents results in four categories: high-high distribution, high-low distribution, low-high distribution, and low-low distribution. These four categories respectively represent four types of spatial association: high values surrounded by high values, high values surrounded by low values, low values surrounded by high values, and low values surrounded by low values. The author used LISA to show the distribution characteristics of selected socioeconomic factors and then analyzed the social equity by overlapping them on the accessibility map.

Based on the idea that various types of public facilities have different characteristics, and residents would have different preference toward different kinds of public facilities, Tsou et al. (2005) provided an integrated equity index (IEI) for examining the equity status associated with various public facilities. They examined equity status in public facilities for both disaggregated and aggregated levels respectively. The results revealed that spatial equity towards accessibility of the entire public facilities was more uneven than that towards accessibility of each single type of public facility.

Though these two methods of measuring equity do well in mapping the spatial distribution, it does not represent relative equity between certain resident groups. In the study of accessibility for people with a disability, Church and Marston (2003) provided a measurement of relative accessibility (RA) between two groups of people. RA compared the accessibility of a person of one group to the accessibility of a person of another group, and the ratio represents the relative accessibility. The background of relative accessibility was that in the study by Golledge (1993), he raised the idea that different travel modes or different routes would exert an influence on accessibility. Therefore, even though within the same geographic space, the accessibility of people with differing transport mobility would be different. In their study, they used the notion of relative access to compare two sets of potential accessibility values, with different distance decay parameters in the two sets. Lee and Lee (1998) also used relative access to compare the accessibilities through different subway routes. In the analysis of equity, access to public facilities is set as the index, RA can be used to represent the difference of accessibility for different groups of people with differing mobility, and therefore reveal the spatial equity status. In the research by Church and Marston (2003), RA was expressed by the following equation.

$$RA = \frac{d_l}{d_m}$$

Where, RA is relative accessibility for person of type l relative to person of type m, providing they have the same origin and destination, and d stands for the access measure for each person.

Methods

Because of the difficulty of data collection, analysis of accessibility or equity has often used aggregated data, and measured the distribution among census tracts or blocks. This would create the modifiable areal unit problem (MAUP). MAUP is a problem when using polygons in the analysis as changing the size or boundaries of polygons will lead to a change in the result. Therefore, with the household travel database available in Atlanta, this thesis can use individual data to do the analysis and avoid the MAUP.

This thesis will use the Huff model to calculate accessibility. As discussed above, the Huff model not only considers the attributes of public facilities (supply), but also takes into accounts the choices of residents (demand). Compared with other measures of accessibility, it provides a more precise measurement of accessibility and reflects a more realistic situation of equity. Also, the Huff model concerns the probability that an individual will visit a facility through a certain travel mode, which can provide a disaggregated measure of accessibility and avoid the modifiable areal unit problem. As to distance decay, 2.0 is the most commonly used value, which is close to the estimated parameter for public open spaces, 1.91 (Giles-Corti & Donovan, 2002). Therefore, this thesis uses 2.0 as the distance decay parameter.

Because accessibility of residents with cars and accessibility of residents without cars are the two groups to be compared in this thesis, travel time will be applied to represent the distance parameter. The Atlanta street network will be used when paths between households and public facilities are calculated in ArcGIS. When calculating distance between a household to each public facility, the path will be selected by choosing the shortest travel time. Travel time by car will be measured by assigning various travel speeds to different classes of roads (Carstensen, 1981; McCall & Weber, 2006), and travel time by public transit will be calculated according to the schedules of buses and subways.

As to the measure of equity, this thesis will use RA to represent equity status, which can do well with disaggregated data. By comparing the relative accessibility between different socioeconomic groups, the equity status can be revealed. Adding the factor of public transportation, changes in accessibility and equity status can be evaluated. Also, the result will show changes of spatial equity through public transportation. Travel impedance through public transit and automobile will be added when calculating the accessibility to different types of public facilities. The following steps will be taken in the analysis. First, accessibilities to public facilities for groups of different socioeconomic characteristics will be calculated. Accessibility of each group will consist of two parts: access of households traveling by cars and access of households without cars traveling by public transportation. RA will then be calculated based on the results of accessibilities adding the factor of public transit.

Through these steps, which include the comparison within and between socioeconomic groups, relative equity status in Atlanta region can be calculated. The result will be used to show the influence of public transportation on the accessibility and equity status in the Atlanta 10-County Region.

CHAPTER 4

ANALYSIS

Data Preparation

This thesis uses travel time as the distance parameter when calculating accessibilities. The Network Analyst extension in ArcGIS 10 is used to select a route from each household's location to each facility of every type and return the total travel times by adding up travel time of links which contribute to this route. Then, accessibility can be measured using the models discussed in the Methodology section.

Therefore, in order to select the routes between household locations and facilities and get total travel time between them, the travel time of each link in the street network is prepared first. Two types of travel time are used to show the difference between traveling by car and by public transportation.

I. Travel Time by Car

This thesis computes travel time by car using the equation:

$$\text{Travel time} = \text{Link Length}/\text{Speed}$$

Where, Link Length is calculated in ArcGIS, speed is calculated by the following process.

There are some equations used to compute speeds of different streets to get as realistic an estimated as possible, with actual street conditions such as congestion and vehicle classification taken into account. For example, NAVTEQ provides real time traffic condition of all roads in the Atlanta region, and average speed along different streets, which can be a good reference when considering precise travel time by car. While speed information in the street network can be added to the method used in this thesis easily, this thesis uses a simple method to estimate speeds approximately. Detailed speed information in a further study could be used to get more detailed travel time.

This thesis classifies the street network in the Atlanta Region according to the Georgia Department of Transportation and MAF/TIGER Feature Class Code (MTFCC) scheme. Atlanta streets have a total of 12 categories according to the MTFCC (Table 7). Depending on road condition, different categories of streets were assigned set different speed limits based on of speed limit laws in U.S. States (Wikipedia contributors, 2011).

Table 7 MTFCC and Descriptions

MTFCC	Description
S1100	Primary road
S1200	Secondary road
S1400	Local neighborhood road, rural road, city street
S1500	Vehicular trail
S1630	Ramp
S1640	Service drive usually along a limited access highway
S1710	Walkway/pedestrian trail
S1730	Alley
S1740	Private road for service vehicles
S1750	Internal U.S. census bureau use
S1780	Parking lot road
S1820	Bike path or trail

Functional classification of the Atlanta Region Streets is shown in Table 8 (Source: Georgia Department of Transportation).

Table 8 Functional Classification of Streets

	Functional Classification	Code in Shapefile	Speed Limit (mph)
Urban	Interstate Highway	11	65
	Primary Arterial	12	55
	Minor Arterial	13	45
	Collector Street	14	35
	Local Road	16	25
	Other (Vehicle Trail)	18	15
Rural	Interstate Highway	21	70
	Primary Arterial	22	60
	Minor Arterial	23	50
	Major Collector	24	50
	Minor Collector	25	40
	Local Road	26	30
	Other (Vehicle Trail)	28	20

Then, travel time by car is calculated in ArcGIS, which is ready for the network analysis before accessibility calculation.

II. Travel Time by Public Transportation

Public transportation in the Atlanta region is operated by Georgia Regional Transportation Authority (GRTA), Metropolitan Atlanta Rapid Transit Authority (MARTA), Gwinnett County Transit (GCT), and Cobb Community Transit (CCT). Bus routes and stops are downloaded from Georgia Department of Transportation (GDOT). Travel time by buses can be found in the websites of GRTA, MARTA, GCT, and CCT respectively. Travel time by railways can be found in the MARTA website.

In order to add the information of in-vehicle time for each link of each transit route, bus schedules are referenced, and then stops of every route are selected and related to that route. With Arcpy in ArcGIS 10, stops of every route can be used to create links between stops (using the script Spider). Travel time by public transportation is made up of two components: one is travel time in vehicles, and the other is walking time to get to the transit stops. Though links created by stops only represent their connections, the analysis will not be influenced because only the travel time of links is used here without taking the shape of routes into consideration.

The overall number of routes for GRTA, MARTA, GCT, and CCT are 31, 93, 9, and 16 respectively. After adding travel time of each link of routes, all of the routes are merged together to build up the public transportation network. Then, the public transportation network with travel time attribute is merged with street network of the Atlanta region, which is then used for network analysis to calculate accessibility by public transportation.

In calculating travel time by public transportation, there is an additional issue to be addressed. Since people traveling with public transportation need to walk to the stops to get on the transit, the travel time of street network is changed based on walking speed.

III. Atlanta Street Network

There are two files of the Atlanta Street Network resulting from the data, which includes one for travel time calculating by car, and the other one for travel time calculating by transit, shown in the figures below (*Figure 3* and *Figure 4*).

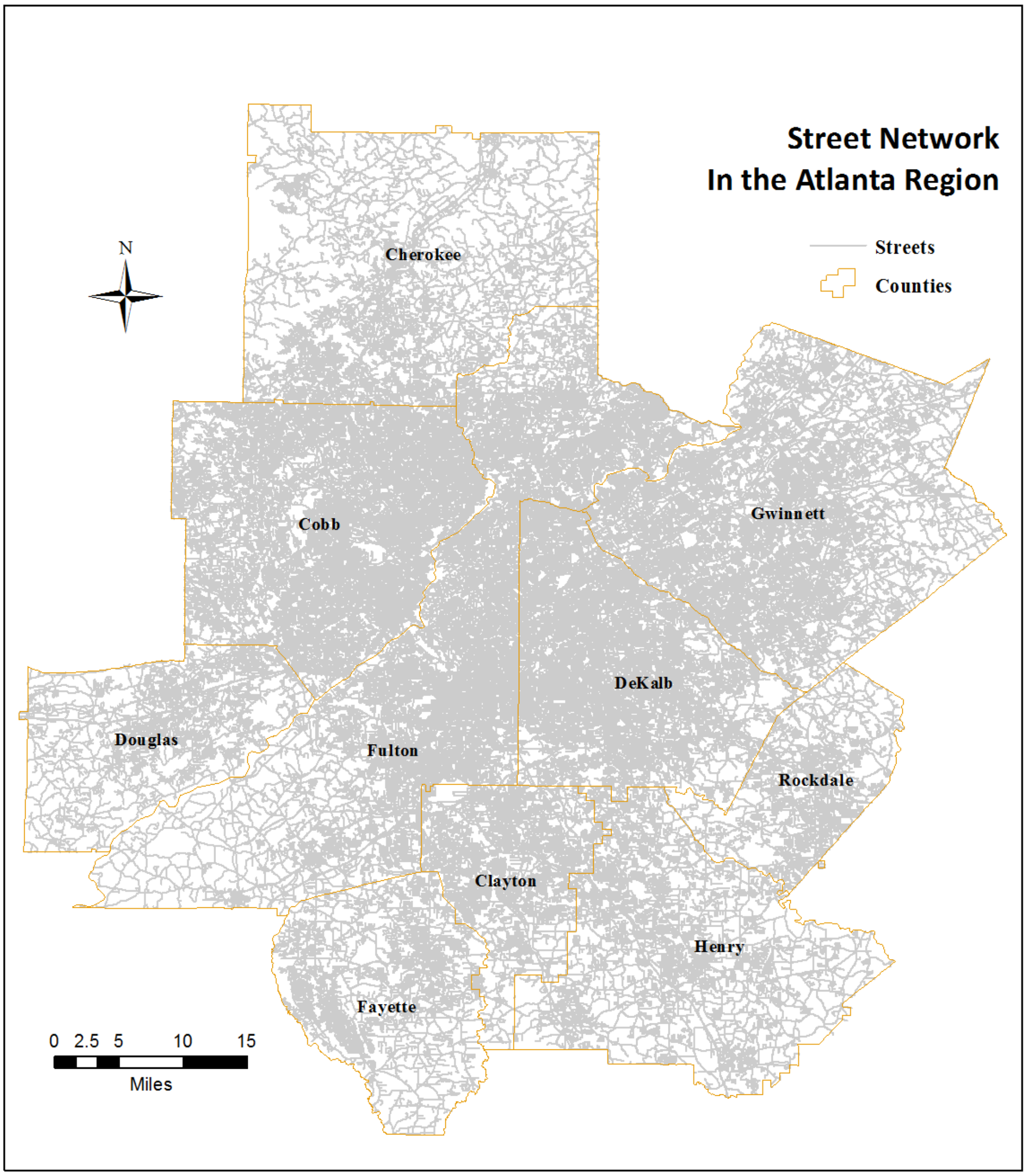

Figure 3 Street Network in the Atlanta Region

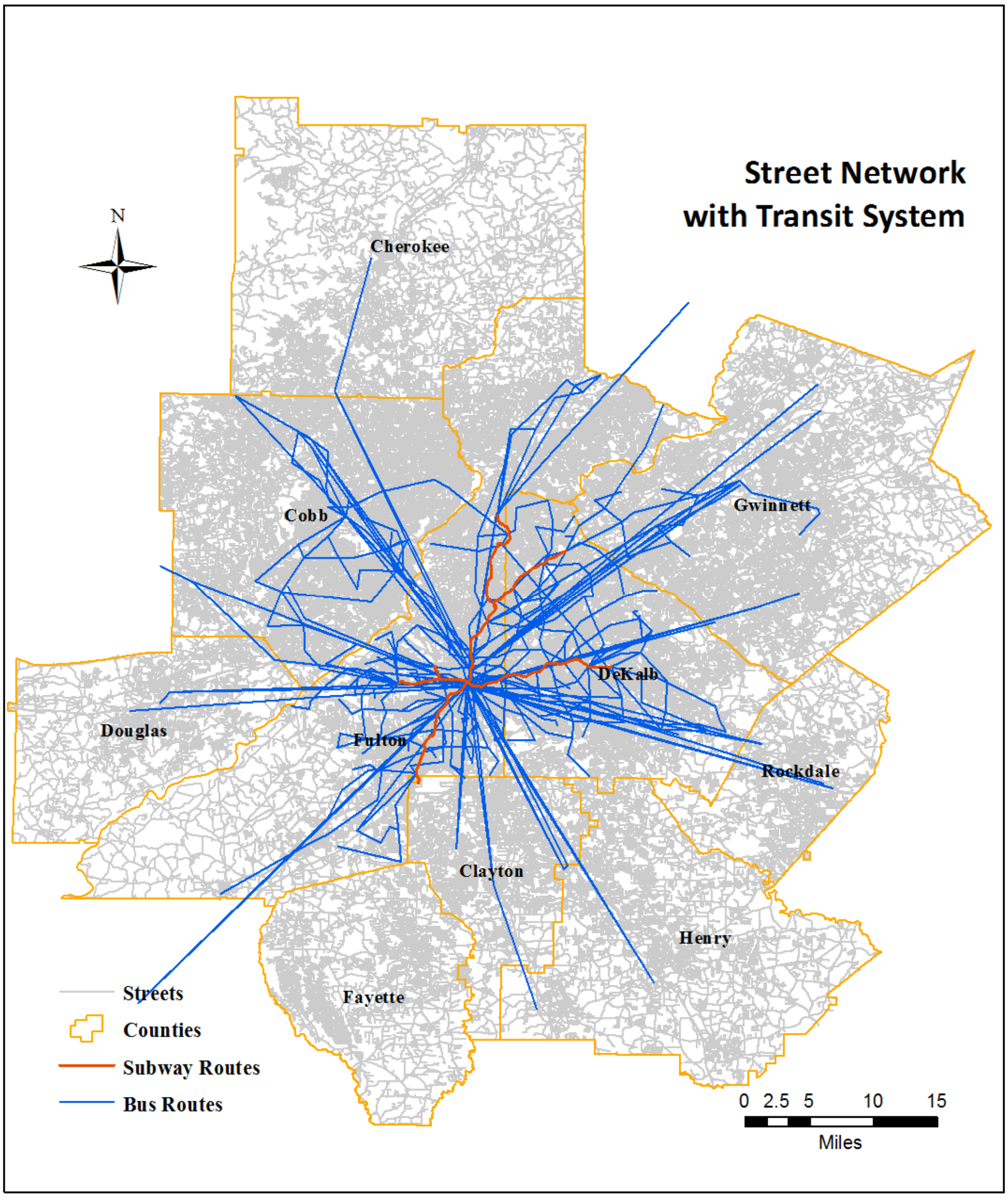

Figure 4 Street Network with Public Transportation System in the Atlanta 10-County Region

Distribution of households and public facilities

Travel time is used as g_{ij} in the equation of calculating possibility when each household decides which one of a specific facility type to visit. Different attributes in different facility types are used as S_j in the equation, which include AV_SCORE and ACRES. For certain types of public facilities that do not have a specific quantitative attribute to describe the attractiveness, only g_{ij} is taken into account when calculating the possibilities, and therefore assuming that the attractiveness of each facility of certain type is the same.

Travel time from each household to each public facility of a certain type can be calculated in ArcGIS with the Network Analyst extension. The Huff model is then used to calculate the possibility of each household choosing to visit each facility, and then the accessibility of each household to each public facility of a certain type can be calculated. Accessibility of each household group can be generated by calculating the average accessibility of households in that group. Therefore, an accessibility comparison between white households and African American households and between households with cars and households without cars to public facilities can be analyzed.

1. Households information

This thesis will analyze equity between households with cars and without cars, and also among households of different racial groups. Among different racial groups, white households are 71.4% of the sample; African American households take up to 20.8%, the rest are Latino/Hispanic/Spanish, Asian/Pacific, Native American, and other groups. Because the major minority group is African American, this thesis chooses African American households and white households to analyze the spatial equity status in the Atlanta 10-County Region. The total number of every category of households is as below: 338 are African American households with cars, 1393 are White households with cars, 75 are African American households without cars, and 23 are White households without cars. *Figure 5* shows the distributions of these four household groups.

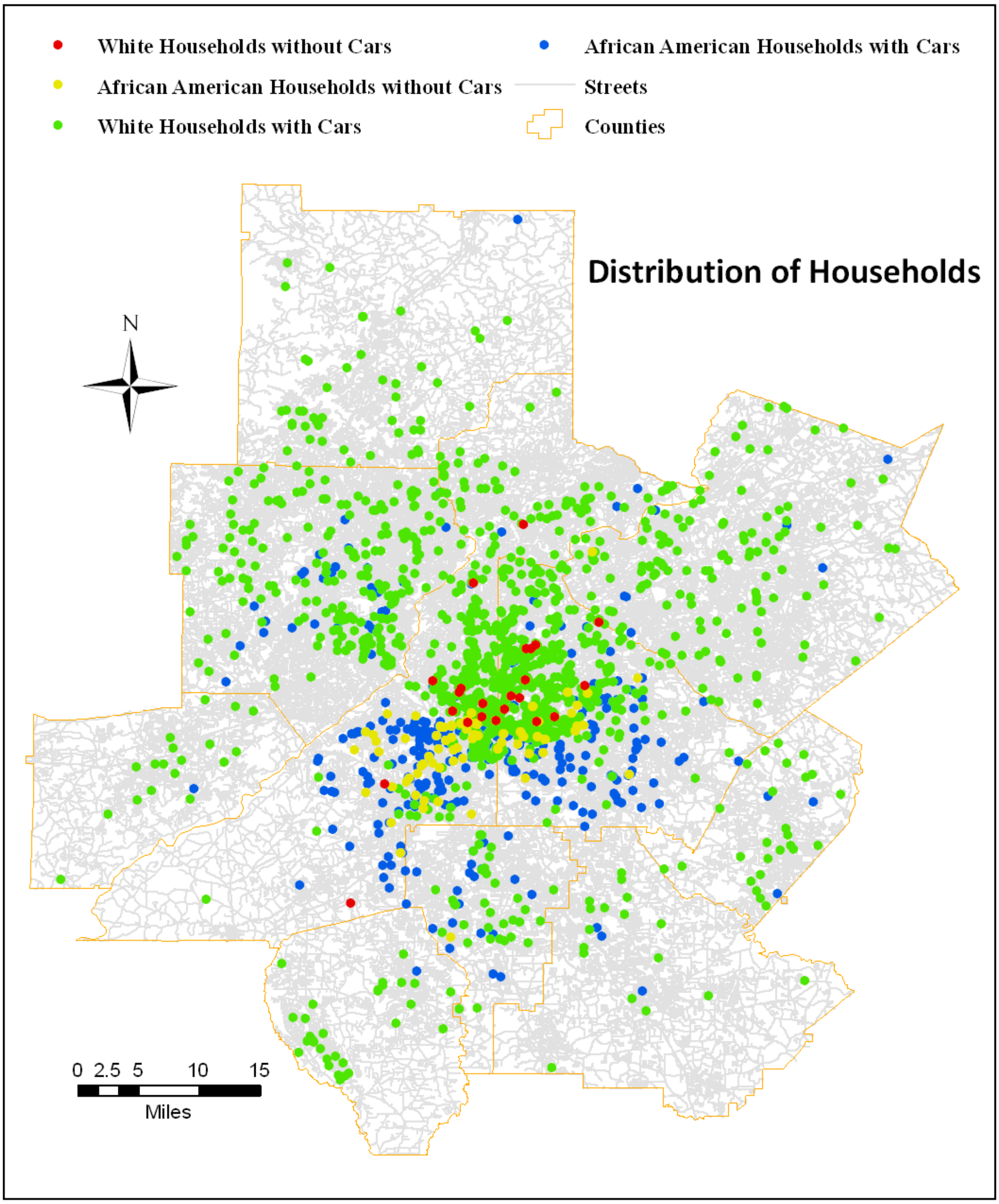

Figure 5 Distribution of Different Household Groups in the Atlanta Region

2. Recreation

    a. Activity Centers

There are a total of 124 activity centers located within the 10-county area. The distribution of activity centers is shown in the following figure. Due to the source of data collection, there is only qualitative information about the classification of activity centers. Thus, only distance between households and activity centers are used to calculate the possibility of households deciding to visit activity centers. Though in fact there will be a difference between attractiveness of activity centers, this thesis supposes that the attractiveness of each activity center is the same because of the lack of quantitative information about the attractiveness.

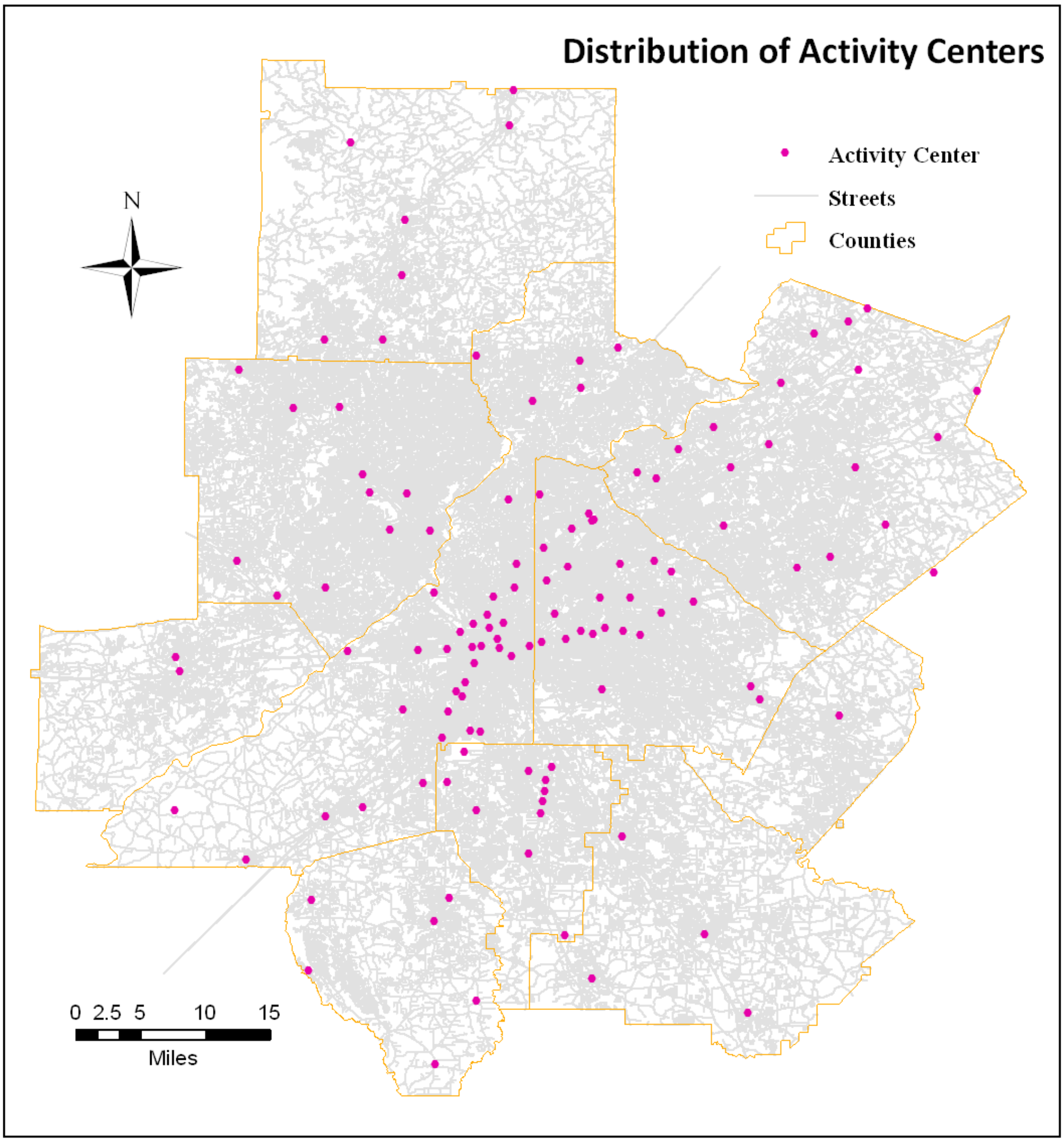

Figure 6 Distribution of Activity Centers in the Atlanta Region

The probability of each household to visit each activity center is calculated using the Huff Model, and a sample of calculation results is shown in the following table.

Table 9 shows the possibility of household No.1 visiting each activity center, and *Figure 7* represents the results.

Table 9 Part of Calculation of Huff Model and Accessibility for White Household without car No. 1

Origin ID	Destination ID	Household ID	Activity Center Name	Total time	Possibility	Accessibility of Household
1	1	1073348	Clarkston	5.09	60.25%	27.58
1	2	1073348	N. DeKalb Mall	23.86	2.74%	
1	3	1073348	Kensington Station	33.28	1.41%	
1	4	1073348	Northlake	34.72	1.29%	
1	5	1073348	East Lake	36.26	1.19%	
1	6	1073348	Tucker	36.64	1.16%	
1	7	1073348	Avondale Station	36.97	1.14%	
1	8	1073348	N.Druid Hills	38.25	1.07%	
1	9	1073348	Avondale Estates	40.04	0.97%	
1	10	1073348	Inman Park Reynolds town	41.17	0.92%	
1	11	1073348	Mountain Industrial	43.71	0.82%	
1	12	1073348	Stone Mountain	46.79	0.71%	
1	13	1073348	Indian Creek	46.95	0.71%	
1	14	1073348	Memorial Drive	48.57	0.66%	
1	15	1073348	Vine City	49.41	0.64%	
1	16	1073348	Century Center	50.23	0.62%	
1	17	1073348	City Center	50.41	0.61%	
1	18	1073348	Ashby	51.04	0.60%	
1	19	1073348	West End	51.06	0.60%	
1	20	1073348	Lindbergh Center	51.22	0.59%	

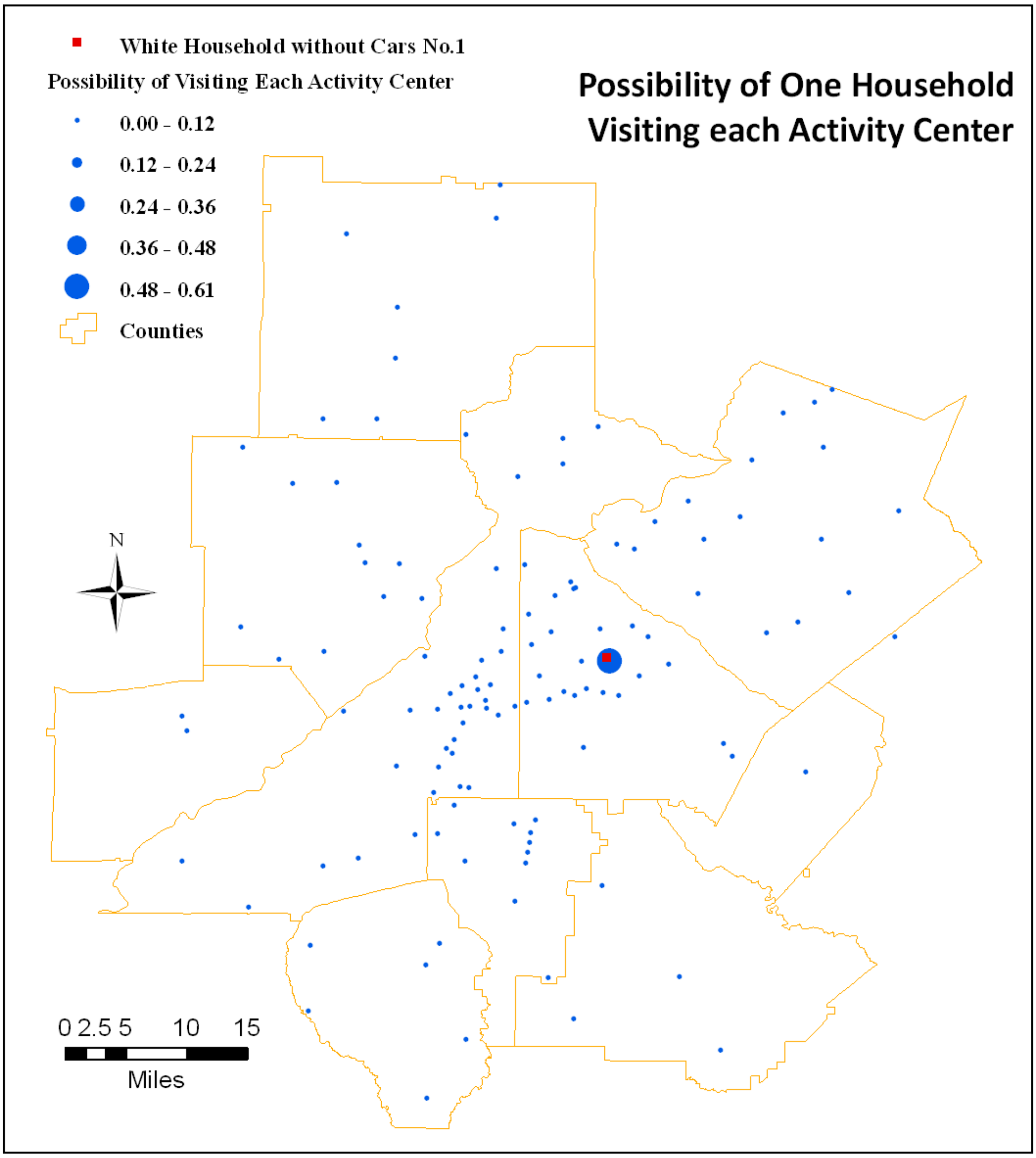

Figure 7 Possibility of One Household from White households groups without cars Visiting Each Activity Center

Then, the accessibility of each household to activity center can be calculated. Table 10 shows a sample result of accessibility of households to activity centers (see Appendix for detail). It shows white households without cars, and *Figure 8* is the map showing the accessibilities of this group to the activity center. From *Figure 8* we can see that most activity centers and households are concentrated in the center of the Atlanta region, and accessibilities of households in the central area are higher than households located outside.

Table 10 Sample of Accessibilities of White Households without Cars to Activity Center

ID	Household ID	Accessibility to Activity Center
1	1073348	27.58
2	1094740	18.84
3	1035280	5.07
4	1093830	99.81
5	1094271	84.71
6	1038764	42.00
7	1038682	27.09
8	1106496	10.96
9	1092586	29.32
10	1054002	27.49
11	1079620	3.19
12	1103209	43.52
13	1101369	32.04
14	1048029	46.01
15	1097436	38.98
16	1032454	58.96
17	1105440	59.16
18	1093061	40.26
19	1050198	41.05
20	1036138	26.12
21	1095281	47.75
22	1094102	40.89
23	1037960	51.69

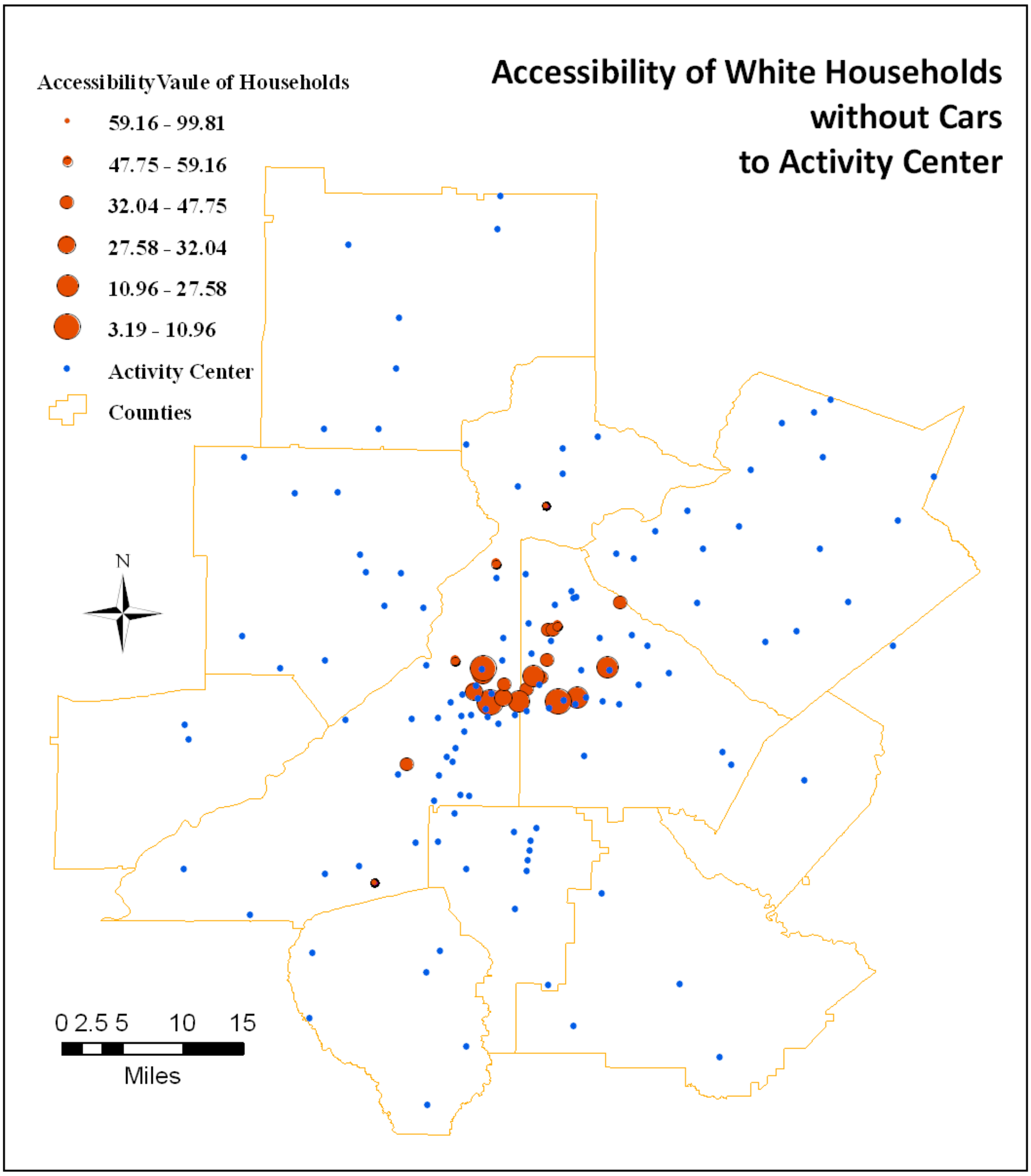

Figure 8 Accessibility of White Households without Cars to Activity Center

b. Parks

There are a total of 625 parks located in the 10-County area, and they are represented in the following figure. There are attributes in the park table describing the types and the sizes of parks. This thesis uses size as the attractiveness of parks in Huff model.

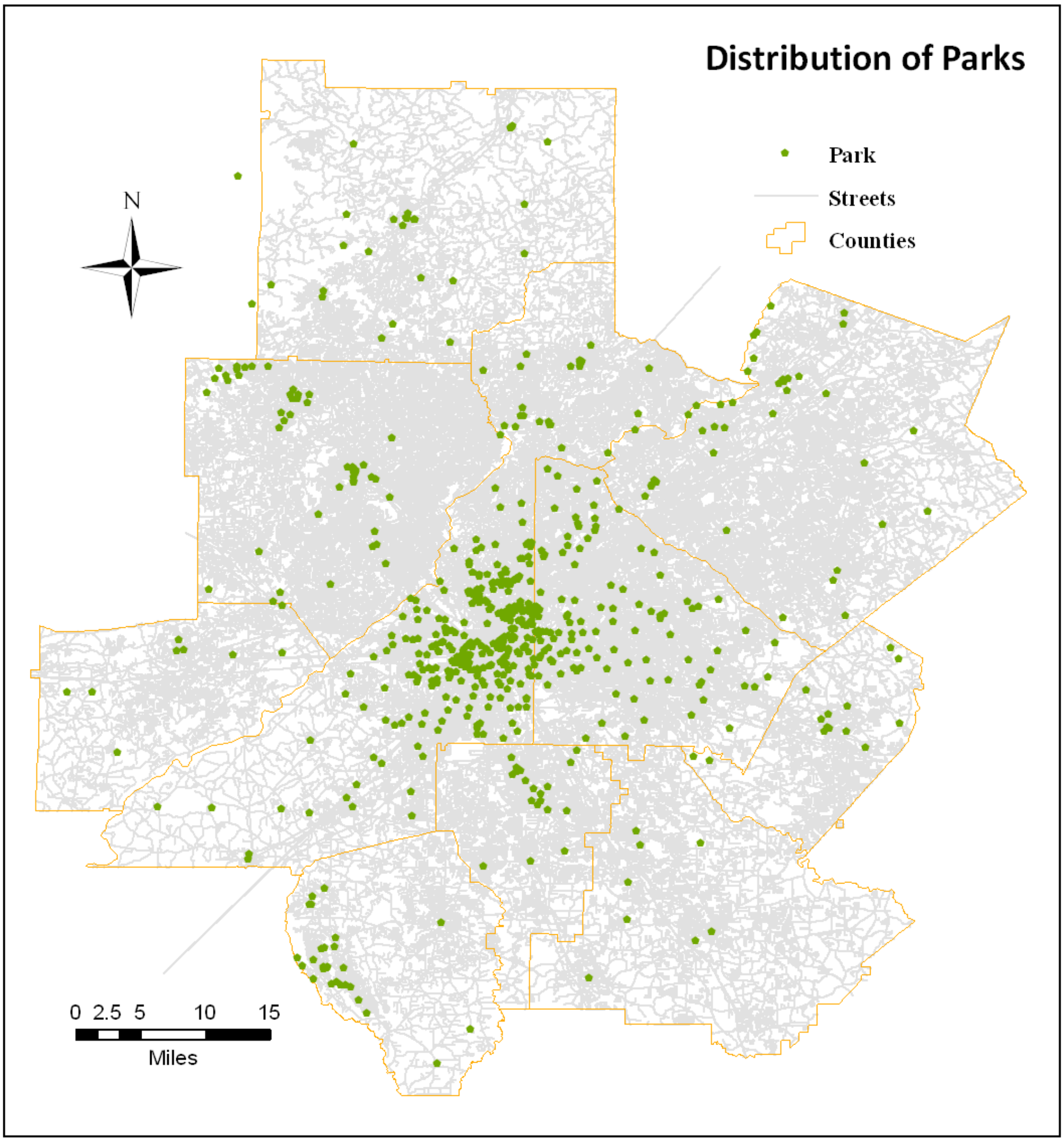

Figure 9 Distribution of Parks in the Atlanta Region

3. Daily Life

   a. Banks

There are a total of 1209 banks in the dataset. Following figure shows the distribution of banks in the Atlanta 10-County area. There is an attribute AV_SCORE in the bank table describing the average score of each bank, which can be used to represent the attractiveness of each bank.

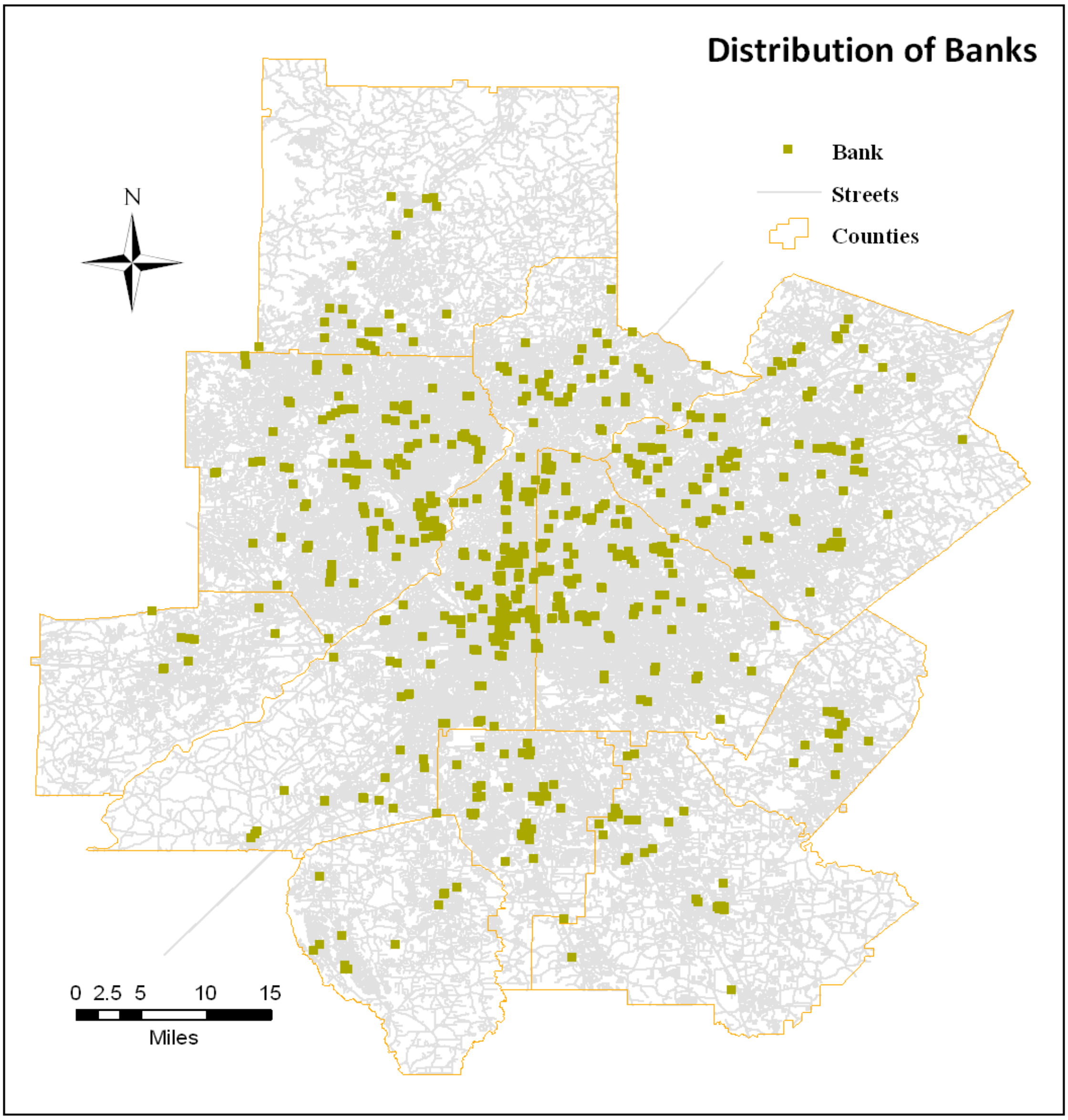

Figure 10 Distribution of Banks in the Atlanta Region

b. Post offices

There are a total of 680 post offices located across the Atlanta 10-County area. The distribution of post offices is shown in the following figure. There is an attribute AV_SCORE in the post office table describing the average score of each post office, which can be used to represent the attractiveness of post offices.

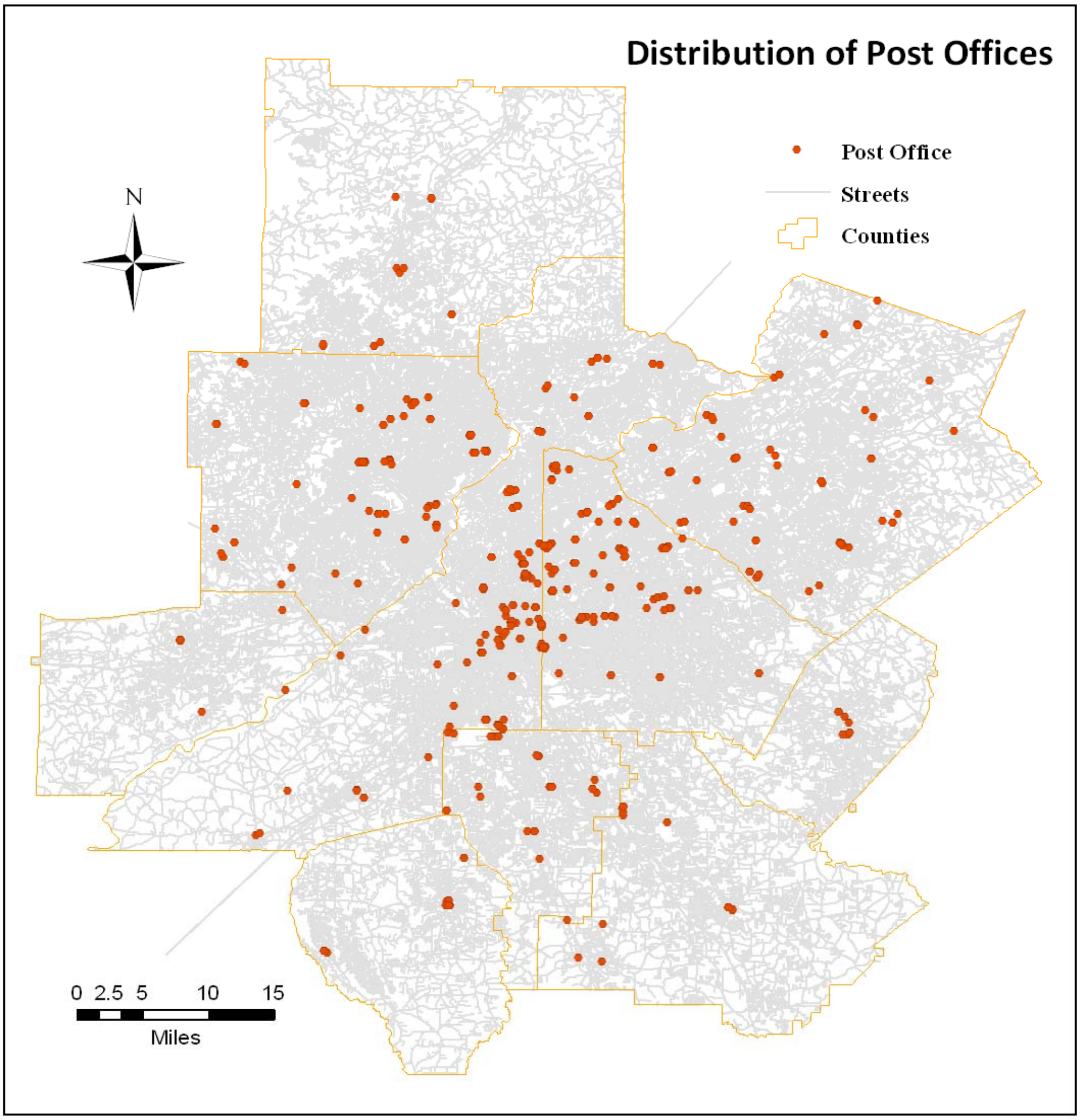

Figure 11 Distribution of Post Offices in the Atlanta Region

c. Supermarkets

There are a total of 881 supermarkets located within Atlanta 10-County area. The distribution of supermarkets is shown in the following figure, and they are represented in blue points. There is an attribute AV_SCORE in the supermarket table describing the average score of each supermarket, which can be used to represent the attractiveness of supermarkets.

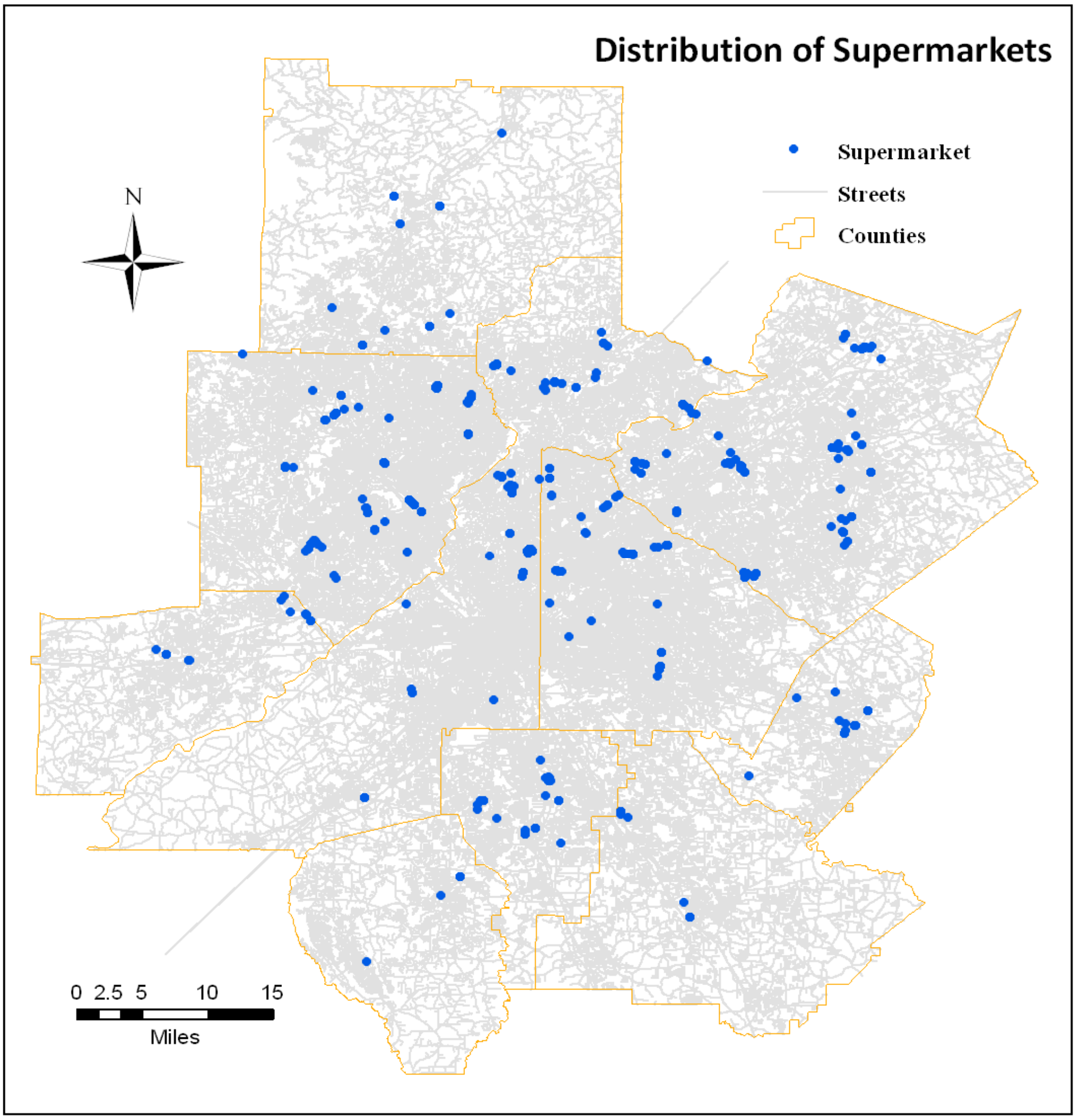

Figure 12 Distribution of Supermarkets in the Atlanta Region

4. Education

    a. Elementary schools

Figure 13 shows the distribution of elementary schools across the Atlanta region, with street network as background. There are a total of 451 elementary schools located across the Atlanta 10-County area. There is no information in the elementary school data source describing their attractiveness. Therefore, when calculating the possibility each household chooses to go to each elementary school, only distance is taken into account, which is represented by travel time.

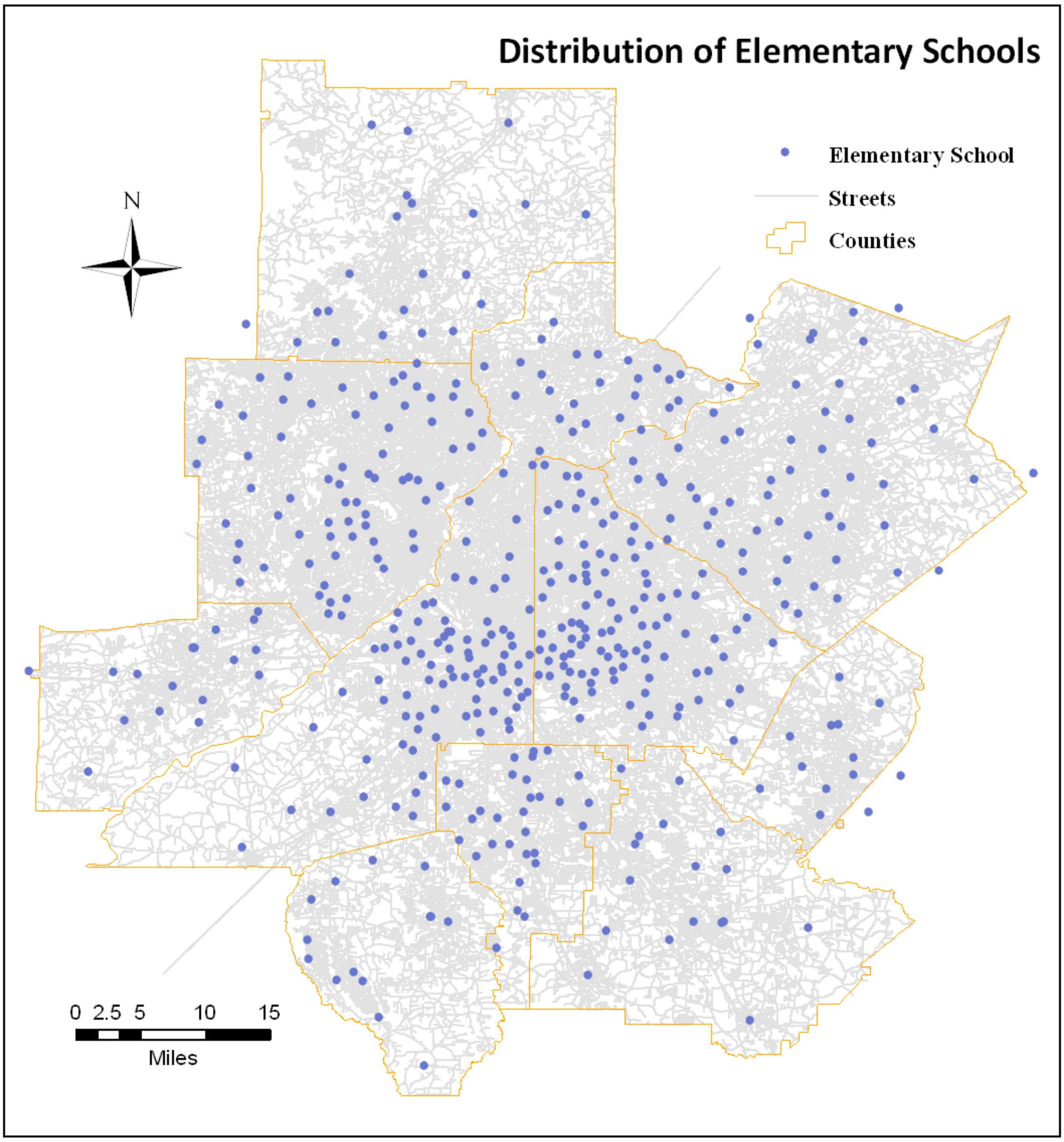

Figure 13 Distribution of Elementary schools in the Atlanta Region

b. Libraries

There are a total of 106 libraries located in the Atlanta 10-county region. Distribution of libraries is shown in the following figure. There is only qualitative information about classification of libraries. Thus, only distance between households and libraries are used to calculate the possibility of households deciding to visit each library.

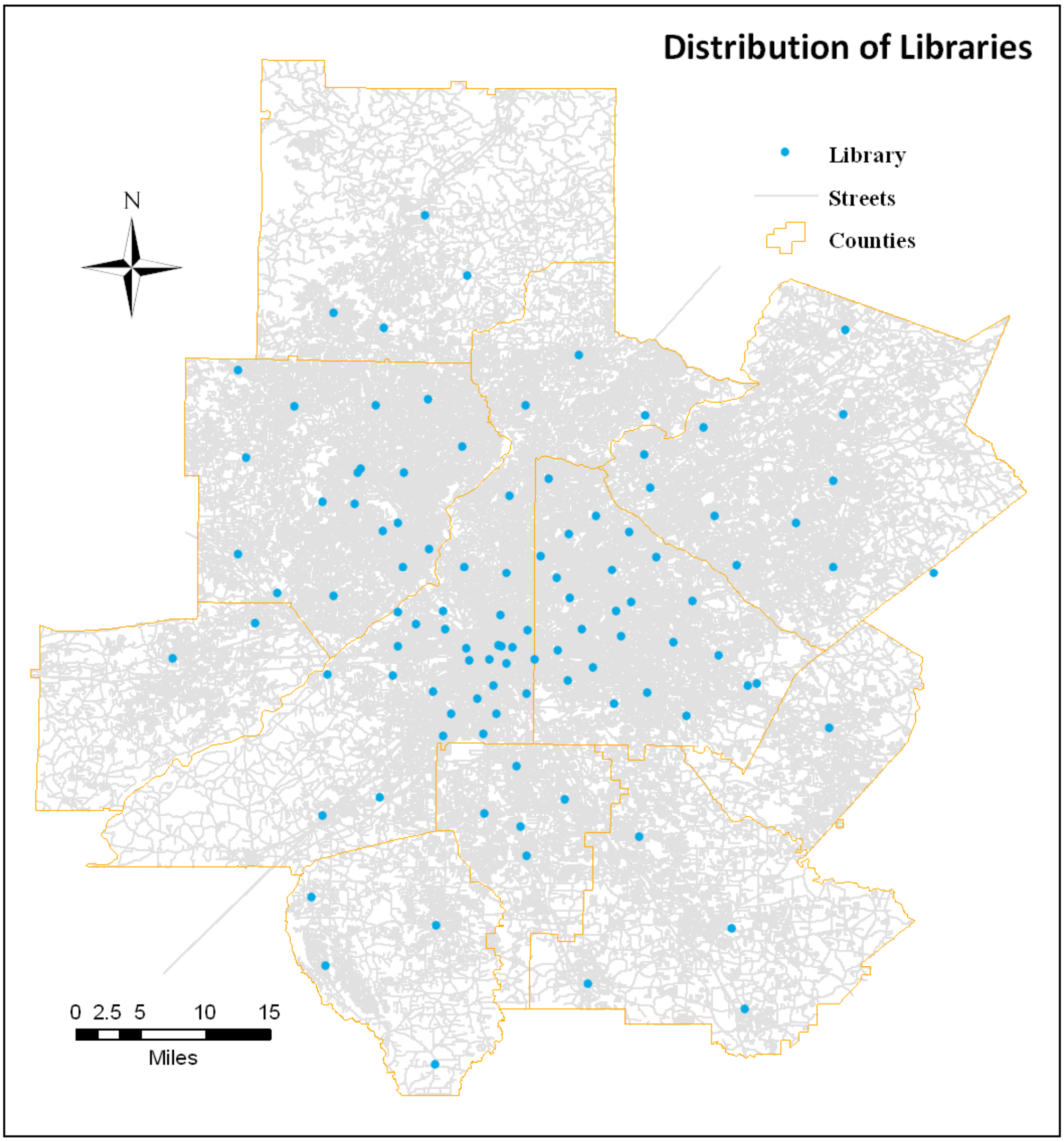

Figure 14 Distribution of libraries in the Atlanta Region

5. Health

a. Pharmacies

There are a total of 349 pharmacies located across Atlanta 10-County area. The distribution of pharmacies is shown in the following figure, and they are represented in red points. There is an attribute AV_SCORE in the pharmacy table describing the average score of each pharmacy, which can be used to represent the attractiveness of pharmacies.

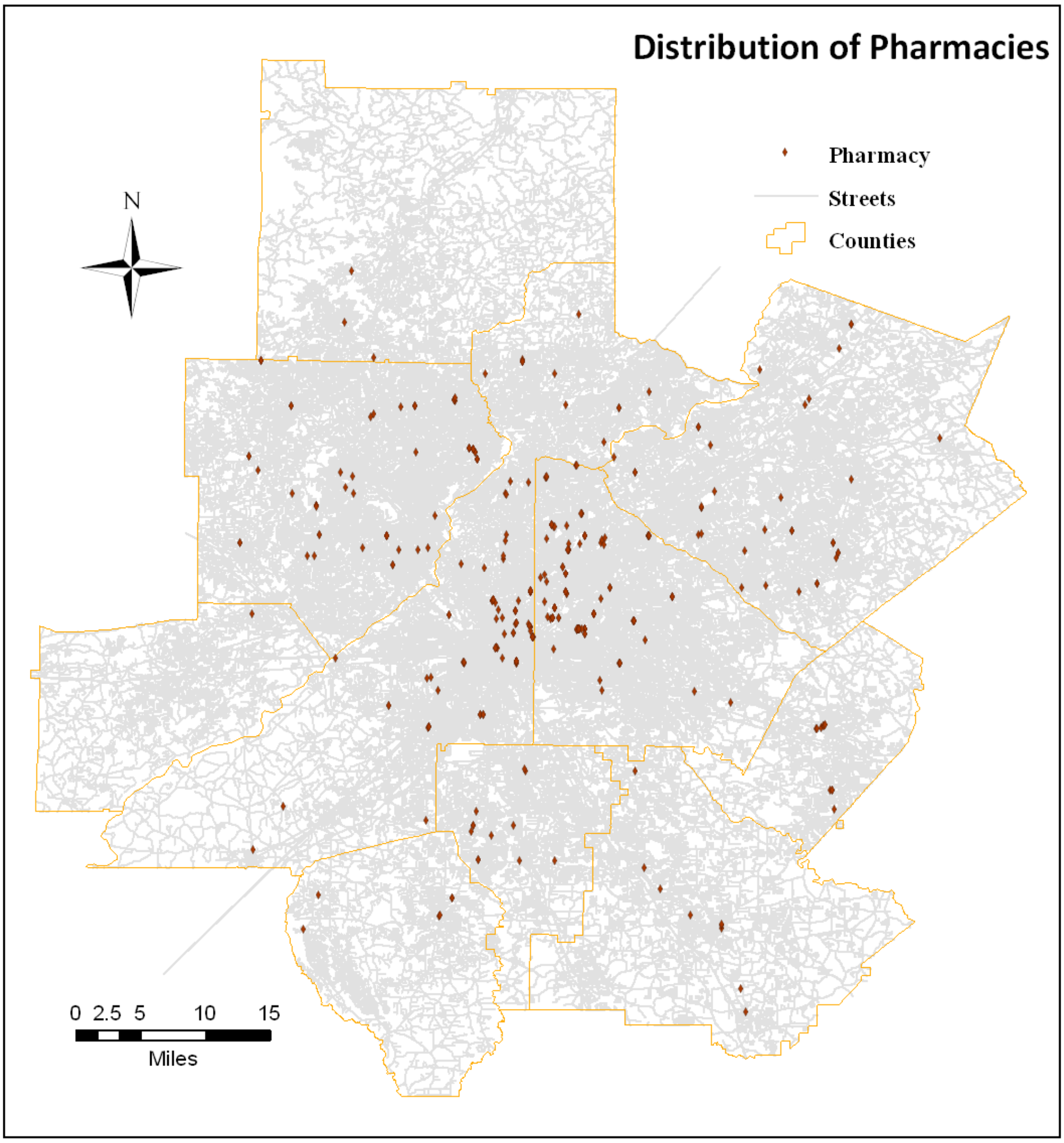

Figure 15 Distribution of Pharmacies in the Atlanta Region

Accessibility of households to public facilities

Table 11 shows the results of accessibilities of different household groups to different types of public facilities. Notice that the accessibility value is from sum of the product of possibility and travel time for each household to each facility. Therefore, if travel time from one household to one type of facility is shorter, which will result in smaller accessibility value, the accessibility of that household is bigger. From the table, accessibility differences can be found between different household groups. Taking traveling by transit groups for instance, African American households have more accessibility to most public facilities than white households. But as to supermarkets, African American households have less accessibility than white households. Also, we can find that in the African American household groups, households traveling by car have much more accessibility than those traveling by public transportation.

Table 11 Accessibility Value of Different Household Groups to Each Type of Public Facilities

Households	Activity center	Bank	Elementary school	Library	Park	Pharmacy	Post office	Supermarket
African American Households with cars	10.55	10.68	10.20	9.43	17.52	10.61	10.90	15.16
African American Households without cars	35.09	37.48	43.50	34.96	70.03	37.02	37.60	57.73
White Households without cars	39.24	36.97	54.29	47.11	77.79	34.38	41.00	54.12
White Households with cars	12.14	10.01	12.11	11.70	18.09	10.74	10.40	12.99

Table 12 shows the accumulated accessibility of different racial groups. The table shows that taking different travel methods into account, white households have more accessibility to all types of public facilities than African American households. Table 13 shows the accumulated accessibility of households groups with different traveling modes. Also, the results in the table reveal that households traveling by car have more accessibility to all types of public facilities than households traveling by public transportation. To different types of public facilities, the differences are different. Differences are bigger for certain types of public facilities, and relative accessibility will be used later to reveal quantitative differences between different households groups.

Table 12 Accessibility Value of Different Household Groups to Each Type of Public Facilities

Households	Activity center	Bank	Elementary school	Library	Park	Pharmacy	Post office	Supermarket
African American Households	15.01	15.55	16.25	14.06	27.06	15.40	15.75	22.89
White Households	12.58	10.45	12.79	12.27	19.06	11.13	10.89	13.65

Table 13 Accessibility Value of Different Household Groups to Each Type of Public Facilities

Households	Activity center	Bank	Elementary school	Library	Park	Pharmacy	Post office	Supermarket
Households traveling by public transit	36.06	37.36	46.03	37.81	71.86	36.40	38.39	56.89
Households traveling by car	11.83	10.14	11.73	11.25	17.98	10.72	10.50	13.41

Relative Accessibility between different household groups

Relative accessibility can reveal quantitative differences between accessibility of different households groups. The ratio of accessibility between the two groups shows the extent that they are different from each other. First, four groups of relative accessibility are calculated to present clear results of differences between household groups. As smaller accessibility value represents more accessibility, relative accessibility value should be explained carefully. In the table, when relative accessibility equals 1, there is complete equity between the two groups. If relative accessibility is smaller than 1, the group in the numerator has more accessibility than the group in the denominator, and the smaller the value of relative accessibility, the bigger difference between the two groups. If the relative accessibility is bigger than 1, the group in the numerator has less accessibility than the group in the denominator, and the bigger the value of relative accessibility is, the bigger the difference two groups has.

Several results can be seen in Table 14. First, for households without cars who travel by public transportation, different racial groups have different advantages towards access to particular sets of public facilities. The table shows that for accessibility to banks, pharmacies, and supermarkets, white households have slight advantages compared with African American households. Accessibility to pharmacies for the two household groups has the biggest difference with a value of 0.93 for the RA index. This means that towards these public facilities, there is a relative equity between African American households without cars and white households without cars. For accessibility to activity centers, elementary schools, and libraries, white households have disadvantages compared with African American households. Accessibility to libraries for the two household groups has the biggest difference, with a value of 1.35 in the RA index. Notice that when calculating accessibility to these three types of public facilities, only the distance between households and facilities is taken into account because of lack of attractiveness information. Therefore, RA indices for these three types of public facilities only represent differences of accessibility in travel time, without households' preference when visiting facilities. In the whole, for households without cars, there is no significant racial difference in accessibility to public facilities, and in turn relative equity exists among households without cars.

There is a similar situation when considering households with cars who travel by car. For accessibility to banks, post offices and supermarkets, white households with cars have slight advantages compared with African American households with cars. Accessibility to supermarkets has the biggest difference, with a value of 0.86 in the RA index. African American households have advantages in access to other public facilities compared with white households. Therefore, for different racial households with cars, there is relative equity towards access to public facilities.

Second, when considering relative accessibility for households traveling by car to households traveling by public transportation, both the RA index for African American households and the index for white households is smaller than 1. The results reveal that accessibility of households without cars is less than that of households with cars, no matter which racial group households belong to. Moreover, the value of relative accessibility is far less than 1, which shows that there is a big gap of accessibility between households traveling by public transportation and households traveling by car. Also, Table 15 shows the overall relative accessibility between households traveling by car and households traveling by public transportation. The results show an equity gap between households with cars and households without cars.

Table 14 Relative Accessibility between Different Household Groups towards Different Public Facilities

RA	Activity center	Bank	Elementary school	Library	Park	Pharmacy	Post office	Supermarket
African American Households with Cars to African American Households without Cars	0.30	0.28	0.23	0.27	0.25	0.29	0.29	0.26
White Households with Cars to White Households without Cars	0.31	0.27	0.22	0.25	0.23	0.31	0.25	0.24
White Households with Cars to African American Households with Cars	1.15	0.94	1.19	1.24	1.03	1.01	0.95	0.86
White Households without Cars to African American Households without Cars	1.12	0.99	1.25	1.35	1.11	0.93	1.09	0.94

Table 15 Relative Accessibility for Household Groups with Different Traveling Modes

RA	Activity center	Bank	Elementary school	Library	Park	Pharmacy	Post office	Supermarket
Households Traveling by car to Households Traveling by Public Transportation	0.33	0.27	0.25	0.30	0.25	0.29	0.27	0.24

The results from Table 14 reveal that within one transportation mode, there is relative spatial equity between different racial household groups considering their access to different types of public facilities.

Table 16 shows overall relative accessibility between white households and African American households. We can observe from the table that white households have advantages in the accessibility to public facilities compared with African American households. That is, towards accessibility to public facilities, for a given transportation mode, there is no big difference between these two racial groups, but there exists spatial inequity between different racial groups considering all transportation modes. This result is reasonable because there are more African American households without cars than white households without cars: there are 75 households without cars among 415 African American households, making up to 18.2% of the whole households. In contrast, there are 23 households without cars among 1416 white households, making up only 1.6% of the households.

Especially in

Table 16, equity status of accessibility to supermarkets should be given close attention. It shows that there is an inequity between white households and African American households in access to supermarkets. As discussed by Deka (2004), access to supermarket plays an important role in the standpoint of equity, because people get fresh food and other necessary items for daily life from supermarkets.

Table 16 Relative Accessibility for Different Racial Household Groups

RA	Activity center	Bank	Elementary school	Library	Park	Pharmacy	Post office	Supermarket
White Households to African American Households	0.84	0.67	0.79	0.87	0.70	0.72	0.69	0.60

CHAPTER 5

DISCUSSION

Result Discussion

This thesis uses the Huff Model to measure the accessibility for households through different travel modes. According to Church and Marston (2003), while residents could or would not visit all the possible facilities, the Huff Model takes consumers' choices into consideration. The idea that people will make a choice from all the facilities when they decide which to visit makes this model more realistic than other models, such as the gravity-based model and coverage model. Despite its advantages, the Huff Model has its own limitations. According to Zhang et al. (2011), there are two problems with the Huff Model: distance decay and destination set selection. Firstly, there are no studies about evaluating the distance decay parameter and this parameter varies towards different public facilities. Secondly, the destination set in the model will exert influence on the results. Whether all the facilities or part of the whole facilities in a study area are selected as the destination set is a complex issue and remains a problem in this model.

Based on the analysis in this thesis there are several significant results. First, there is a large equity gap between those households with cars and households without cars. In both of the racial groups, households traveling by car have much more accessibility than households traveling by public transportation. Though households without cars are located mainly in the central area of the Atlanta 10-County Region where public facilities concentrated, households with cars have advantages in access to public facilities considering both of the attractiveness of facilities and distance from households to facilities.

Second, though there is no obvious inequity between African American households and white households taking into account each transportation mode, overall accessibility for white households to each type of public facilities is greater than that for African American households. Because there are a higher percentage of African American households without cars, they suffer from the disadvantages in access to public facilities. For those facilities without attractiveness information, African American households tend to be located nearer to public facilities than white households. For those facilities with attractiveness information and taking the attractiveness into account, white households tend to have more accessibility than African American households. This shows that African American households have no advantages in access to public facilities of better quality.

Third, in terms of accessibility to certain types of public facilities, African American households suffer disadvantages no matter whether they have cars or not. The results show that for access to supermarkets, there is an inequity status between African American households and white households, with white households having more accessibility to supermarkets. Many studies also show that food deserts exist among poor urban neighborhoods and there are disparities in access to healthy food (Alwitt & Donley, 1997; Bertrand et al., 2008; Chung & Myers, 1999; Zenk et al., 2005). According to prior research, while supermarkets are located in the suburbs, low-income and the minority groups are concentrated in the central areas. Therefore, the disadvantaged population must pay more for food access than the others (Chung & Myers, 1999). Since food access plays a vital role in daily life and social equity, such an accessibility gap should be given more attention.

Although it is common for people to drive everywhere in the United States, many people have to rely on public transportation because of a lack of automobiles. Also, according to Meyer and Miller (2001) and the study of Pucher (2004), the transportation system is a determining factor in the community quality of life. Especially in large cities such as the Atlanta region, public transportation also plays a vital role of relieving congestion. Therefore, accessibility analysis for public transportation in this thesis provides information about the improvement possibilities not only for public transportation services, but also in the distribution of public facilities. On the one hand, accessibility through public transportation needs to be improved. Due to the large accessibility gap between households traveling by public transportation and households traveling by car, there is a long way to go for public transportation to improve the equity status for all households. On the other hand, though African American households may be located near most types of public facilities, their access to facilities of better quality is still less than that of white households. Spatial equity is related not only to the distribution of public facilities, but also the distribution of facilities of equal quality. Therefore, to improve the equity status of service to public facilities, equal distribution as well as equal quality of facilities should be taken into consideration.

Further Research

In terms of further research, there are several factors that could be considered, which reflect areas of insufficient analysis and further consideration of data and methodology improvements. First, when considering travel modes of households and accessibility through different modes of transportation, this thesis supposes that households with cars only travel by car. Actually, households with cars have more transportation choices to visit public facilities. They can either drive to the destinations, or they can drive to public transportation stops and stations, then transfer to transit system and get to the destinations. This model for households with cars can therefore become more complicated for the calculation of accessibility, but it can provide more realistic results. A study by Lee (2005) provided a more precise method in measuring accessibilities by public transit. For one type of facility, he first identified all destinations, then identified all stops within certain travel distance of each destination, and then calculated travel time from each destination to each transit stop. A similar study by Shaw (1991) calculated buffer zones which showed certain auto travel times to the nearest stations. Also, for travel times of households traveling by public transportation, the model used in the thesis only adds up in-vehicle time and walking time to transit stops and stations. When people travel by public transportation, there is another time that needs to be considered – waiting time between different routes. Travel time calculated in this thesis only reflects part of the time cost in transit travel, but it can be refined by adding other parameters. For example, accessibility analysis by Chang and Lee (2008) used an equation to represent travel cost by public transportation, including parameters for in-vehicle time, access time to stops, and waiting time at stops, and also transfer time consumed. This method provides a precise measurement of travel cost and accessibility in turn.

Also, recent research reveals that travel time reliability is significant to transportation system users (Lyman & Bertini, 2008). According to the Federal Highway Administration (FHA), congestion and unexpected delay in big cities makes travel time unreliable and exerts influences on transportation system users. Based on the report from FHA (2009), the consistency of travel time needs to be paid more attention in the further travel time calculation.

Second, due to data collection, some types of public facilities have no information about their attractiveness. When calculating accessibility to these public facilities, this thesis just adds the distance parameter to measure the possibilities of households visiting public facilities. These facilities can be categorized by different characteristics. For instance, libraries can be classified into regional libraries or city libraries; activity centers have types such as town center, city center, and regional center. Services provided by different categories of these types of public facilities will be different, and in turn the attractiveness of these facilities varies considerably. Therefore, quantitative descriptions of the attractiveness of these types of public facilities could be collected and used to refine the accessibilities of households in further research.

Third, accessibility and equity status for households located in different areas can be analyzed to find out in which area public transportation does a good job and in which area public transportation does not do a good job. Consequently, specific and detailed equity status in different areas can be revealed to make improvements for equity clearer. Also, as Tsou, Hung and Chang (2005) pointed out, accessibility to all types of public facilities matters a lot. Further work can add this factor into equity analysis between different ethnic households and households traveling by different transportation modes. Previous studies show that ethnicity and income are the two major themes pertaining to equity. With data available on households' income and other ethnic household groups, detailed information about equity status in the Atlanta 10-County region can be analyzed.

Last but not least, though this thesis uses a disaggregated level of data to do the analysis, and accessibility for each household could be examined if further work is needed, this would require a large amount of individual data such as the location of each household and also a considerable amount of calculation work. Whether it can be applied into other accessibility analysis needs to be examined carefully, and the methods to be used in the equity analysis can vary according to different goals.

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APPENDIX

Accessibilities of White Households without Cars to Public Facilities (a)

ID	Household ID	COUNTY	Activity center	Bank	Elementary school	Library
1	1073348	13089	27.58	58.01	66.03	45.81
2	1094740	13089	18.84	20.26	33.83	31.78
3	1035280	13089	5.07	46.28	60.94	5.84
4	1093830	13121	99.81	85.21	25.28	103.58
5	1094271	13121	84.71	79.77	98.63	89.03
6	1038764	13089	42.00	35.93	53.71	45.98
7	1038682	13121	27.09	11.76	41.05	17.40
8	1106496	13121	10.96	0.81	27.45	19.02
9	1092586	13121	29.32	20.76	44.37	34.34
10	1054002	13121	27.49	34.53	55.35	45.05
11	1079620	13121	3.19	33.40	55.80	49.08
12	1103209	13121	43.52	49.71	54.08	47.99
13	1101369	13121	32.04	32.64	29.16	43.15
14	1048029	13089	46.01	42.67	62.07	51.60
15	1097436	13121	38.98	19.12	53.90	44.27
16	1032454	13121	58.96	55.43	71.42	63.08
17	1105440	13121	59.16	35.71	77.01	59.31
18	1093061	13089	40.26	8.94	59.31	50.89
19	1050198	13089	41.05	20.83	51.64	42.49
20	1036138	13089	26.12	26.57	44.86	34.76
21	1095281	13089	47.75	46.81	61.31	55.26
22	1094102	13089	40.89	37.15	59.04	48.54
23	1037960	13089	51.69	48.08	62.33	55.25

Accessibilities of White Households without Cars to Public Facilities (b)

ID	Household ID	COUNTY	Park	Pharmacy	Post office	Supermarket
1	1073348	13089	95.77	52.22	47.21	67.47
2	1094740	13089	63.16	12.72	20.15	46.43
3	1035280	13089	84.25	48.12	46.53	62.25
4	1093830	13121	102.73	97.52	86.99	97.41
5	1094271	13121	134.58	91.80	91.91	96.25
6	1038764	13089	76.95	28.41	31.84	45.50
7	1038682	13121	46.91	9.50	10.78	45.05
8	1106496	13121	30.14	11.80	9.74	32.75
9	1092586	13121	55.09	20.86	27.84	45.18
10	1054002	13121	74.05	2.95	38.52	52.92
11	1079620	13121	77.86	10.16	40.60	51.83
12	1103209	13121	84.78	49.60	52.35	54.82
13	1101369	13121	70.62	36.65	35.01	49.76
14	1048029	13089	80.56	32.65	39.40	51.13
15	1097436	13121	62.29	21.27	29.08	53.33
16	1032454	13121	95.55	58.15	55.57	72.08
17	1105440	13121	85.68	25.88	50.06	34.08
18	1093061	13089	85.63	13.36	39.23	55.65
19	1050198	13089	79.28	18.93	36.11	32.94
20	1036138	13089	60.02	31.48	28.95	46.50
21	1095281	13089	89.40	46.44	47.17	59.43
22	1094102	13089	73.52	42.72	35.50	41.29
23	1037960	13089	80.47	27.65	42.40	50.77