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A Spatial Assessment of the GO bg Transit Services in Bowling Green, Kentucky

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A SPATIAL ASSESSMENT OF THE *GO bg* TRANSIT SERVICES IN BOWLING GREEN, KENTUCKY

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A SPATIAL ASSESSMENT OF THE *GO bg* TRANSIT SERVICES IN BOWLING GREEN, KENTUCKY

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

A SPATIAL ASSESSMENT OF THE *GO bg* PUBLIC TRANSIT SYSTEM IN BOWLING GREEN, KENTUCKY

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The decision to live in a particular place, accept a job at a distant location, where to go shopping or purchase groceries, and many other similar decisions are all largely influenced by the availability of transportation. As such, it is important that everyone who requires transportation can have access. However, certain population segments, such as low income earners, are less likely to own cars due to the cost involved. There are others who may be impaired physically or have other difficulties that may prevent them from driving. Access to transportation is essential for people of all backgrounds and social statuses. Public transportation is therefore put in place by some cities to enhance the mobility and accessibility of commuters.

This study assesses the services of the *GO bg* public transit service in Bowling Green, Kentucky, to determine how well its services meet the transportation needs of some population sub-groups in the city. A number of Geographic Information Systems (GIS) techniques, including service area analysis, intersect, areal proportion, and demand mapping, were employed in assessing the existing transit routes and stops, and the extent to which certain demographic groups, such as African Americans, Hispanics, seniors aged 65 and older, and low-income households, were served. The study also used spatial proximity to determine accessibility options from transit stops for transit riders. In this study, accessibility was determined based on the available destinations of some basic

consumer necessities in the study area such as health, education, shopping, and recreation.

The results of this study suggest that the *GO bg* transit service on the whole has a reasonable level of coverage, particularly within five-minute and seven-minute walking distances. It also provides acceptable accessibility to major activity centers such as health centers, higher educational institutions, grocery stores, and other places of basic needs, and most of these centers are within five-minute walking distance from the current bus stops. Findings from this study should help the management of public transit services in the study area and improve the provision of transit services to meet the transportation needs of vulnerable members of the community, such as transit dependent individuals. In addition, it could also contribute to the rather limited literature on studies of public transportation in small U.S. cities.

CHAPTER 1: INTRODUCTION

Transportation has always been a critical part of human societies. Modern global economic practices have been accompanied by a considerable rise in the need of transportation on all geographic levels in the past two hundred years. While this trend can be traced back to the industrial revolution, the latter part of the twentieth century and the beginning of the twenty first century have seen an unprecedented growth of such need, largely due to the increased level of trade liberalization, emergence of economic blocks, an increased exploitation of economies of scale and urbanization (Rodrigue et al., 2009).

According to the United Nations (UN, 2012), over the half of the world's population lived in cities in 2011 and the world urbanization rate will reach around 70% by 2050. In cities around the U.S., the most recent residential development is concentrated in suburbia with more and more people living in outskirts and away from traditional urban centers. In addition to residential and employment demands, socializing, shopping, dining out, and other forms of recreational activities form part of the daily lives of the Americans. As noted by Litman (2010), shopping and recreation represent nearly half of all trips and about a third of travel mileages. To fulfill these activities requires some form of transportation since these human activities tend to occur across geographic space. As such, it is important that everyone who requires transportation can have access to it. Fair access to transportation is becoming more and more recognized as an essential component of sustainable development and transportation (Banister, 2002; Deakin, 2001; Richardson, 2005). People in high-income and middle-income classes tend to have a better financial standing and therefore can afford automobiles and in general enjoy a higher level of mobility and for that matter greater accessibility. Indeed, the automobile has been the main means of commuting in the U.S., accounting for the majority of overall trips each year (Pucher and Renne, 2003).

There are several advantages associated with using public transportation, including improved air quality as a result of reduced carbon emission, less road traffic due to mass movement, and savings that individuals make by avoiding fuel and maintenance cost on personal vehicles. However, many cities across the U.S., especially small urban areas, continue to struggle with inadequate or non-existent public transportation services. The most widely and concentrated use of public transport systems are found in large metropolitan areas such as New York, Boston, Chicago, and San Francisco. Overall, the northeastern U.S. has the most public transit services and ridership. In 2002, approximately 43% of all transit trips in the U.S. took place in the three states of New York, Pennsylvania, and New Jersey, while only 14% of the American population was from this region. The rest of the country was unevenly serviced by public transportation (FTA, 2002).

When compared with major cities, small urban areas are faced with even more challenges when it comes to the provision of public transit. Some of these challenges are simply due to low ridership, low densities and high average operation cost. Just like the national trend of high automobile usage as means of commuting, there are less people around to utilize a transit service if available in small cities. This means high average operation cost for transit service. The problem is further compounded by a dispersed land use pattern which usually leads to low population density. Since one of the main factors for effective public transit is high density, small cities will continue to struggle in that regard. These are the challenges faced by the small communities like the City of Bowling

Green, Kentucky. Indeed, a study by the engineers of the Department of Public Works, City of Bowling Green, Kentucky (1992) identified an exceptionally low density as one of the primary setbacks for the operation of public transit in the city.

The City of Bowling Green, Kentucky, the study area of this thesis, is a predominantly auto-dependent city. Nearly 80% of the labor force drive alone to work (U.S. Census, 2010a). Although this is a national trend, there is still a significant number of people who do not own vehicles and who depend on other forms of transportation, such as cycling, walking, carpooling, or public transportation, for their mobility needs. Studies have attributed this lack of car ownership to low income, old age, and disability (City of Bowling Green, KY, 1992), particularly in auto-dependent metropolises where car ownership is essential. Research shows that minority groups, particularly African Americans and Hispanics, constitute a large share of public transportation ridership. Their relatively higher dependency on public transit can attribute to low income as the underlining factor. Pucher and Renne (2003) found in their study that African Americans were almost six times more likely than Whites to travel by transit at a rate of 5.3% vs. 0.9%, and about eight times as likely to take the bus at a rate of 4.2% vs. 0.5%. It was also found that, although Hispanics used less transit than African Americans, they were still about three times more likely than Whites to use transit generally at a rate of 2.4% vs. 0.9%, and relied on buses four times more at a rate of 2.0% vs. 0.5%.

Another group that needs attention in the mobility and accessibility discourse is the elderly. Like many Americans, the automobile is integral to their lives. Many seniors age 65 and older tend to rely more on their personal vehicles for the majority of their trips than any other age group, making the majority of their trips in a private vehicle either as a passenger or driver (Houser, 2005; Pucher and Renne, 2003; Rosenbloom, 1993). In spite of the progress in medicine, physical and mental deterioration remain part of the aging process and, as such, may impede their ability to drive, mostly for persons older than 75 (Shaheen and Rodier, 2007; Lyman et al., 2002). Accordingly, driving cessation can decrease the mobility of older people, particularly if other modes of transportation are not easily available (Bailey, 2004), causing a reduction in contact with the outside world. This may subsequently lead to greater psychological distress and lower life fulfillment for seniors (Collia et al., 2003; Lyman et al., 2002).

While these population variables have been identified as potentially generating transit ridership, we know very little about how much access these demographic groups have to public transit service in small cities like Bowling Green and whether it leads to an acceptable level of accessibility to various essential activities for these vulnerable populations, This is largely due to the fact that most of the existing studies on transit access focus on large cities, and smaller-sized cities are often overlooked. This thesis intends to fill this gap and address the level of public transit access, namely the *GO bg* transit, in the City of Bowling Green, Kentucky. To achieve this, the following questions were examined. How many and what proportion of people live within five, seven, and ten minutes walking distances from a bus stop in the study area? How many African Americans and Hispanics live within reasonable access to a transit service? How accessible is the bus service to the aging population? Do people actually gain access to social and economic opportunities by using the transit service? Questions such as these are critical to understanding the coverage of transit service in the study area and to determining its effectiveness.

Therefore, the primary objective of this study is to understand the spatial distribution of socially disadvantaged demographic groups in terms of their mobility and accessibility, and to examine how the *GO bg* transit system meets their transportation needs. Certainly, barriers remain in mobility and some groups are more likely to face them, posing a disadvantage in their accessibility needs. This study only identifies a few of these mobility challenging factors by examining the level of transit access of low-income earners, minorities (particularly African Americans and Hispanics), and the aging population.

To achieve the objective stated above, a geographic information system (GIS) was used to examine the level of accessibility of *GO bg* transit services. GIS techniques have been widely used in transportation analysis and travel demand forecast (O'Sullivan et al., 2000; Kwan, 1998; Shen, 1998; Arentze et al., 1994). The main reason for its popularity is that GIS helps capture, store, analyze, and display the geographical and temporal characters of a phenomenon (Hanson and Giuliano, 2004). To achieve the above-mentioned objective, this study utilizes a variety of GIS techniques, including choropleth mapping, network analysis, intersect, and areal proportion to determine the number of people served by the transit services within five, seven, and ten minutes walking distance, the potential demand for transit, and the level of accessibility provided by the transit services. U.S. Census (2010a,b,c,d,) data were the main source of demographic data used in this study. Accessibility was determined based on the locations of some basic human needs in the study area, such as health, education, grocery, and recreation. This study aims to add to the literature on public transportation in small-sized U.S. cities. Further, the findings from this study could help the operators of the *GO bg* transit to identify areas of poor service and improve the selection and design of transit routes and stops to better serve the transit needs of the city.

CHAPTER 2: LITERATURE REVIEW

This chapter provides a brief review of a number of selected fields of direct relevance to this research. The chapter begins with a broad overview of transportation planning and urban land-use development. It follows with a discussion of the general relationships among commuting, employment, and public transit services. In Section 2.3, a brief review is presented of a few selected issues related to social equity and transit access. Then the roles of GIS in transportation studies and accessibility analysis are discussed generally in Section 2.4. Lastly, the chapter concludes with studies on transit stops and accessibility, where the Euclidian buffers, Manhattan distance, and network distance methods were compared to show how transit stop analysis has evolved.

2.1. Transportation Planning and Urban Land-Use Development

Transportation plays a vital role in our daily lives and in society, largely affecting many socio-economic decisions that we make every day. For instance, the decision to live in a particular place, accept a job at a certain location, choose vacation spots, and many other similar decisions, are all more or less influenced by the availability of transportation. In the U.S., land-use patterns and life styles have created a great demand for mobility in order to accomplish these daily tasks. Mobility refers to the ability to move between activity sites; for example, from home to a hospital. Closely-related is the concept of accessibility, which refers to the number of activity sites available to individuals constrained by space and time. These two concepts are central to understanding the nature of transportation and the dynamics of transportation and land-use interaction in urban areas (Hanson and Guliano, 2004).

The interaction between land-use patterns and transportation services has been studied a great deal for many years. Ewing and Cervero (2010) stated that land-use patterns have a modest but often statistically significant effect on transportation behaviors. These days, the primary objective of transportation planning is to direct the development of land use and transportation systems in urban areas to attain positive socio-economic and environmental goals. This has resulted in adoption of the term "Transit-Oriented Development" (TOD), which includes making strategic decisions like planning public transit routes or new rights-of-way to coincide with the objectives of land-use development.

Litman (2003) asserts that land-use patterns affect accessibility which in turn is influenced by mobility. In planning for transportation services, therefore, it is important to consider the structures and patterns in land use, basically the spatial distribution of socio-economic activities as well as population, in a way that will enhance accessibility. Aurbach (2003) and Litman (2003) argued that there are often comparisons between two different types of contemporary land-use development patterns, generally termed sprawl and smart growth. Basically, sprawl is a land-use pattern that develops toward the urban outskirts with low population densities. It is more automobile dependent in that streets are designed to maximize motor vehicle travel in terms of volume and speed. Other transportation planning decisions encouraging sprawl development include generous minimum parking requirements, free or affordable parking, poor public transit service, and inadequate and poor walking and cycling conditions.

In contrast to sprawl, smart growth is a high-density development pattern that is urban centered. It is more oriented towards a multi-modal transportation system that supports walking, cycling, and public transit use. Moreover, smart growth has other transportation characteristics associated with it, including reduced roadway capacity and speeds, reduced parking supply, parking pricing and management, transit service improvements strategies, better pedestrian and cycling facilities, among others (Galster et al., 2001; Litman, 2007).

Transportation planning decisions have direct impacts on land use and transportation infrastructure, such as roads, parking lots, and terminals, and indirect impacts on accessibility and development costs (Boarnet et al., 2008; Kelly, 1994). The direct impact is a result of land requirements for transport facilities and, basically, more land occupied by transportation means that less land is available for other development uses. This is especially the case for road transport where there is more emphasis on automobile use. Manville and Shoup (2005) found that automobile dependency tends to increase per-capita transport land requirements. Walking cities typically devote less than 10 % of land to transport, while automobile-oriented cities devote two or three times more to roads and off-street parking (Dimitriou, 1993).

Indirect impacts, on the other hand, are mainly associated with the level of accessibility and development costs. For instance, certain policies may encourage sprawl development, which is low density, dispersed, and automobile dependent. If so, a city usually becomes less accessible as more traveling is required to reach activities centers like jobs, services, and recreation, and travel options are often reduced, particularly walking, cycling, and public transit. A number of studies conducted by Ewing et al. (2002) and Litman (2005) indicate that households in sprawled communities tend to have considerably higher expenses for transportation than households in communities with more accessible, multi-modal land-use patterns. To buttress this, McCann (2000) found that households in automobile-dependent places on average spend more than 20% (over $8,500 annually), while those in smart growth communities spend less than 17% (under $5,500 annually) of household expenses on transportation. Other indirect impacts on land use include housing cost, public service, and infrastructure cost. Generally, housing costs in sprawled communities are cheaper than in urban centers due to lower land cost, one of the main driving forces behind urban decentralization and sprawl. Many studies have shown, however, that sprawl tends to increase infrastructure and public service costs due to dispersed land development (Litman, 2004; Muro and Puentes, 2004).

In practice, it may not be an easy task to determine the exact impacts on land use by a particular transportation planning decision, particularly because many of these impacts are often indirect and long term as discussed above. For example, it is generally expected that expanding roadway capacity on the urban fringe will probably simulate sprawl development, whereas improving transit service and implementing supportive land-use policies on the other hand may stimulate smart growth. The exact impact may not be easily predictable in the short term, as there are many other factors that could affect land use, including the relative demand for different types of development, the degree to which a particular transportation project will improve accessibility and reduce costs, and how a transportation policy or project integrates with other factors and how it is implemented.

2.2. Transit, Commute and Employment

Between 1945 and 1970, a reviving economy, new urban development, extensive highway construction, and more efficient cars resulted in an exodus from U.S. cities (Muller, 1997). Urban development from the 1980s has revealed substantial changes in the structure of metropolitan areas, particularly the growing polycentrism within metropolitan areas, where employment became concentrated in various sub-centers beyond the central business district (CBD), as well as the increasing sprawl of economic activity in suburbs (Giuliano et al., 2010). The mid-1980s to1990s saw suburbs mature into full-fledged urban centers, termed "edge cities" by many, as their land-use complexities diversify and perform several important economic, social, civic, and recreational functions traditionally limited to CBDs (Muller, 1997). These dispersed urban forms do encourage automobile dependency and are often associated with high levels of mobility for most people but, unfortunately, they result in low levels of accessibility, particularly for population and communities with inadequate means of transportation.

There is no consensus yet in the transportation community on how public transit may affect job opportunities, particularly for low-income workers. In a bid to understand the effects of spatial mismatch between changing trends in urban development patterns and the spatial distribution of low-income workers, some transportation researchers argued for a more central role for public transit to bridge the gap (Sanchez, 1999; Wachs and Taylor 1998). Others, however, consider personal vehicles as a better option to narrow that gap (Waller and Hughes, 1999; Taylor and Ong, 1995). In examining the connection between public transit and employment in Atlanta, Georgia, and Portland, Oregon, Sanchez (1999) concluded that access to transit had a positive effect on employment participation in the two cities. On the other hand, others contended that car ownership provided better opportunities in moving people from welfare to work (Shen and Sanchez, 2005; Cervero et al., 2002; Ong, 1996). Some researchers argue that a better way of spending public funds is to assist low-income earners acquire automobiles rather than spending large sums to support the growth and expansion of public transit (Waller and Hughes, 1999; Taylor and Ong, 1995). Programs that either provide direct financial assistance or support others to help low-income earners acquire used vehicles are considered more beneficial. Skepticism, however, has been expressed about the sustainability of such ideas, especially in terms of the possible negative environmental impact and the ability of low-income earners to keep up with the maintenance of used vehicles (Cervero et al., 2002). Another study found that proximity to transit produced a positive effect on employment rates for Hispanics but showed insignificant outcomes for African American hiring rates (Holzer et al., 2003). In addition, Sanchez et al. (2004), in assessing the relationship between increased transit access and employment status of low-income families on Temporary Assistance for Needy Families (TANF) in six major U.S. metropolises, found that there was no direct association between transit access and employment status of TANF recipients. This issue becomes even more complicated as changes in urban structure could also influence transit-job relationships. Kawabata and Shen (2006) examined job accessibility between auto owners and public transit users for three major U.S. cities in comparison to a similar study in Tokyo, Japan, where commuters depend largely on public transits. They found that public transit users in the U.S. have lower access to jobs than those in Tokyo.

2.3. Social Equity and Transit Access

Social equity has been used to promote what may be considered fairness. In public transportation, the term is used when evaluating the level of access that different segments of society attain when traveling to various activity centers. Equity in the distribution of transportation service has been discussed in many studies (Welch and Mishra, 2013; Litman, 2012; Garrett and Taylor, 1999; Hay, 1995). Litman and Brenman (2012, p.3) broadly defined social equity as the "equitable distribution of impacts," where impacts are the advantages, disadvantages, and costs associated with a particular situation. What is often being examined is a good measure of fairness in the distribution of public transportation services. Equity in access to public transportation could be influenced by different factors such as race, gender, sexual orientation, income level, age, among others (Martens et al., 2012; Currie et al., 2009; Church et al., 2000).

Two types of equity can be identified: horizontal and vertical (Litman, 2012; Khisty, 1996; Repetti and McDaniel, 1993; Berliant and Strauss, 1985; Kakwani, 1984) Horizontal equity refers to the equal treatment of people with similar circumstances, while vertical equity is concerned with the allocation of benefits among particular groups. Horizontal equity suggests that individuals or groups of equal standing should share equal benefits as well as the costs of a resource. This also means that public policy should not favor an individual or group over another (Alsnih and Stopher, 2003). Vertical equity, on the other hand, implies that individuals or groups should be treated according to their abilities or need. Rawls (1971) sets a theoretical basis for vertical equity. His assertion was that primary social goods including opportunity, liberty, and wealth must be shared equally or should favor less-advantaged people. For example, transportation policies that favor socially and economically disadvantaged groups may be regarded as equitable. Often times, public transit has been recognized as having the prospect to reduce social exclusion and increasing social equity for the people identified as needing help (Hine, 2008; Farrington and Farrington, 2005).

The ultimate goal of equity studies in transportation is to promote equal access to social and economic opportunities (Sanchez et al., 2003). Issues such as access to jobs, health care facilities, groceries, and recreation have all been examined. For instance, it was found that minority groups and low-income populations have relatively less access to health facilities (Ginzberg, 1991). In the suburbs, African Americans and Hispanics have also been identified as disproportionately living in neighborhoods with relatively low job growth rates (Raphael and Stoll, 2010; Luce et al., 2006). This suggests that accessibility to job centers is crucial to their livelihood. In their study, Garrett and Taylor (1999) deplored the vast differences in resources spent to attract new riders versus the quality of service offered to those who were transit dependent. They considered this as wasteful and socially unfair. Research shows that minority groups, particularly African Americans and Hispanics, constitute a large share of public transportation ridership in relative proportions in the U.S. Low income is the underlying factor in their relatively higher dependency on public transit.

2.4. GIS and Accessibility Analysis

Transportation research in the U.S. during the 1980s mainly focused on government policy, the deregulation of motor carriers, and intercity bus transport. In the 1990s, however, there was much focus on transport technology, infrastructure, intelligence transport systems, and sustainable transportation (Black, 2003). The 1990s saw the first widespread use of GIS in transportation research and management and the term, GIS for Transportation (GIS-T), was introduced to describe the emerging GIS techniques for transportation planning, management, and analysis (Thill, 2000), including accessibility analysis (O'Sullivan et al., 2000; Kwan, 1998; Shen, 1998; Arentze et al., 1994)

Accessibility analysis is often dependent on the selection of a suitable accessibility measure, which may be formulated based on spatial units for analysis, certain socio-economic groups, and types of socio-economic opportunities being assessed (Liu and Zhu, 2004). This means that the ability to store, manage, and manipulate both spatial and non-spatial data is an essential aspect of accessibility analysis. As an integrated system for many forms of data, a GIS could hold many kinds of transportation, land use, and socio-economic data. Many studies identified that the primary advantages of a GIS include its speed, analytical capabilities, visualization power, and the efficiency applied to data storage and management (Hartgen et al., 1993; Niemeier and Beard, 1993; Anderson, 1991). Basically, GIS technology can be seen as an integration of three software technologies, namely, data management, spatial analysis, and map visualization (Hanson and Giuliano, 2004).

Data management provides the platform for data compilation and development relating to geographic features. The importance of data to any phenomena cannot be overstated. A GIS provides the means for creating and storing vital data from multiple sources. The locational capability of GIS also ensures that feature attributes have spatial information such as coordinates, making it possible to relate a feature to a place. The spatial analytical capability of GIS enables data to be combined using a variety of techniques in order to explore relationships and assess phenomena that vary with geographic locations. GIS allows analytical and computational tools to be used in conjunction with detailed representations of the local geography, allowing analysis and problem-solving to be tailored to the local context (Miller and Shaw, 2001).

2.5. Transit Stop and Accessibility

The sustainable growth of a modern and healthy urban metropolis is strongly linked to the availability of a good and effective transportation service. The urban population needs access to health care, education, employment, and recreational opportunities, among others. Accessibility is an essential feature of urban areas and plays a major role in providing a connection between transportation and land use (Liu and Zhu, 2004). Improving accessibility has also been a major part of the goals for a majority of transportation planning practices in the U.S. (Handy, 2002).

The term “accessibility” has sometimes been confused with mobility and, therefore, there is a need to explain the differences here again. Hansen (1959) and Handy (1994) define mobility as the prospect and ability to move from place to place. Accessibility, on the other hand, is the ability to reach desired goods, services, and activity centers in space and time (Litman, 2012). This simply means that there can be no accessibility without achieving mobility. Public transportation is a major means to achieving mobility and, hence, accessibility, especially for certain segments of society who lack or have limited mobility such as the elderly and low-income households.

Achieving mobility and accessibility also depends on a person’s location in relation to a transit stop. Research shows that majority of public transit users usually come from the vicinity around a transit stop or station (Wibowo and Olszewski, 2005). Different spatial analysis methods have been used by transportation analysts to evaluate the coverage areas of transit service, also known as transit catchment areas. A transit catchment area can be defined as the surrounding area of a public transit stop. Early research used the Euclidian buffers to estimate the population within a catchment area of transit stops by creating a straight-line buffer around a stop and calculating the population within (Biba et al., 2010). The limitation with this method is that it ignores physical barriers to walking. These barriers may include waterways, buildings, and directional turns within the built environment, thereby underestimating travel distance (O'Neill et al., 1992).

To solve the problem associated with the Euclidian method, therefore, some researchers introduced the Manhattan distance method. This was based on the assumption that people walk along a perfect grid-like path and make only right-angled turns (Cheng and Agrawal, 2010). This method, however, fails to consider the fact that street layouts could differ and transit stops are not likely to be distributed in perfect grid-like urban settings. Clearly these two methods do not take road networks into consideration when estimating coverage but rather assume that people can get a direct path to stops from any point within a buffer. It is generally agreed in transit research that the Euclidean buffers overestimate service areas since potential passengers can only access transit stops by using road networks, hence network buffers are preferred (Kimpel et al., 2007; Zhao et al., 2003; Hsiao et al., 1997; O'Neill et al., 1992). Not surprisingly, in recent years the advances in GIS have led to the improvements in transit catchment-area analysis using methods such as network analysis. Network analysis is a process that uses an actual road network to compute distances and, therefore, navigate away from the problems of physical barriers associated with the Euclidian approach (Andersen and Landex, 2009).

Many researchers have examined stop-level transit demand using various methods. Many of these studies have focused on large metropolises with populations greater than 100,000 and have also used a more generalized approach in estimating potential transit demand. In evaluating public transit access in South East Queensland, Australia, Murray et al. (1998) examined access as a distance from populated census units to bus stops. Their findings suggest that access was attained when the distance from bus stop falls within a set threshold. The study, however, fails to integrate demographic and socio-economic components.

Using a measure of integral accessibility, Kimpel et al. (2007) examined the effects of overlapping bus-stop service areas on the demand for transit at the bus-stop level during morning rush hours. Their study used tax-parcel data to calculate the potential transit demand at each stop. They also used automatically collected passenger data at bus stops for their analysis. The study concluded that the number of accessibility weighted dwelling units has a positive association with the number of boarding passengers. In another study of bus stop and transit ridership, Foda and Osman (2010) developed three indices to assess bus stops, given the surrounding road network. While two of the measures present variations on pedestrian road-network density, the third compares the other two. They used major roadways in Alexandria, Egypt, as a case study and found that using the actual pedestrian road network resulted in a more accurate measurement.

Focusing on a defined area within the radius of a transit station, Guerra et al. (2011) used what they termed a *direct demand model* to predict potential transit passengers. The research used the model to test multiple catchment areas and found that a quarter-mile catchment area best predicts ridership as a function of jobs, while a half-mile zone does the best projection for the population. Their study used ridership data from large transit stations in the U.S. Even though their research projects events in the immediate surroundings of transit stations, it gives little consideration to other areas of potential transit demand. This is an issue that runs through most of the literature. Yet studies have shown that certain segments of the population, such as low income earners, aging populations, African Americans, and Hispanics, are more dependent on public transit. There is a strong need to examine how transit services serve these segments that often lack or have limited means of transportation and mobility.

Walking is regarded as an essential means of getting to a bus stop when planning a bus-based transit service (Foda and Osman, 2010). The distance people would walk to get to a stop is considered vital in transit planning and analysis. It can be assumed that, generally, people would prefer a short distance to walk in order to use public transit. As a rule of thumb, public transit planners and researchers have typically used 400 meters (again, roughly 0.25 mile) as the walking distance to determine how far people would walk to a stop (Kimpel et al., 2007; Murray and Wu, 2003; Murray et al., 1998; Queensland Government, 1997; FTA, 1996; Neilson and Fowler, 1972). Other distances, such as 300, 500 and 800 meters, were also used in other studies (Schlossberg et al., 2007; Chapleau and Morency, 2005; Kuby et al., 2004; Mondou, 2001).

In short, walking distance from origins to a transit stop has been widely used to estimate transit catchment areas and to evaluate how accessible people are within certain geographic vicinities. The Euclidian and Manhattan distance measures, however, have several limitations, and network analysis was later introduced to provide a more accurate estimation of walking distance, thanks to the advances in GIS. This study, therefore, utilized network distance instead of Euclidian and Manhattan distance measures.

CHAPTER 3: STUDY AREA

3.1. Study Area Overview

The City of Bowling Green (Figure 3.1), with a population of 58,067 (U.S. Census, 2010a), is located in Warren County, south central Kentucky. As the third largest city in Kentucky after Louisville and Lexington, it is the seat of the Warren County government. Since its founding in 1798, the City of Bowling Green has steadily become a major hub for economic, education, medical, and recreational activities in the region.

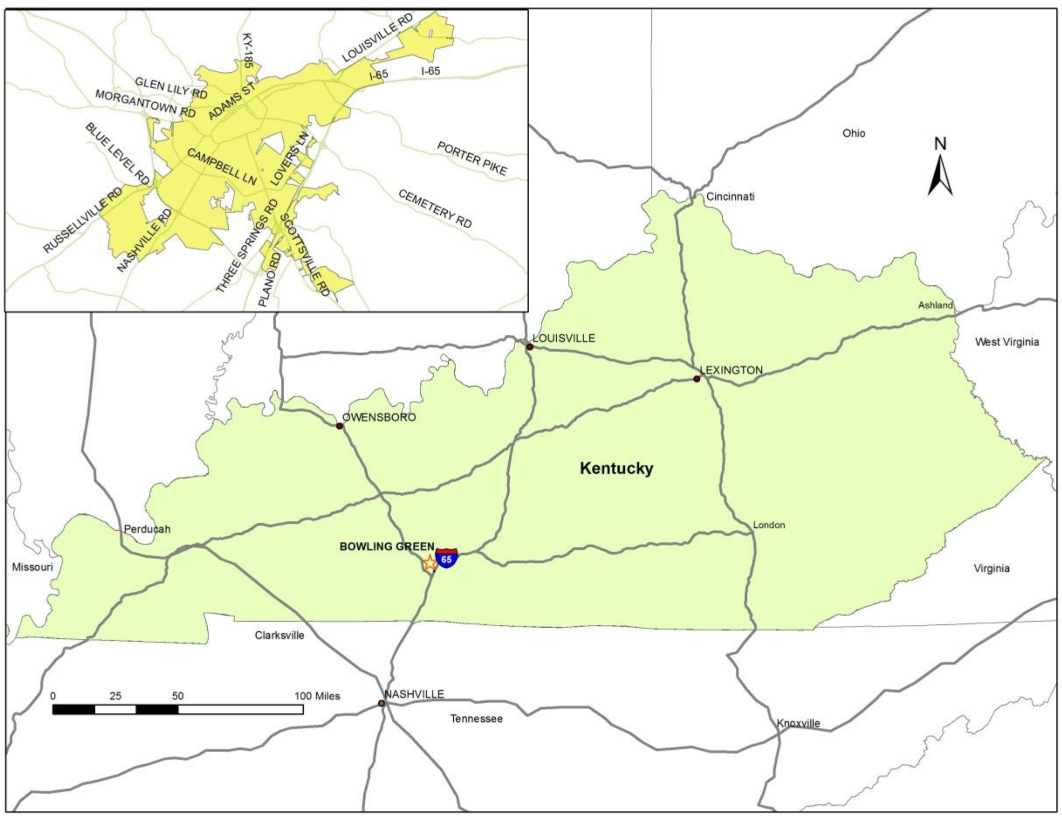


Figure 3.1: Geographic Location of City of Bowling Green, which is located in south central Kentucky, where Interstate 65 connects it to major cities like Louisville, KY and Nashville, TN. Source: U.S. Census (2010b).

The City of Bowling Green is located at where two major highways, namely I-65 and the William H. Natcher Parkway, intersect. These two highways connect the city to the other major urban centers within the state and beyond, including Louisville, Lexington, Owensboro, and Nashville (Figure 3.1). Besides road transport, the city is also accessible by private air service from the Bowling Green-Warren County Regional Airport (Figure 3.2).

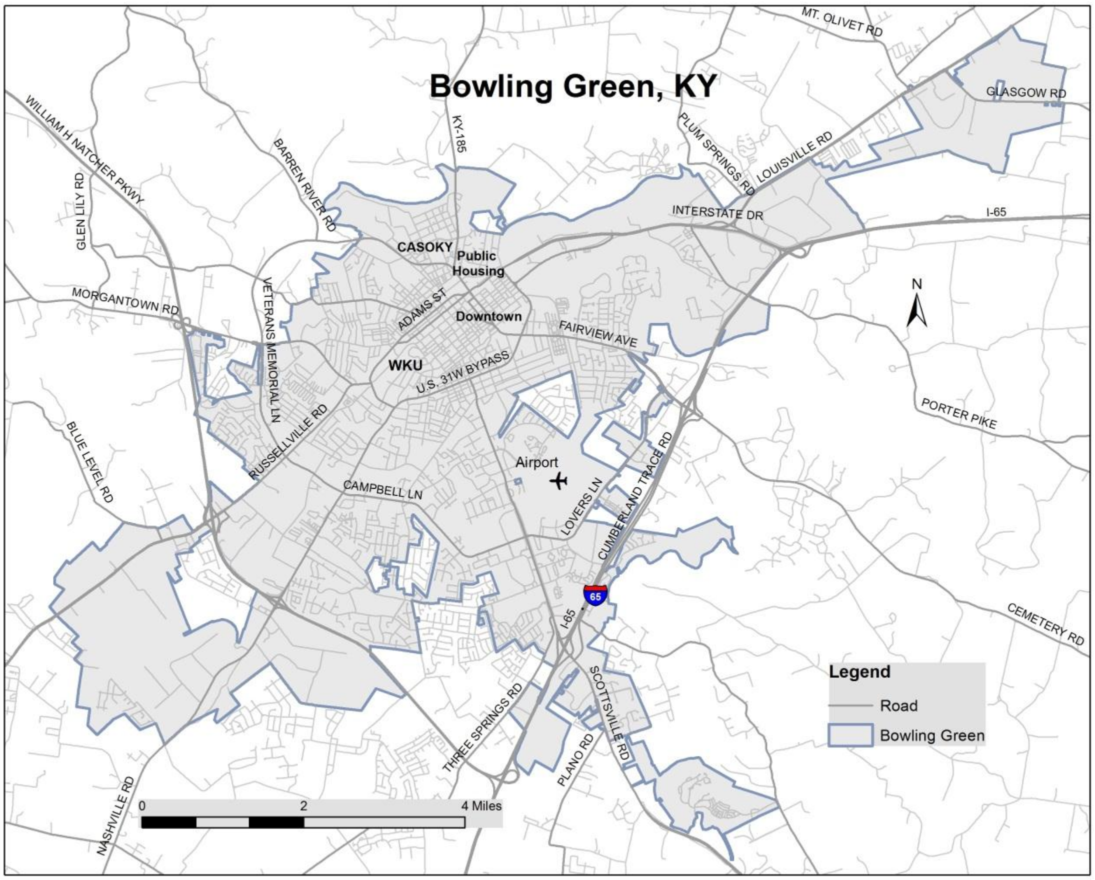


Figure 3.2: City of Bowling Green, Showing Major Landmarks.
Source: U.S. Census (2010b).

3.2. Population and Demographics

The City of Bowling Green has seen consistent growth in population over the last two decades. From 1990 to 2000, the population grew from 40,641 to 49,296, a 21.3% increase, and then, in 2010, a total population of 58,067 was reported, making a 17.8% growth in 10 years from 2000. The population growth rate between the last two decennial censuses is a lot higher than the state average of 7.36% and also higher than the national average of 9.71%. The city covers a land area of 38.5 square miles, putting the population density of the area to about 1,508 persons per square mile (U.S. Census, 2010a). The population is concentrated in and around the downtown and near the environs of Western Kentucky University (WKU).

The racial composition based on the most recent U.S. Census (2010a) indicates that the inhabitants are largely White, accounting for 75.8% of the total population. African Americans and Hispanics make up 13.9% and 6.5% respectively. There is also a growing Asian population, which accounts for a much higher proportion than those in the previous years, constituting 4.2% of the population (U.S. Census, 2010a).

3.3. Employment and Income Level

Bowling Green serves as a major economic center in south central Kentucky. Thanks to major industries such as the General Motors Corvette assembly plant, Fruit of the Loom, Camping World, and Houchens industries, among others, workers are attracted from Warren County as well as neighboring counties. Given the location of WKU, South Central Kentucky Community and Technical College (SKYCTC), and the Medical Center, Bowling Green also serves as a focal point for education and health care, particularly in workforce training and medicine. Indeed WKU and the Bowling Green Regional Medical Center are the two leading employers (Table 3.1), employing 4,614 and 1,905 people respectively (City of Bowling Green, KY, 2011). The data in Table 3.1 also show a comparison of employment level in 2001 and 2010.

Labor statistics indicate that out of the 30,156 citizens in the labor force, 26,268 were employed, constituting 56.6% of the population. According to U.S. Census (2010a), the private sector accounted for 78.3% of the employment. In general, educational services, health care, and social assistance employed the most people, making up a total of 26.1%. This is followed by retail trade (15.3%) and manufacturing (14.5%). The agricultural sector accounted for just 0.8% of those employed. With a 19 minutes average commute time to work, 26,141 of the labor force did commute to work, making transportation to work a vital part of the economy. Table 3.2 lists the statistics about the employment status by industry.

The median household income in Bowling Green was $33,362 in 2010, an increase from 14.86% in 2000. The income growth rate was below the average for Kentucky (18.98%) and lower than the national rate of 19.17%. About 27.7% of the population was below the poverty level with 30.9% of those under age 18 also falling below poverty (U.S. Census, 2010a). These statistics indicates that income in Bowling Green increased at a relatively slower pace and also had appreciable number of low income earners who can potentially be transit riders. The spatial distribution of income levels at the census tract level reveals that the majority of those who earn $25,000 and below were concentrated in the mid to north-west of the city (Figure 3.3). While the southern portion of the north-west area is mostly made up of students who attend WKU, the northern part is typically made up of regular households. The northern area of Bowling Green is the home to government housing projects where low income families and some international refugees live. Households earning between $50,000 and $75,000 and those earning above $75,000 were mostly located in the south and eastern part of the city (Figure 3.3).

City of Bowling Green, Principal Employers						
	2010			2001		
Employer	Employees	Rank	% of Total City Employment	Employees	Rank	% of Total City Employment
Western Kentucky Univerty	4,614	1	11.29%	3,767	1	7.78%
The Medical Center at BG	1,905	2	4.66%	1,630	2	3.36%
Union Underwear Co. LLC	1,537	3	3.76%	935	4	1.93%
Wal-Mart Associates Inc.	1,026	4	2.51%	- - -	- - -	- - -
Warren County Board of Education	1,015	5	2.48%	783	5	1.62%
Sun Products	959	6	2.35%	- - -	- - -	- - -
BG Metalforming LLC	750	7	1.84%	- - -	- - -	- - -
Houchens Food Group Inc.	710	8	1.74%	- - -	- - -	- - -
City of Bowling Green	635	9	1.55%	612	8	1.26%
Bowling Green Independent Schools	606	10	1.48%	- - -	- - -	- - -
NAO Comp Oper-North America Oper	- - -	- - -	- - -	1,626	3	3.36%
Desa International Inc.	- - -	- - -	- - -	576	9	1.19%
Eagle Industries LLC & Subs	- - -	- - -	- - -	687	6	1.42%
Express Services Inc.	- - -	- - -	- - -	657	7	1.36%
Commonwealth of Kentucky	- - -	- - -	- - -	541	10	1.12%
Total	13,757		33.68%	11,814		24.39%

Table 3.1: Employment Statistics of Major Companies between 2001 and 2010. Source: City of Bowling Green, KY (2011).

EMPLOYMENT RATES BY INDUSTRY, BOWLING GREEN, KY		
INDUSTRY	Estimate	Percent
Civilian employed population 16 years and over	26,628	---
Agriculture, forestry, fishing and hunting, and mining	209	0.8%
Construction	1,239	4.7%
Manufacturing	3,864	14.5%
Wholesale trade	537	2.0%
Retail trade	4,070	15.3%
Transportation and warehousing, and utilities	918	3.4%
Information	493	1.9%
Finance and insurance, and real estate and rental and leasing	968	3.6%
Professional, scientific, and management, and administrative and waste management services	2,281	8.6%
Educational services, and health care and social assistance	6,957	26.1%
Arts, entertainment, and recreation, and accommodation and food services	3,376	12.7%
Other services, except public administration	1,221	4.6%
Public administration	495	1.9%

Table 3.2: Employment Rates by Industry in Bowling Green, KY.
Source: U.S. Census (2010a).

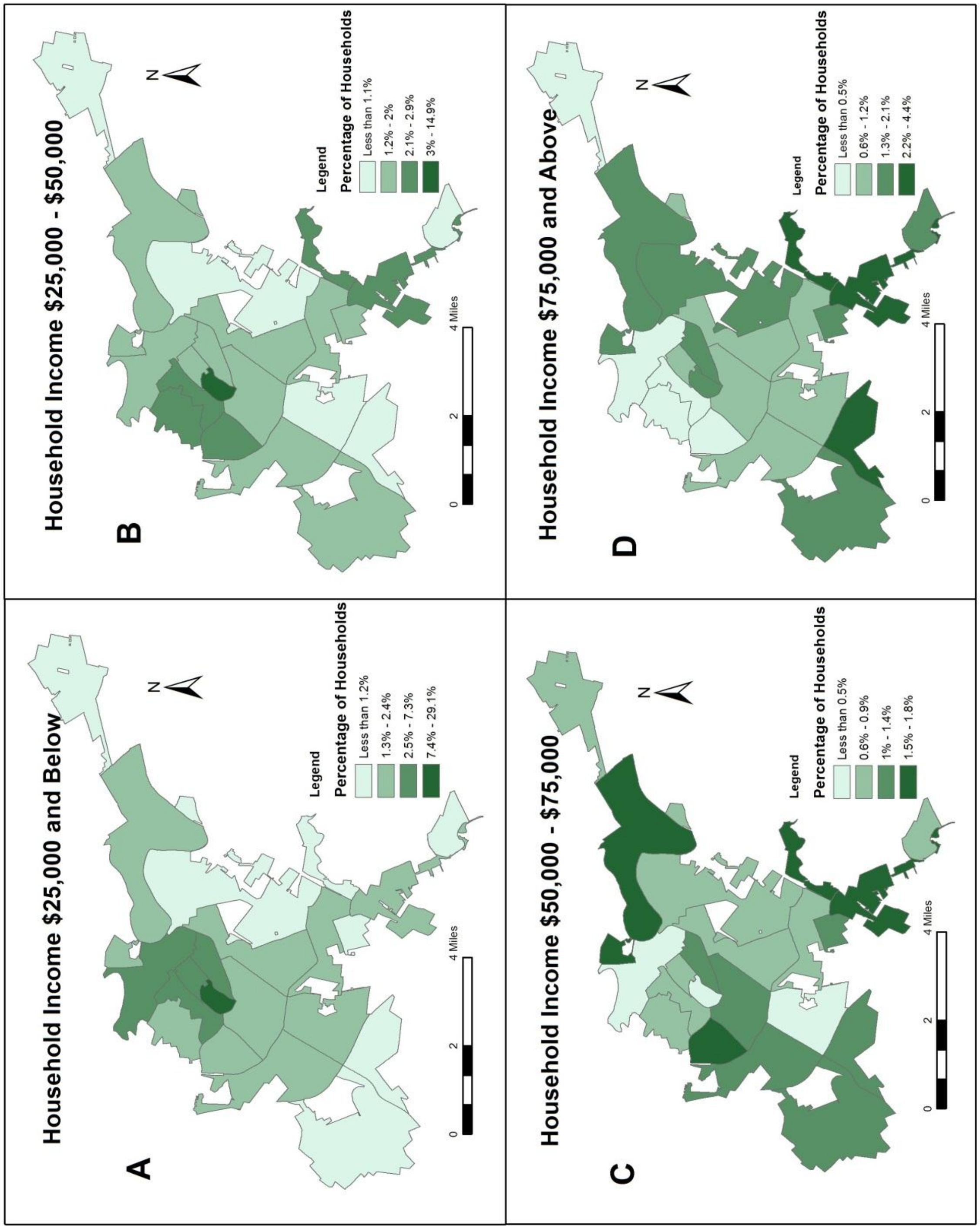


Figure 3.3: Income Distribution Comparison at Census Tract Level.
Source: U.S. Census (2010d).

Although the City of Bowling Green is relatively small in terms of size and population, it seems to possess a good balance in a socio-economic structure that sustains its economy and jobs. Zoning maps (Figures 3.4 and 3.5) from the Warren County Planning Commission (WCPC, 2009) indicate that Campbell Lane, Russellville Road, US 31 W, Louisville Road, and Scottsville Road have the highest concentration of highway businesses. These areas are more likely to attract people due to the commercial activities taking place there. Also, these streets have the highest share of the general community business, with the exception of Louisville Road. While the CBD is naturally concentrated in the downtown around central Bowling Green, the heavy industrial districts are mostly located towards the fringes of the city in the north, northeast, south, and west.

In summary, income growth rates in the study area are not as high as those at the state and the national level, and a noticeable proportion of the population (27.7%) also falls below the federal poverty line. Bowling Green is predominantly an automobile-dependent city just like many other American cities of similar size. While this poses a big challenge to public transit, certain segments of the population (e.g., low income people) may not be able to afford reliable personal vehicles and ought to be considered one of the the main sources of demand for transit in the study area.

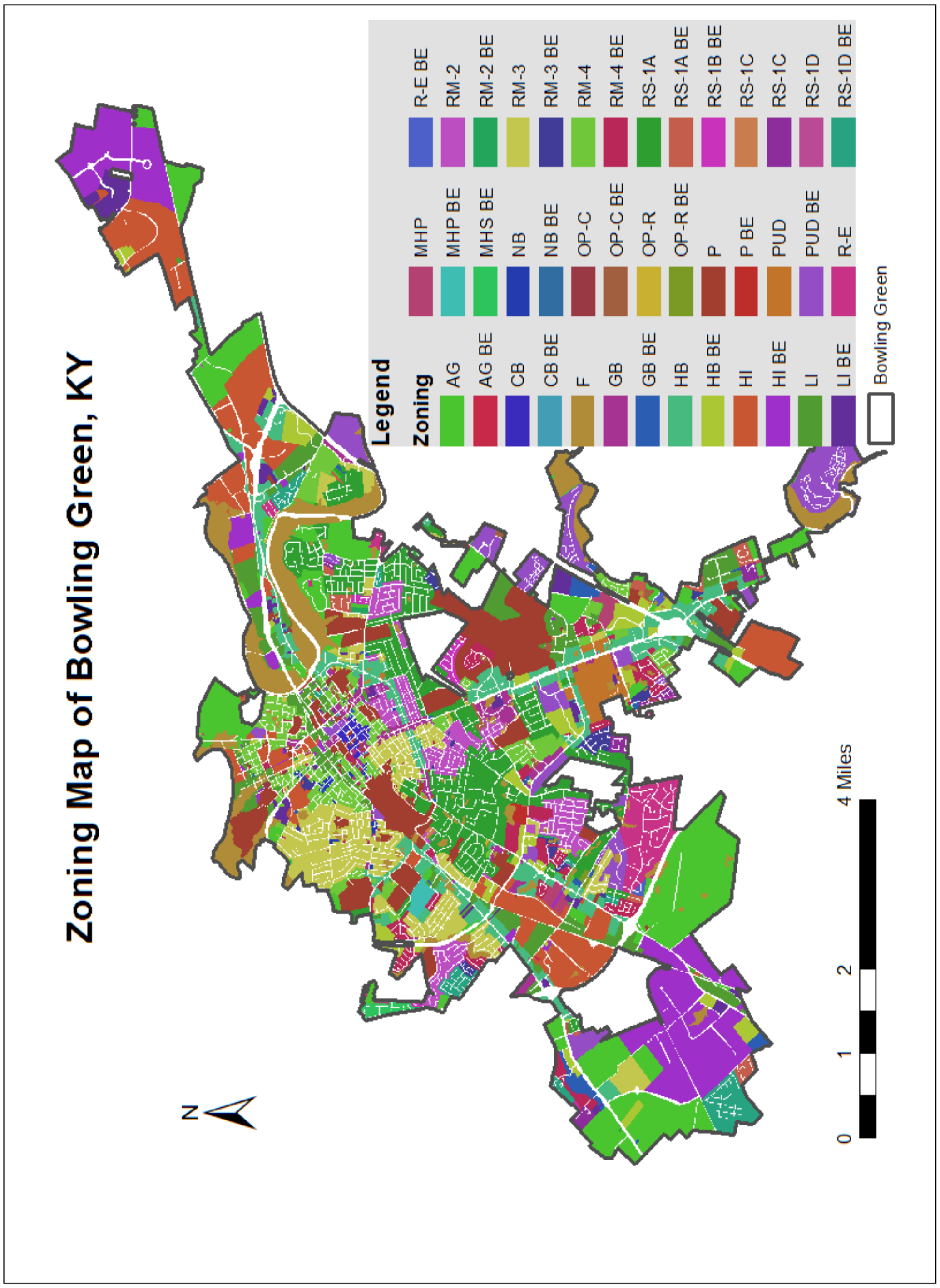


Figure 3.4: Zoning Map of Bowling Green. Source: WCPC (2009).
Note: see the next page for the complete legend code names.

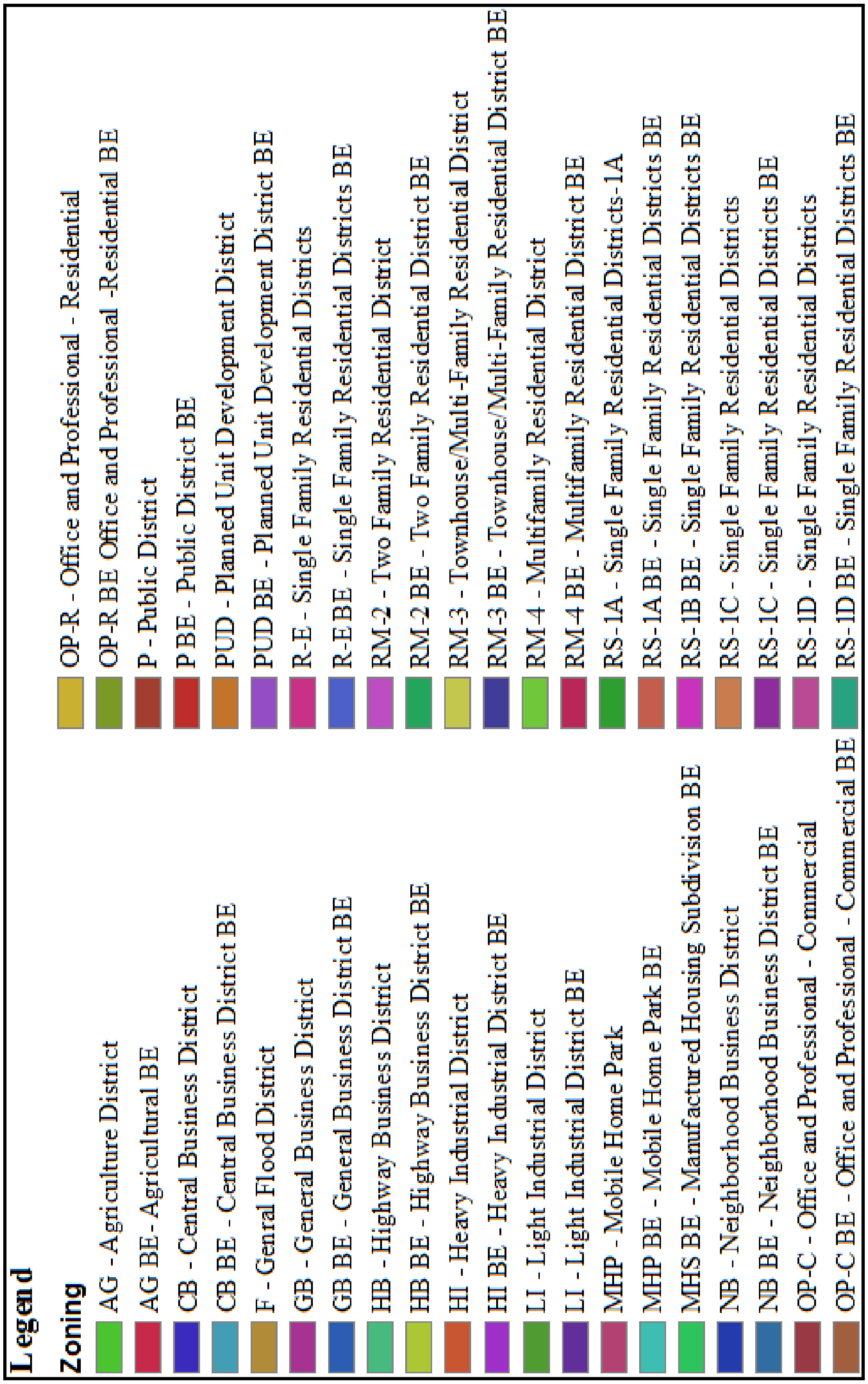


Figure 3.5 Legend with Full Zoning Code Names.
Source: WCPC (2009).

3.4. The ***GO bg*** Public Transit Service

The *GO bg* public transit service is a bus service operated within the city limits of Bowling Green, Kentucky, by the Community Action of Southern Kentucky (CASOKY, 2013). Figure 3.6 shows the type of buses used for *GO bg* public transit service.

Figure 3.6: Buses used by the *GO bg* Transit Service. Source: Photo by Author.

Prior to the establishment of the *GO bg* service, there was no evidence of an existing fixed-route public transit service, although a study by the City of Bowling Green (1992) stated that the city had some type of public transportation services, but they were either too expensive or too restrictive to serve those in need. Indeed the study conducted by the city was one of the contributing factors leading to the establishment of the current transit service.

The bus service has progressed over the years from its initial two-bus fleet. It started in 1989 after CASOKY was awarded a non-profit bus-operating permit for the ten counties in the Barren River Area Development District (BRADD), by the Kentucky Transportation Cabinet (KYTC). It operated a rural transportation service for the elderly and disabled in each county within BRADD. In 1993, CASOKY used a grant from United Way Venture to undertake a pilot transportation service based on a demand response. This was done for designated social-service agencies for their clients to access needed medical and other social services. Two buses were obtained for this purpose. During the early part of 1994, CASOKY got another grant, but this time for a demonstration operating grant under Section 18 of the Urban Mass Transit Act. This allowed it to undertake a demonstration transit project using two buses on a two point-deviation fixed route (CASOKY, 2013). A point-deviation is a system where buses would not necessarily follow a specific route but instead stop at designated bus stops, while performing intermittent passenger pick up and drop offs between stops (JETC, 2011).

Late 1994 saw the beginning of route service, and attempts at route design and experimentation took place. The two buses and two point-deviation fixed routes were still being used at this point. In early 1995, the initial routes were expanded and structured with a focus around high-demand areas while experimentation continued. Demand response was introduced around this time in addition to the existing service. The transit service operated a two-route (red and blue lines) schedule in 1999. By late 2001, five more buses were added bringing the number of buses to seven. The third and fourth routes (green and yellow) were added in 2001 and 2006, respectively, with only fixed routes being operated without the point-deviation service. In 2006, the transit service was re-branded as *GO bg* Transit. Since then, the *GO bg* service has implemented an additional route (purple line in 2009), making five routes in all. It also increased its fleet to 22 in 2014, with 20 being ADA accessible. This signifies the continued growth and expansion of the transit services.

The transit service runs on a fixed-route system on five color-coded bus routes, namely red, yellow, green, blue, and purple (Figure 3.7). The bus service operates from Monday through Friday between 7:00am to 6:00pm and the majority of the buses are wheelchair accessible. The service costs $2.00 per ride for adults (12 and older) and $1.00 for children (7-11 years). There are also price packages for students, senior citizens, and other groups to make the fare more affordable, as shown in their brochure in Figure 3.8 (CASOKY, 2013). Outside the regular bus service, the system also operates a specialized service for people with disabilities and provides other customized shuttles.

As of the 2011/2012 fiscal year, the service transported an average of 10,313 passengers per month, a drastic increase from a modest average of 2,594 in 2004. Indeed, statistics for an eight-year period indicate that the *GO bg* has seen steady growth in ridership from fiscal years 2003/2004 to 2011/2012 (Figure 3.9). Some of the main *GO bg* destinations include the Greenwood Mall, WKU, grocery and discount stores, doctors' offices, Greenview Hospital, the Medical Center, the Convention Center, and Downtown Bowling Green (CASOKY, 2013). As an added service, the *GO bg* transit has thirteen transfer stops spread across its network (Figure 3.7). These stops allow passengers to transfer from one route to another (Figure 3.10).

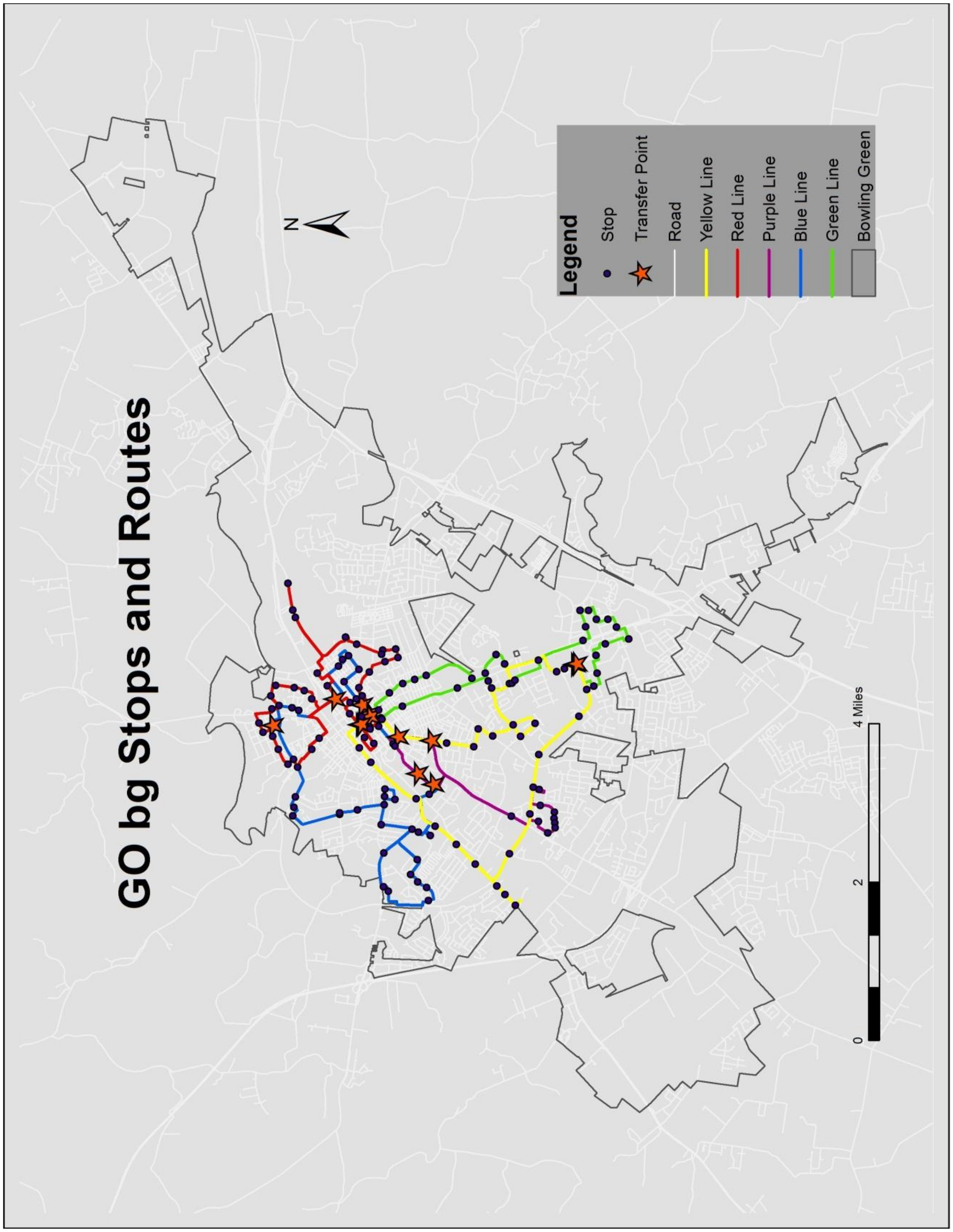


Figure 3.7: *GO bg* Bus Routes and Stops.
Source: CASOKY (2013).

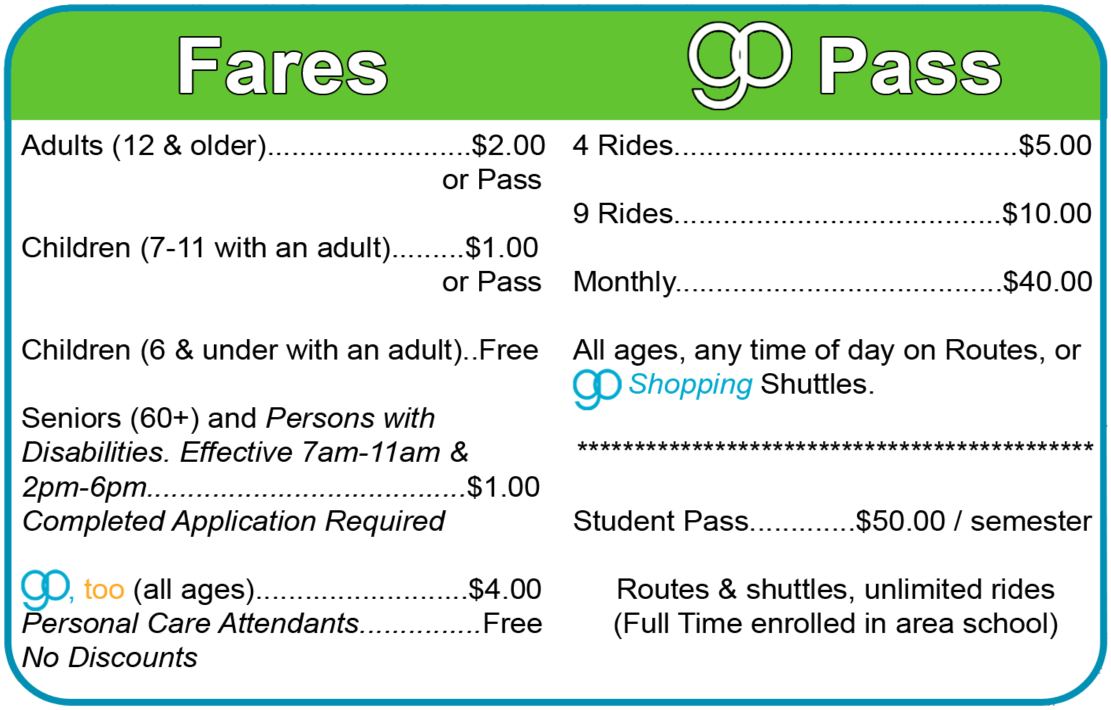


Figure 3.8: Bus Fares on *GO bg* Rides. Source: CASOKY (2013).

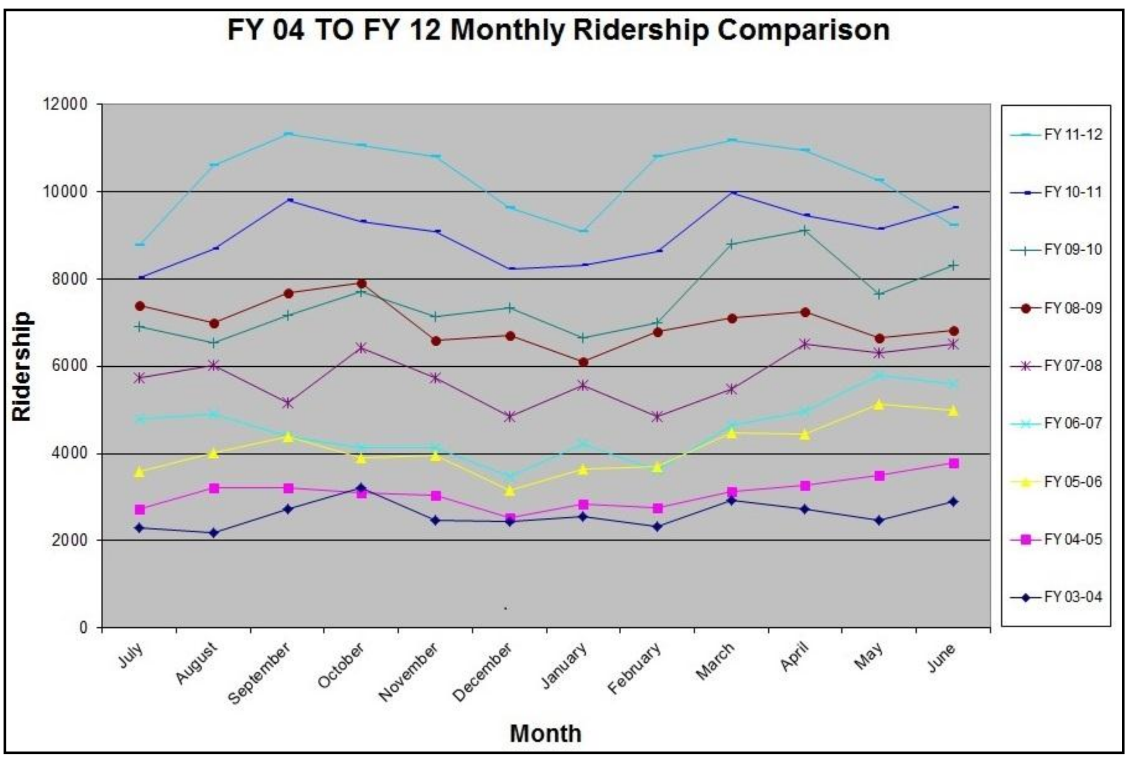


Figure 3.9: Monthly *GO bg* Ridership (2003/2004 – 2011/2012 Fiscal Years).
Source: CASOKY (2013).

Figure 3.10: *GO bg* transfer facility in downtown Bowling Green.
Source: Photo by Author.

CHAPTER 4: DATA AND METHODOLOGY

This study uses a combination of data from different sources with multiple GIS techniques. This chapter describes the datasets, data sources, and how data were processed, and then explains the steps and the techniques employed in Section 4.3.

4.1. Data Overview

Multiple data sources were used to complete the analysis for this project, including: 1) tabulations from U.S. Census data (2010a,b,c,d) Summary File 1 (SF1) and American Community Survey (ACS) five-year estimates (2006-2010); 2) 2010 TIGER/LINE datasets for the boundaries of census units and roads; 3) bus stops, bus routes and ridership data; and 4) the locations of main activity centers.

4.1.1. U.S. Census Data

The U.S. Census Bureau is a crucial source of the data used in this study. The datasets downloaded for this study include geographically defined boundaries and line features in the TIGER/LINE databases. Also used were demographic data for the study area. The census demographic datasets are from the 2010 Summary File 1 (SF1) tabulations. Another useful source of data would be the Census Summary File 3 (SF3) but, unfortunately, it was not available in the 2010 census data compilations. While the SF1 gives precise figures even for very small area clusters such as blocks, the SF 3 approximates for small groups and areas for example tracts and less precise small areas such as block groups and census tracts (U.S. Census, 2008). However, the SF3 samples social, economic, and housing data which are not contained in the SF1 tabulations particularly at a lower census tabulation level such as block groups. Due to the unavailability of SF3 in the 2010 Census, data such as household income were obtained from the ACS five-year estimates (2006-2010) at the census tract level instead. The ACS is a nationwide survey that has been designed to offer communities dependable and well-timed demographic, social, economic, and housing data annually. The ACS is supposed to take the place of the long-form sample (SF3) used in the 2000 census (U.S. Census, 2008). It would have been more ideal to obtain these data at the block-group level like the 2000 Census SF3. However, according to the U.S. Census (2008), using highly skilled personnel as well as permanent interviewers has led to a much enhanced and accurate ACS data relative to those from the decennial census long-form samples. There are some limitations in ACS data. According to the U.S Census (2008), ACS data users are faced with a major challenge of understanding and using estimates from multiple years and its associated confidence intervals, which are relatively large for smaller geographic area subgroups of the population.

The geographic boundaries and line features for Bowling Green including Warren County boundaries, block groups, blocks, tracks, and roads, were obtained in shapefile format from the U.S. Census Bureau's website (U.S. Census, 2010b). The demographic tabulations were downloaded at the block, block group, and tract levels to correspond with the geographic boundary files and they were obtained from the Census Bureau's (U.S. Census, 2010c) American Fact Finder website: (http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t). These tabulations included population totals, age composition, and race as shown in Figure 4.1. The data for households at various income levels were obtained from the ACS five-year aggregate (2006-2010) reports at the census tract level.

Table

BlkgrpRace

GEOID10	NAMELSAD10	POPULATION	NOT_HISP	HISPANIC	RACE_TOT	WHITE	BLACK	IND_ALASK	ASIAN
212270113003	Block Group 3	1261	1153	108	1261	1063	100	4	7
212270101001	Block Group 1	1525	1495	30	1525	1174	273	5	43
212270102003	Block Group 3	996	838	158	996	412	462	2	16
212270102002	Block Group 2	901	837	64	901	300	479	1	59
212270103004	Block Group 4	808	719	89	808	575	144	3	5
212270103001	Block Group 1	983	656	327	983	491	215	1	20
212270103003	Block Group 3	999	908	91	999	542	267	3	87
212270104001	Block Group 1	3338	3258	80	3338	2478	623	14	114
212270105001	Block Group 1	810	784	26	810	734	24	2	44
212270106002	Block Group 2	1141	1122	19	1141	1001	69	5	38
212270106003	Block Group 3	1377	1265	112	1377	1064	152	0	39
212270109005	Block Group 5	733	725	8	733	600	55	0	59
212270109003	Block Group 3	744	732	12	744	718	9	0	9
212270109001	Block Group 1	791	787	4	791	677	83	1	19
212270109004	Block Group 4	937	922	15	937	836	53	1	21
212270109002	Block Group 2	748	712	36	748	654	50	4	1
212270110012	Block Group 2	1275	1131	144	1275	894	165	8	91
212270112001	Block Group 1	1024	879	145	1024	550	353	0	20
212270114014	Block Group 4	796	782	14	796	772	6	0	9

70 (0 out of 74 Selected)

BlkgrpRace

.

Figure 4.1: Census SF1 Demographic Table at Block Group Level.
Source: U.S. Census (2010c).

4.1.2. Transit Data

The data used for the analysis also include bus routes, stops, and ridership obtained from CASOKY (2013). While it was convenient to obtain the ridership data in Microsoft Excel spreadsheet format, the same cannot be said of the routes and stops data. Having these data in a shapefile format would have made data processing much faster. Unfortunately, it was in a more descriptive rather than graphic format (Figure 4.2), hence further processing was needed.

	A	F	G	H	I	J	K	L	M
1	PUBLISHED STOPS								
2		FR		M	T	W	TH	FR	
3	*Mar-09*	6		9	10	11	12	13	
4									
5	C/O Transfer Pick-up	14		12	17	12	16	13	
6	C/O *Non* -Transfer Pick-up	1			2	2	2	1	
7	Payne & Main	4			1	3	3	2	
8	Woodford & Payne								
9	Woodford & Vine	1				1			
10	Vine & Glen Lily								
11	Pedigo Park								
12	Glen Lily & Stratford			1	4	2	2	1	
13	Collegeview & Glen Lily (Family Dollar)	1		2	1	2	6	1	
14	Family Dollar Transfer Pick Up	1							
15	Collegeview & Strathmoor						1		
16	Collegeview & Old Morgantown Rd	1		1	1	2		5	
17	S. Sunrise & Old Morgantown Rd							1	
18	S. Sunrise & Morgantown Rd	1			1	2			
19	Western Gateway (Roses/Houchens)	1		8	4	2	7		
20	Western Gateway (Roses/Houchens) transfer						2		
21	Highland Heights Mobile Hm Prk & BG Estates	4		4	1	1			
22	Russellville Road & Springhill	2							
23	Emmett & Russellville Rd	1							
24	Emmett & Industrial (Draughn's Jr College)	3		4	3	2	2	1	
25	WKU South Campus	2			2		4		
26	Daystar Village			1					
27	Lorie Village	1							

Figure 4.2: List of Bus Stops. Source: CASOKY (2013).

4.2. Data Processing

To get the data organized and ready for analysis, further processing was required. The transit stops and routes needed to be converted into shapefiles. In addition, demographic tabulation needed to be joined to their corresponding census units such as blocks, block groups and tracts. Figure 4.3 gives an overview of the workflow for data processing and analysis.

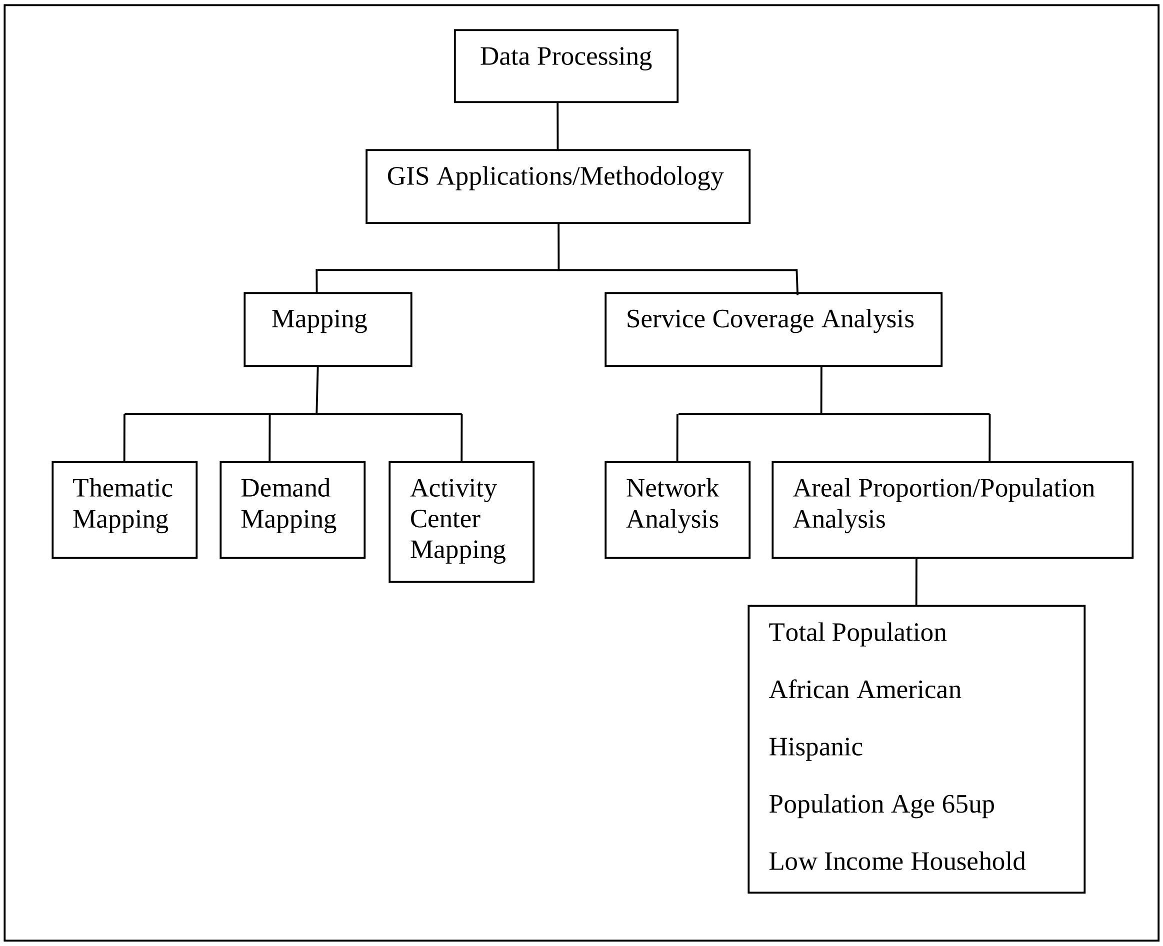


Figure 4.3: A Diagrammatic Workflow for Data Processing and Analysis.

4.2.1. Deriving Bus Stops and Route Data

CASOKY (2013) could not provide shapefiles for the bus stops and routes at the time when this project was started. As a result, the data had to be obtained via other options. We could simply guess the stop locations and routes from the descriptions of those places and routes, or ride each route and record its stops and route with a GPS unit. We could also virtually navigate the street network on a map and record geographic coordinates accordingly or digitize the bus stops and route directly from a brochure.

The fourth option, georeferencing and digitizing, was chosen for this study since it was less time-consuming and more cost-effective. The *GO bg* transit brochure was used to derive the needed information through georeferencing and digitizing. Georeferencing is simply a process of assigning a geographic reference to an image in order to define its existence in the physical geographic space. This step was necessary to ensure that the map on the brochure was positioned spatially so that features on the map can be located in the digital geographic space.

The georeferencing process requires an existing dataset containing the desired spatial reference, referred to as target data, which do not necessarily have to be in the same format as the raster data being georeferenced. The road shapefiles obtained from the U.S. Census were therefore used as the target data. In choosing target data it is important to ensure that there are identical and well-defined points in order to be consistent on both datasets (route image map and road data). This is necessary since the process requires identifying several ground control points (GCP) that link the locations on both datasets and may lead to errors if points are improperly identified. GCPs are known positions on the earth surface and they are used to geographically reference image data, for example scanned maps or satellite imageries (EC, 2008; USGS, 2013; ESRI, 2011a,b).

Georeferencing was accomplished using the Georeferencing tool in ArcGIS 10 Desktop. Further, the tool requires that the data being georeferenced must be in an image file format. Fortunately, the brochure was available in a PDF format on the CASOKY website at (http://www.casoky.org/storage/downloads/Transit/GOBG_Brochure.pdf). The PDF file was first converted to a .tiff file before inputting to the Georeferencing tool. Alternatively, should the brochure not be available in a soft copy it could be easily scanned and saved in an image-file format. Once the data aligned, the bus route and stops were then digitized into line and point shapefiles respectively (Figure 4.4).

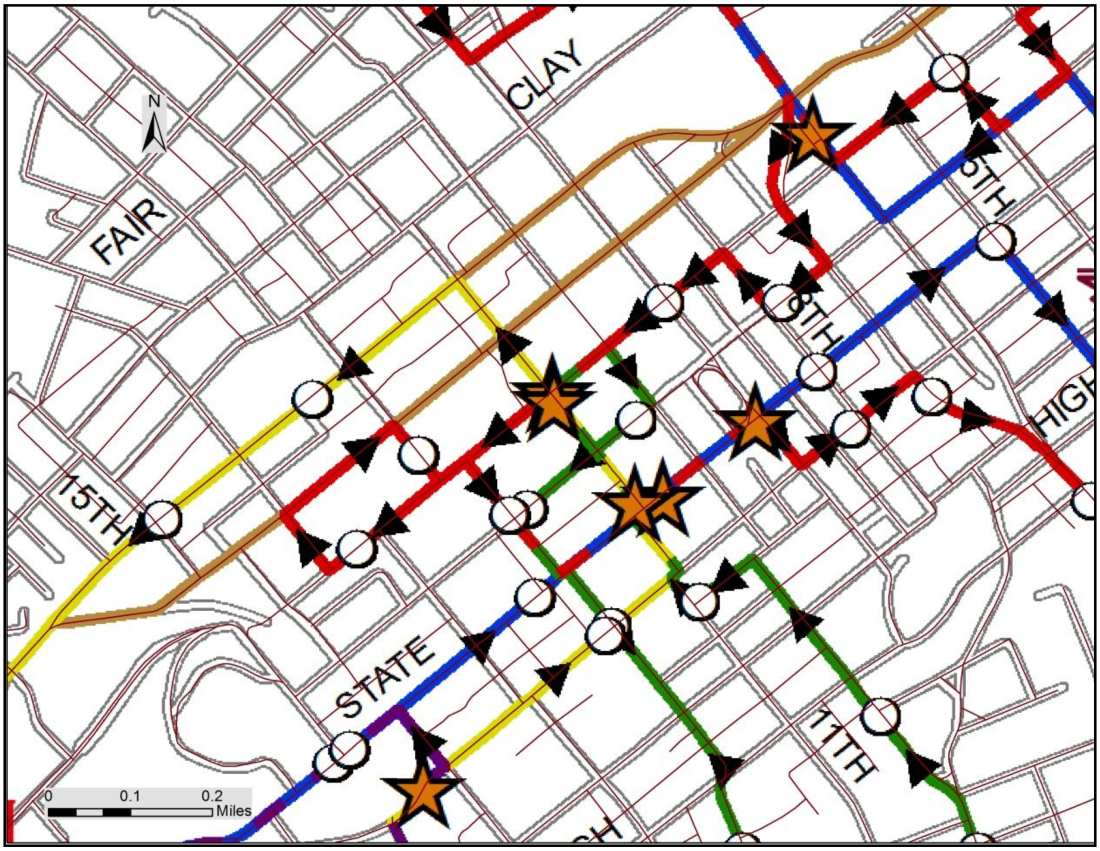


Figure 4.4: Aligned Bus Route and Road Map. Digitizing is done by digitally tracing the colored lines in a line shapefile for the bus routes, while the dots are digitized in a point shapefile. The stars represent transfer or connection points.
Source: Created by the author.

4.2.2. Census Data Manipulation

The demographic tabulations and geographic unit files were joined in ArcGIS 10 Desktop as well. Joining basically adds fields of one table to another through a common attribute field in both tables, known as a primary key. Although names of two primary key fields in both tables can be different, their data types must be the same. For instance, the fields containing census block IDs were used as the primary key for joining demographic data at the block level to the block features in this study. Once joining was completed, several choropleth maps were created, such as the maps showing the spatial distribution of total population, African Americans, Hispanics, low income households, populations age 65 and above, and general income distribution.

4.2.3. Deriving Activity Centers

The data for places that people normally visit for their basic socio-economic needs, such as health, shopping, education, and recreation, were used to demonstrate the accessibility options. Unfortunately there were no such data available in digital format for GIS use. To derive activities centers in the study area, several steps were taken including searching through Yellow Pages (YP, 2013) online to obtain the addresses of these places and then geocoding them. Geocoding is a procedure to convert data from one type of descriptive spatial reference information (e.g. street addresses) to geographic coordinates (e.g. longitudes and latitudes) so that descriptive geographic locations can be recognized in the digital geographic space. In this study, the geocoding was done via an online geocoding service (http://www.findlatitudeandlongitude.com/batch-geocode/#.Ux0xjoW_MqJ). Before geocoding, the address information of the main activity centers in the study area were manually entered and organized in an Excel spreadsheet.

4.3. Methods

To fulfill the research objective presented in Chapter 1, various tasks were completed to show the spatial distribution and the relationships among the variables under examination. The tasks include: 1) using choropleth maps to show the spatial distribution of Bowling Green population subgroups being assessed, including African Americans, Hispanics, people aged 65 or older, and low-income households; 2) allocating values to variables based on their importance to public transit ridership; 3) determining accessibility to bus transit within certain walking distance from bus stops; and 4) finding the location of activity centers. To complete these tasks, multiple techniques were used including thematic mapping, demand mapping, network analysis, intersect, and areal proportion.

4.3.1. Thematic Mapping

As the name suggests, thematic maps are those designed to show a particular theme associated with a designated geographic area. This is necessary to identify the distribution and concentration of population and households deemed essential to transit demand. These demographic characteristics were compiled mainly in the SF1 tables, while the household income data were from the ACS 5 year aggregate (2006-2010). By means of the natural breaks classification method, choropleth maps for Bowling Green were created to show total population, African American, Hispanic, population aged 65 and above, and low income households. Natural breaks classification is a type of data classification method that divides the values into a number of classes via an embedded histogram of the values.

4.3.2. Demand Mapping

There are several factors affecting who, when, and where an individual rides on a public transit system. These factors have different influences on public transportation ridership. Thus a person's income level, for instance, may determine his or her ability to either own a private car or look for public transportation as a means of travel. The demand analysis is an assessment of the spatial distribution of the factors considered significant transit-trip generators. This study used a "weighted method" to create a composite score of the relevant variables. Thus scores were assigned to each variable.

To achieve this, the values of each variable, including Bowling Green's population density, population aged 65 and up, African Americans, Hispanics, and the population below poverty, were first sorted into classes. Using the natural break classification method, four break values were applied to show four different levels of the original values. New scores were then assigned to each of the four classes accordingly (Figure 4.5). High scores were assigned to classes with high original values (potentially high transit demand), with the low scores going to classes with low values (low demand). In addition variables with greater importance to public transit were assigned higher scores. The four classes of population below poverty were assigned relatively higher scores, as shown in Figure 4.5, because people from low-income households usually have high transit ridership. All these scores were then aggregated and subsequently mapped. It is expected that areas with high overall scores should be associated with a high demand for transit service.

In an analysis of the 2001 National Household Travel Survey (NHTS), Pucher and Renne (2003) found that households with annual incomes less than $20,000 made an average of 3.2 trips per person, per day in 2001, relative to households earning over $100,000 who made 4.8 trips per day. Higher income households also made longer per-person trips at 31.8 miles daily, almost twice the total trip length of a typical low-income household (17.9 miles). These statistics to a large extent underscore the importance of income to transit demand.

Population Density	5= 7549 - 14723	Age 65 and Up	5= 178 - 351
	4= 3385 - 7548		4= 94 - 177
	3= 1374 - 3384		3= 28 - 93
	2= 0 - 1373		2= 0 - 27
African-American	5= 354 - 623	Income Below Poverty	20= 1198 - 2188
	4= 193 - 353		15= 737 - 1197
	3= 70 - 192		10= 248 - 736
	2= 0 - 69		5= 0 - 247
Hispanic	5= 182 - 327		
	4= 94 - 181		
	3= 38 - 93		
	2= 0 - 37		

Figure 4.5: New scores assigned to the variable being analyzed. This was done at block group level except for the population with income below poverty which is at the census tracts level. Source: Created by the author.

4.3.3. Mapping Activity Centers

The activity centers are where people are expected to visit regularly and they were mapped and displayed as points in this study. The activity centers were also overlain on the service area map in order to relate the locations of these places to the proximity of bus stops in terms of walking distance. These activity centers were grouped into themes and mapped separately to reduce cluttering on the map. The themes include healthcare, grocery, recreation, and other points of interest.

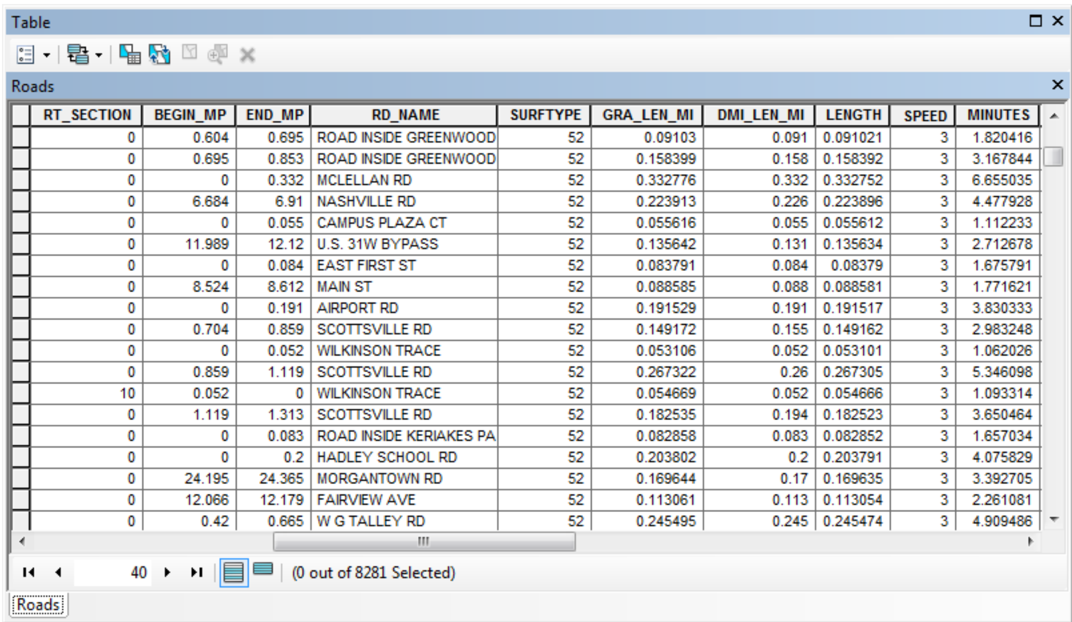
4.3.4. Service Coverage Analysis

To further assess the accessibility of *GO bg* transit service, a service-area analysis was conducted to examine the coverage of potential transit catchment areas from the bus stops. A number of GIS techniques, namely network analysis, intersect, and areal proportion, were used to estimate the number of people within certain walking distance from the transit stops. The distances were measured in terms of walking time and three critical time values were used, including five, seven, and ten minutes.

4.3.4.1. Network analysis

To identify the population being served within a certain distance from a bus stop, network analysis was first used to create a service (or catchment) area. This is a common GIS approach used in transit analysis. Since pedestrians utilize sidewalks and sidewalks are often constructed along street networks, using the street network for computing walking distances would yield similar results. A recent survey of the *GO bg* riders by the Corradino Group Inc. (2010) indicated that most people, about 74.4%, walked to a bus stop.

A service area can be created using the Network Analyst Extension in ArcGIS 10 for Desktop (ESRI, 2011a). The extension computes and creates a region based on all accessible streets within specified impedances. This study used time (in minutes) instead of length as the impedance. In order to estimate walking time along road segments, road segment length and walking speed were added to the road shapefiles. An average walking speed of three mph was used based on the estimated National Personal Transportation Survey average speed of 3.16 mph (Ewing, 1999) and Naismith's Rule, which states that one should "Allow one hour for every three miles forward and half an hour for every 1,000 feet of ascent" (BBC MMII, 2008). William Naismith developed the "Naismith" rule in 1892, and it is generally used as a rule of thumb to calculate walking time from one point to another (Wild Walks, 2012). We need to point out here that the average walking speed of three mph used in this study is simply a general representation of how an average person may walk under normal conditions. Many other factors, such as the topology of the study area, were not considered in this study. With a three mph walking speed, it takes about ten minutes to walk one half of a mile and five minutes to walk a quarter mile. The walking time (minutes) that it takes to traverse each road segment was hence computed using the formula: (minutes = distance / speed * 60). Notice that walking time is measured in minutes and thus the formula is multiplied by sixty (minutes) to convert the time in hours into minutes (In theory, any cost attribute can be used as impedance). The distance breaks of five, seven, and ten minutes were used to generate three service areas (transit catchment areas) from all bus stops respectively.



Table

Roads

RT_SECTION	BEGIN_MP	END_MP	RD_NAME	SURFTYPE	GRA_LEN_MI	DMI_LEN_MI	LENGTH	SPEED	MINUTES
0	0.604	0.695	ROAD INSIDE GREENWOOD	52	0.09103	0.091	0.091021	3	1.820416
0	0.695	0.853	ROAD INSIDE GREENWOOD	52	0.158399	0.158	0.158392	3	3.167844
0	0	0.332	MCLELLAN RD	52	0.332776	0.332	0.332752	3	6.655035
0	6.684	6.91	NASHVILLE RD	52	0.223913	0.226	0.223896	3	4.477928
0	0	0.055	CAMPUS PLAZA CT	52	0.055616	0.055	0.055612	3	1.112233
0	11.989	12.12	U.S. 31W BYPASS	52	0.135642	0.131	0.135634	3	2.712678
0	0	0.084	EAST FIRST ST	52	0.083791	0.084	0.08379	3	1.675791
0	8.524	8.612	MAIN ST	52	0.088585	0.088	0.088581	3	1.771621
0	0	0.191	AIRPORT RD	52	0.191529	0.191	0.191517	3	3.830333
0	0.704	0.859	SCOTTSVILLE RD	52	0.149172	0.155	0.149162	3	2.983248
0	0	0.052	WILKINSON TRACE	52	0.053106	0.052	0.053101	3	1.062026
0	0.859	1.119	SCOTTSVILLE RD	52	0.267322	0.26	0.267305	3	5.346098
10	0.052	0	WILKINSON TRACE	52	0.054669	0.052	0.054666	3	1.093314
0	1.119	1.313	SCOTTSVILLE RD	52	0.182535	0.194	0.182523	3	3.650464
0	0	0.083	ROAD INSIDE KERIAKES PA	52	0.082858	0.083	0.082852	3	1.657034
0	0	0.2	HADLEY SCHOOL RD	52	0.203802	0.2	0.203791	3	4.075829
0	24.195	24.365	MORGANTOWN RD	52	0.169644	0.17	0.169635	3	3.392705
0	12.066	12.179	FAIRVIEW AVE	52	0.113061	0.113	0.113054	3	2.261081
0	0.42	0.665	W G TALLEY RD	52	0.245495	0.245	0.245474	3	4.909486

40 (0 out of 8281 Selected)

Roads

Figure 4.6: Additional Attributes Added to Roads Shapefiles (length, speed, and minutes). Source: Compiled by the author.

4.3.4.2. Areal proportion

The service areas created were then used as a catchment area to identify the number of people living within each service area and determine the level of access to the bus stops via a procedure called areal proportion. Areal proportion is possible as we must assume that the population is evenly distributed within a census unit, such as blocks and block groups. It is necessary to point out beforehand that this can be a problem when dealing with vast areas with sparse and skewed populations, as it could lead to a

Modifiable Areal Unit Problem (MAUP), one of the main limitations of spatial analysis when dealing with data at aggregated units such as census blocks or tracts (Gatrell et al., 1996; Openshaw and Taylor, 1979). Two components of MAUP have been identified: namely scale effect and zonal effect (Armhein, 1993). The scale effect arises when different results are attained due to variations in the scale of aggregation units, while zonal effects occur when a constant scale of analysis is used with a variation in the shape of aggregation units. I had to contend with the issues of scale effect particularly in the case of the income distribution, where data were only available at the census tract level, This is at a larger scale than desired but these were the only data available in the ACS five-year aggregate report for the study area.

To complete areal proportion analysis, several tasks were conducted in sequence. First an intersect operation was conducted between each of the walking distance zones (e.g., five-minute service area) and census polygons. An intersect is a GIS operation that computes the geometric intersection of input features (the three walking distance zones and census layers) and write all overlapping portions of the features to an output feature (ESRI, 2011b). After the intersect operation, it is now possible to estimate the population within the specified intersected polygons. The following formula was used:

$$NPop = \frac{Pop \times NArea}{Area}$$

where: *NPop* is the population (or the population of an intended subgroup, e.g. African American) to be estimated for the newly created polygon; *Pop* is the population (or the population of an intended subgroup) of the original census polygon; *NArea* is the size of a newly created polygon resulting from the intersect operation and *Area* is the original area size of the original census polygon.

CHAPTER 5: RESULTS AND DISCUSSION

This chapter presents the findings from the analysis and their significance. The chapter is organized into four sections: Spatial Distribution of Transit Demand, Weighted Transit Demand, Service Area Analysis, and Accessibility from *GO bg*.

5.1 Spatial Distribution of Transit Demand

To understand transit demand, first we need to analyze the spatial distribution of the population in Bowling Green. Areas around WKU, the north-central districts, and around the south and west of the city have a relatively higher concentration of people as shown in Figure 5.1. In addition to the overall population distribution, it is also important to understand the sources of demand for transit services. Identifying these conditions is essential to ascertaining the coverage of the *GO bg* services, as various segment of the population tend to have different levels of transit demand. To achieve this, maps showing the spatial distribution of a few population subgroups vital to public-transit ridership were produced, including African Americans, Hispanics, persons aged 65 and above, and persons below poverty. As shown in Figure 5.2, African Americans are mainly concentrated to the north of the study area, Hispanics heavily populate the north-west of the city, as shown in Figure 5.3, while the population aged 65 and above is mostly found in the south-central and north-central part of the study area (Figure 5.4).

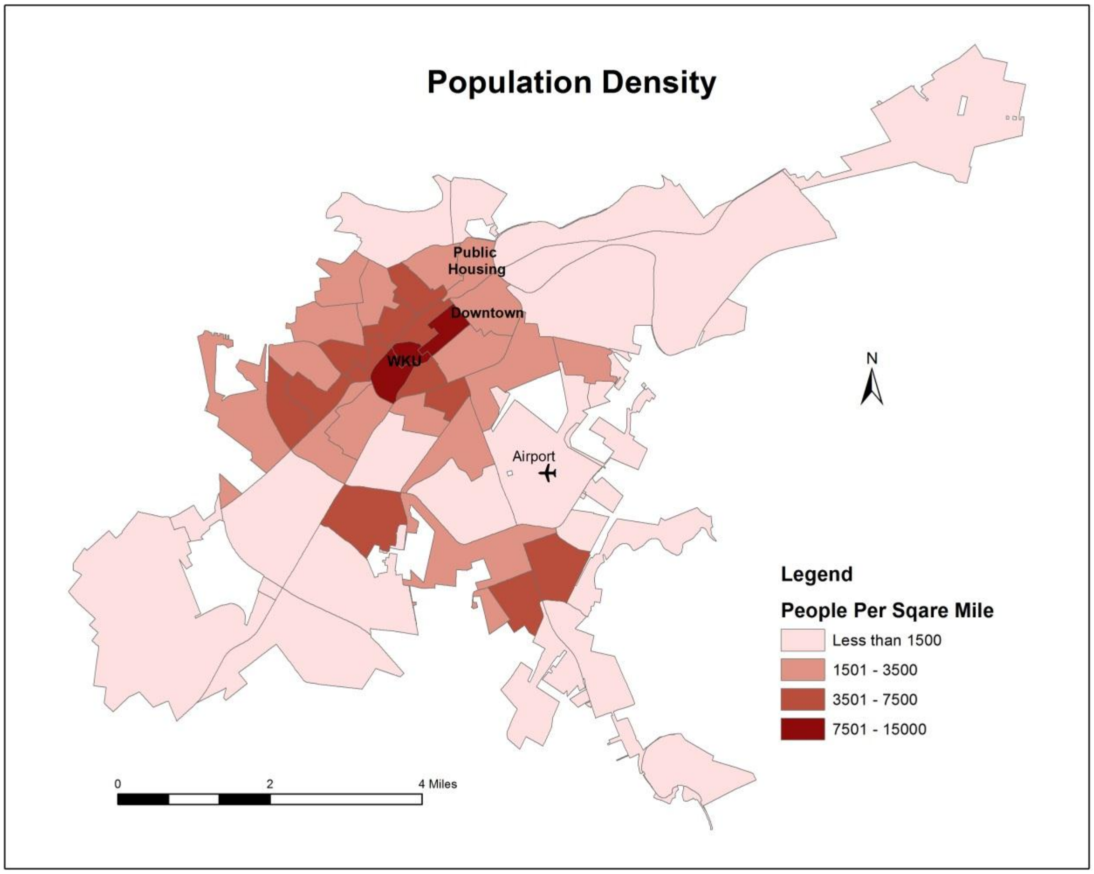


Figure 5.1: Population Density at Block Group Level. The highest density occurs around WKU in the north-central of the city. Source: U.S. Census (2010c).

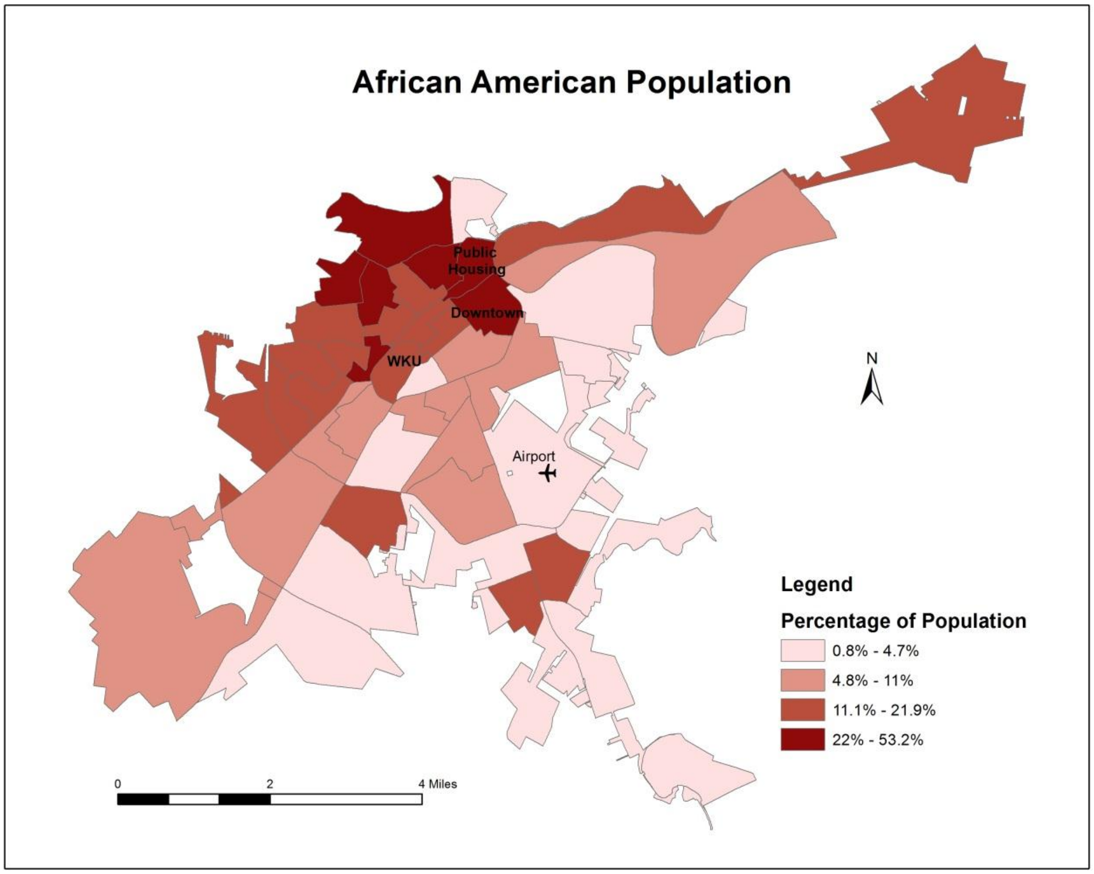


Figure 5.2: Spatial Distribution of African Americans at Block Group Level. Data Source: U.S. Census (2010c).

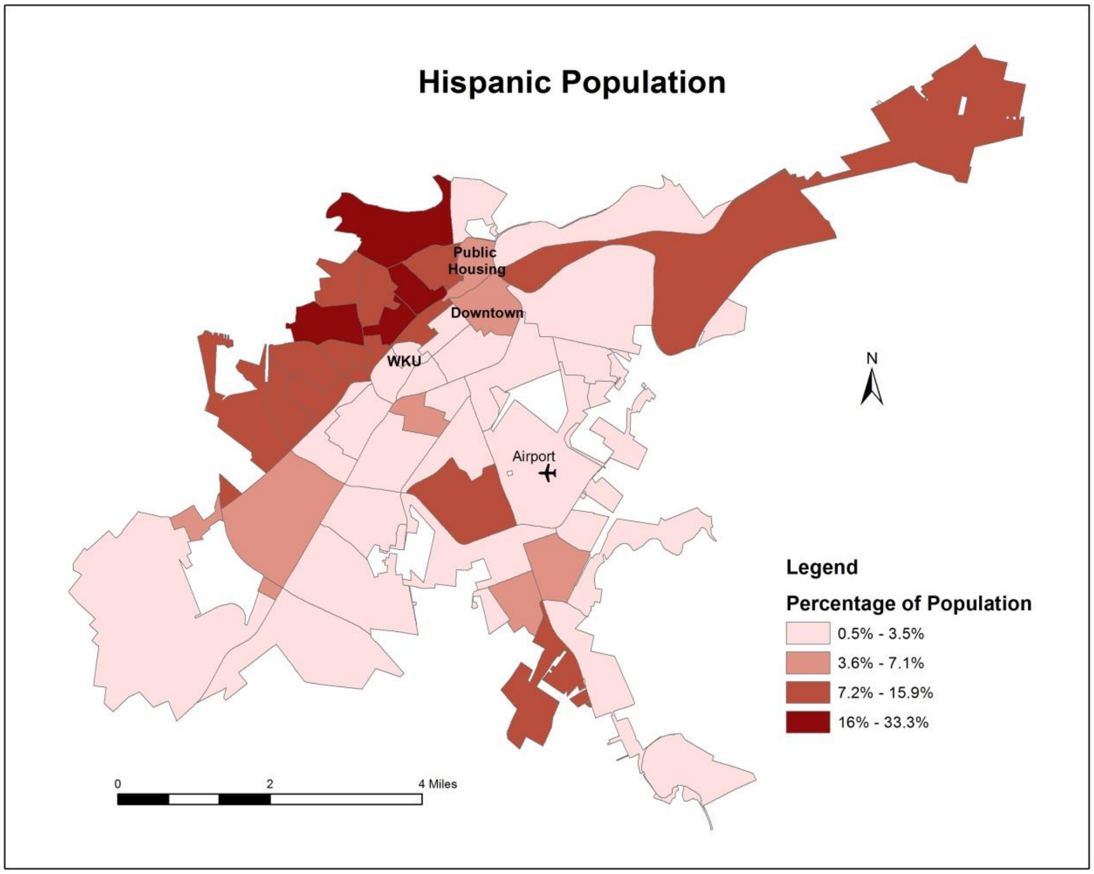


Figure 5.3: Spatial Distribution of Hispanics at Block Group Level.
Source: U.S. Census (2010c).

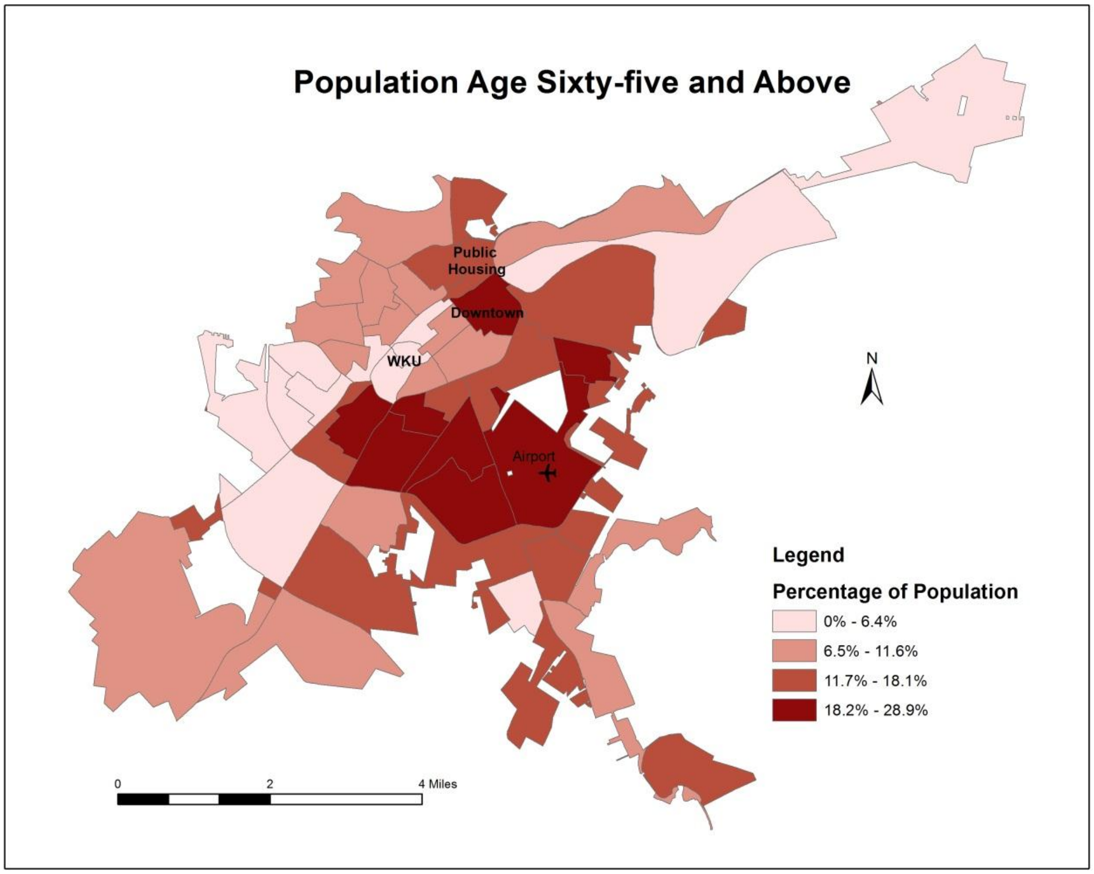


Figure 5.4: Spatial Distribution of Population Age 65 and Above at Block Group Level. Source: U.S. Census (2010c).

The populations below the federal poverty line are mainly concentrated in the north and north-west sectors of Bowling Green where federally-subsidized housing is also located. It is worth pointing out that Figures 5.2 and 5.3 have a notable similarity to Figure 5.5. It is, unfortunately, the reality in the U.S. that poverty and low-income communities are often associated with minority groups, particularly African Americans and Hispanics (Holzer and Stoll, 2007). This is perhaps the reason why several studies have found these two minority groups to account for disproportionately greater percentages of public transit ridership.

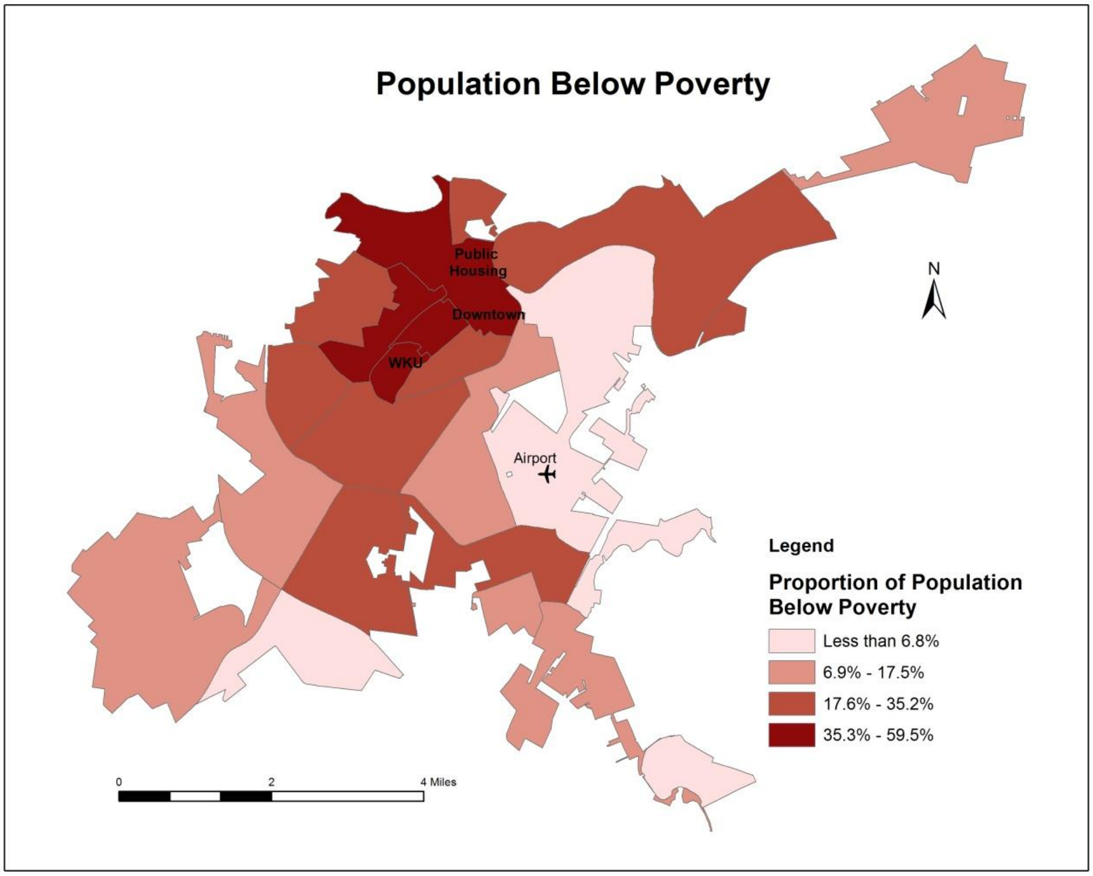


Figure 5.5: Spatial Distribution of Population below Poverty at Census Tract Level. Source: U.S. Census (2010d).

The land-use map (Figure 5.6) shows the likely location of businesses and industries where residents normally commute to work. The map only shows the portion of land uses overlain with those five *GO bg* bus routes. It can be seen that the central business district, general business district, and commercial office/professional areas are generally well serviced by the *GO bg* transit system. The highway business district, light industrial district, and heavy industrial district are only serviced by the transit in the busiest parts of the city, while those in the outlying areas to the north-east and south-west do not have any coverage. Although potentially those may be the areas that need to be covered, it might not be economically viable to expand to those regions of the city as yet. This is not to suggest that the *GO bg* transit operates for profit, but that it could be financially more draining to extend service to these areas. However, if these are active job centers with demand for transit services, then extending the transit service to these areas should be considered.

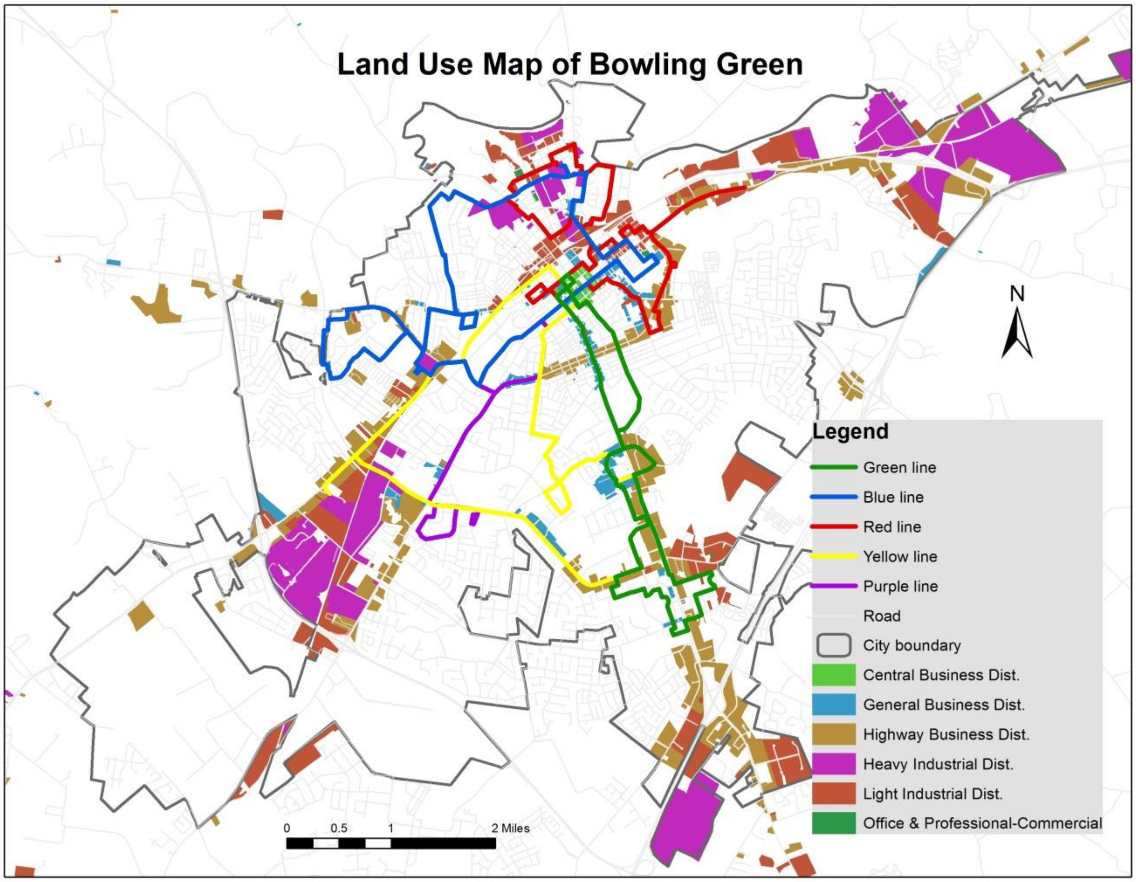


Figure 5.6: Land Use of Bowling Green Overlaid with Transit Route.
Source: CASOKY (2013); WCPC (2009).

5.2 Weighted Transit Demand

Figure 5.7 shows the aggregate scores from weighted transit demand analysis, on top of which are overlain the bus routes and stops. The areas with red shades indicate the priority areas for bus service, since those places have the highest total scores. Understandably, the maps shows a lot of similarity to the spatial distribution of population density in Figure 5.1 and the population below poverty in Figure 5.5, with the highest concentration found around the college district in north-central Bowling Green around the vicinity of WKU. An overlay of the bus routes shows that areas with high scores indeed have one or more routes passing through their vicinity. To give added credence to this, most of the areas with high demand scores are indeed within five minutes walking distance to the transit stops, as shown in Figure 5.8.

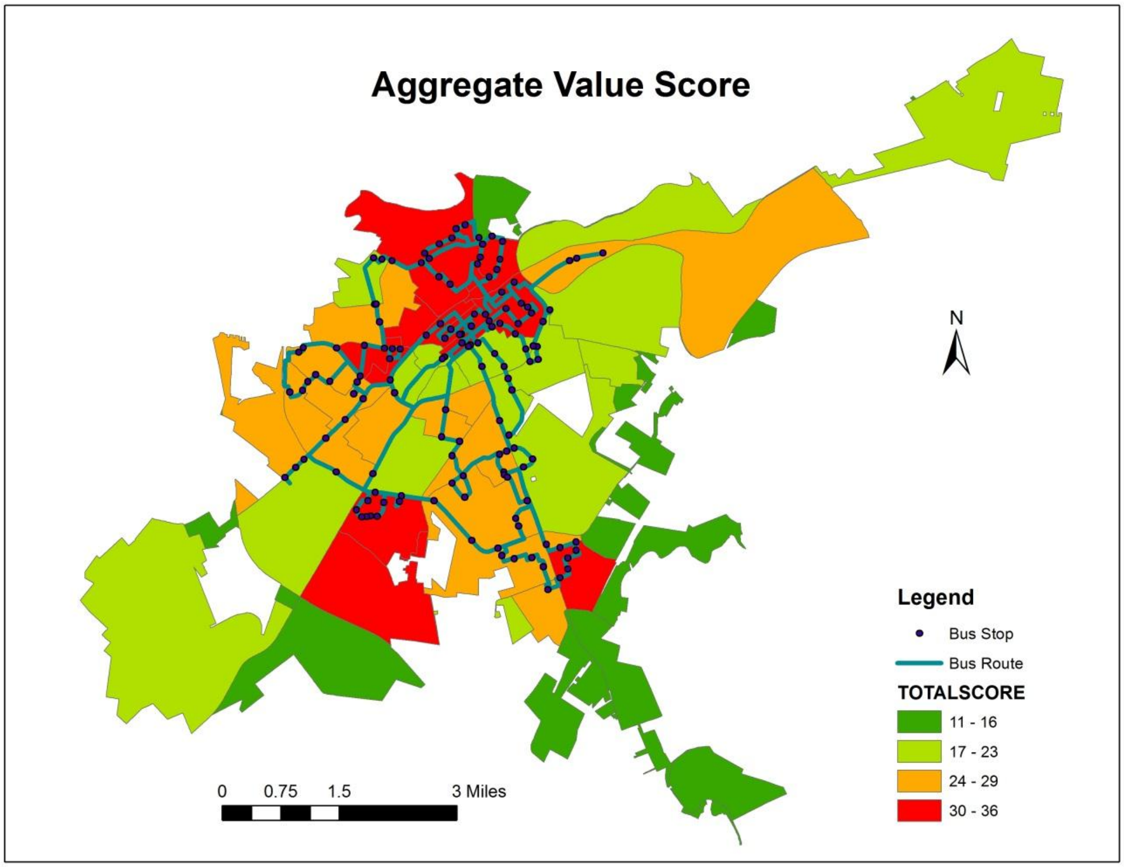


Figure 5.7: Aggregated Transit Demand Scores.
Source: U.S. Census (2010c; 2010d); CASOKY (2013).

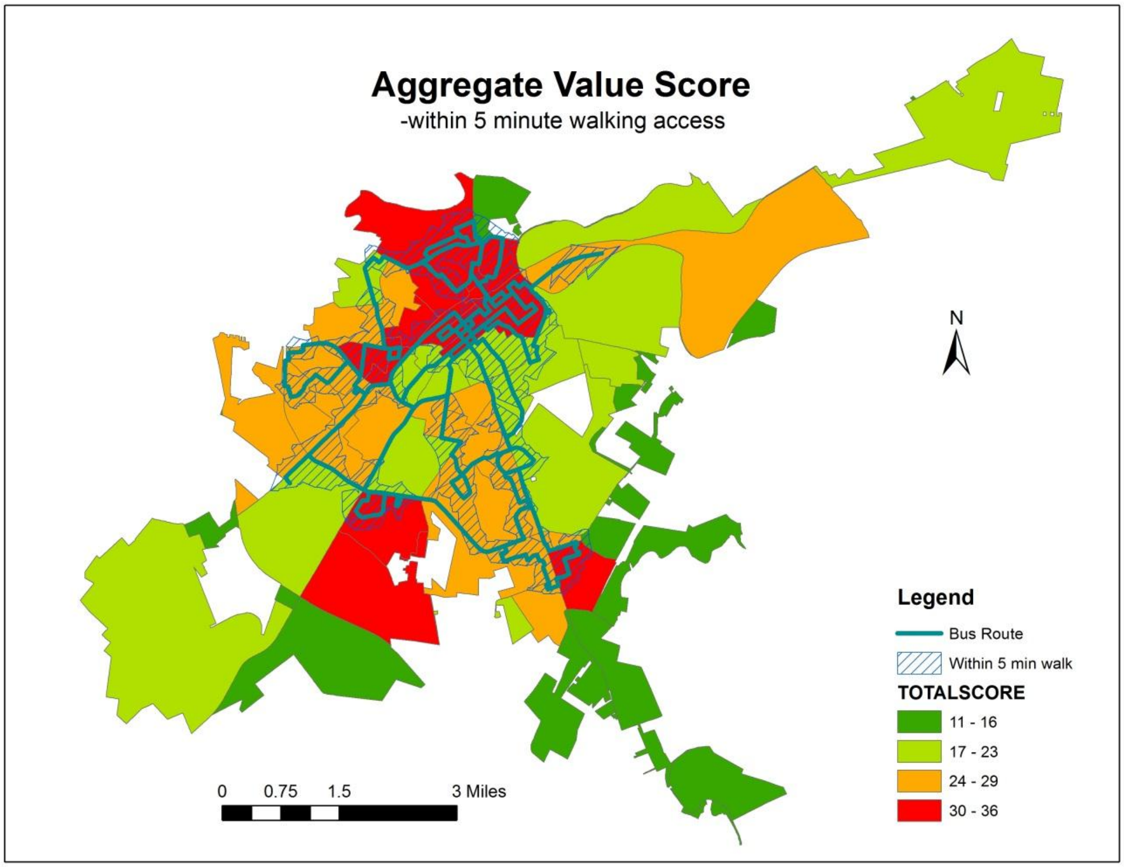


Figure 5.8: Aggregated Transit Demand Scores Overlaid with Five-Minute Walk Distance Zone. Source: U.S. Census (2010c; 2010d); CASOKY (2013).

5.3 Service Area Analysis

The map in Figure 5.9 show the five-minute, seven-minute, and ten-minute walking distance zones from the *GO bg* bus stops. As shown in Figure 5.9, a considerable portion of Bowling Green is fairly well covered, especially the main residential and commercial areas. Overall, about 40% of the total population is within the five-minute access zone to a bus stop, and 68.5% is within a ten-minutes walking distance (Figure 5.10 and Table 5.1).

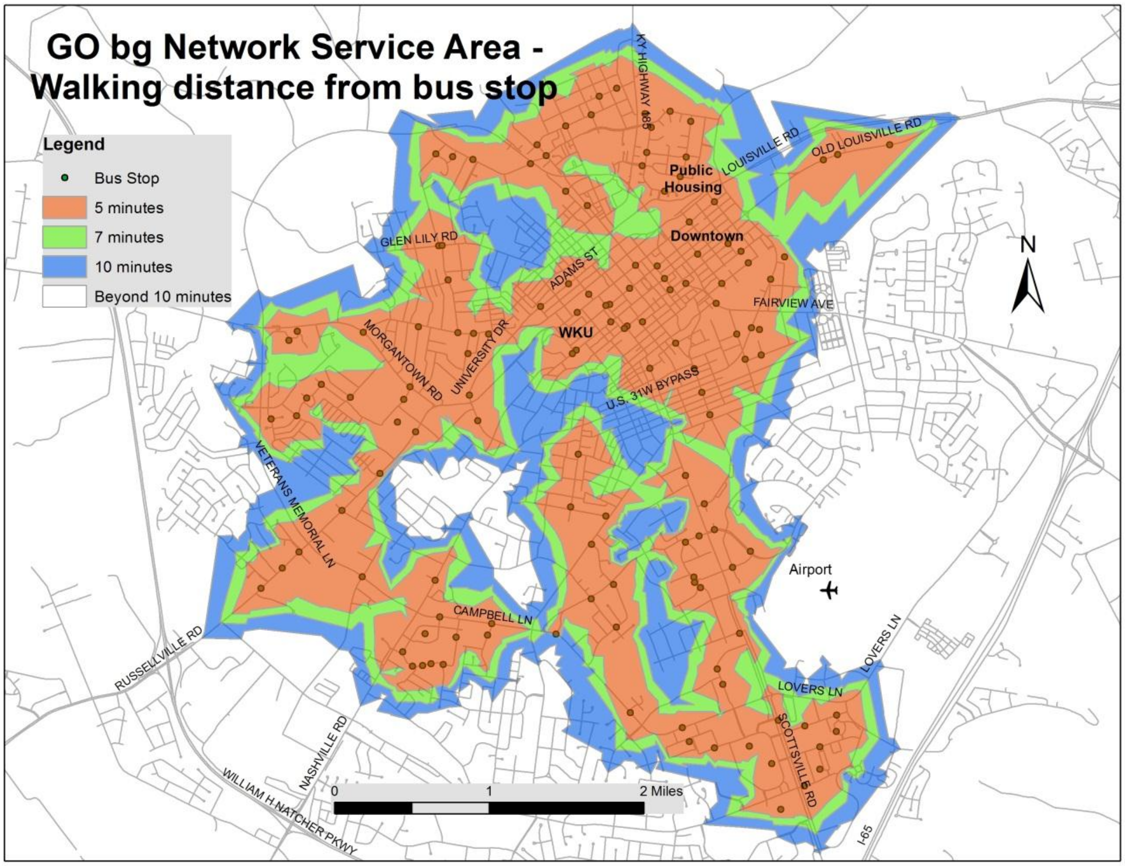


Figure 5.9: Walking Distance Zones.
Source: U.S. Census (2010c; 2010d); CASOKY (2013).

Table 5.1 shows the numbers and percentages of people covered for all populations as well as for each demographic group. More than half, 55.3%, of the African Americans and about 46.3% of Hispanics, can access the transit service within five minutes. This is crucial as both races have been linked to high public-transit ridership use, particularly the bus mode, constituting up to 62% of all bus riders in the U.S. (Pucher and Renne, 2003). Within seven minutes, higher percentages in both groups have access to *GO bg* transit, at 70.1% and 64.8% for African Americans and Hispanics respectively.

Walking Time Analysis								
	Total	Within 5 min.		Within 7 min.		Within 10 min.	
Population	58,067	23,278	40.1%	31,699	54.6%	39,754	68.5%
African- American	8,071	4,460	55.3%	5,658	70.1%	6,671	82.7%
Hispanic	3,749	1,737	46.3%	2,431	64.8%	2,907	77.5
Pop. Age 65 and Above	6,223	2,162	34.7%	2,907	46.7%	3,818	61.4%
Pop. Below Poverty (Includes All Population)	11,684	5,531	47.3%	7,067	60.5%	8,581	73.4%

Table 5.1: *GO bg* Service Coverage and Population Analysis.
Source: U.S. Census (2010c; 2010d); CASOKY (2013).

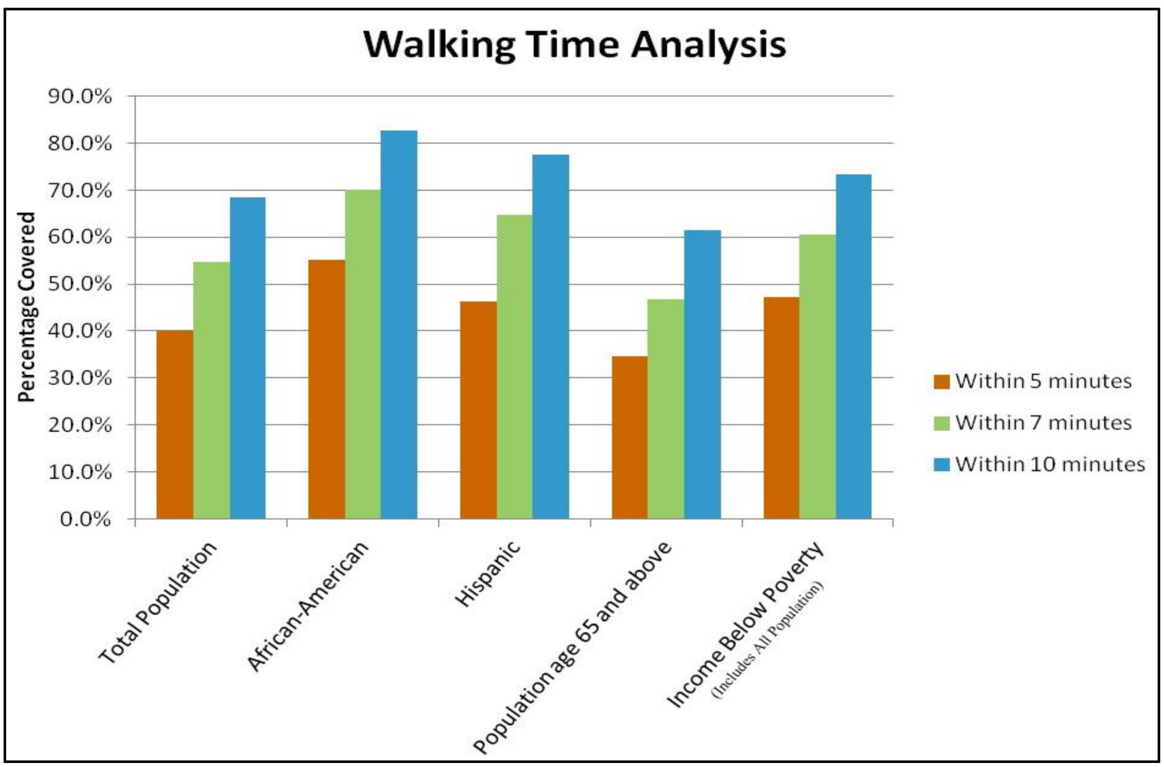


Figure 5.10: Percentage of Total Population Covered within Walking Distance Zones.
Source: US Census (2010c; 2010d); CASOKY (2013).

GO bg service coverage for seniors was not as good as the other population sub-groups examined. Only about 34.7% of the population aged 65 and above is within a five-minute walk of a bus stop. Studies have shown enormous variations in mobility for the elderly. Elderly populations between ages 65 to 69 travel more miles than those aged 89 and above. Studies have found that the elderly depend on automobiles nearly 90% of the time, which constitutes a higher rate than any age group and about three percent more than the general population (Pucher and Renne, 2003). That is to say, a majority of the population age 65 and above is more likely to depend on automobiles for travels in the study area than in less auto-dependent cities. Moreover, the spatial distribution of this population (Figure 5.4) shows that the majority do not fall within the same area as the population below poverty, suggesting that they might have a relatively higher income. Therefore, the percentage covered within five minutes walk is reasonable. Lastly, having the population below the poverty line living within reasonable access to public transit is crucial for their livelihoods. About 47.3% and 60.5% of the population below the poverty line are within five-minute and seven-minute walking distances respectively to a *GO bg* bus stops.

5.4 *GO bg* and Accessibility

In evaluating a transit system, it is imperative to examine its effectiveness in delivering passengers to amenities and activities that transit patrons desire to reach. Some of the locations considered as key transit-trip generators include health centers, educational institutions, shopping centers, employment centers, and government/ community centers (MST, 2010). The spatial distribution of major health facilities within

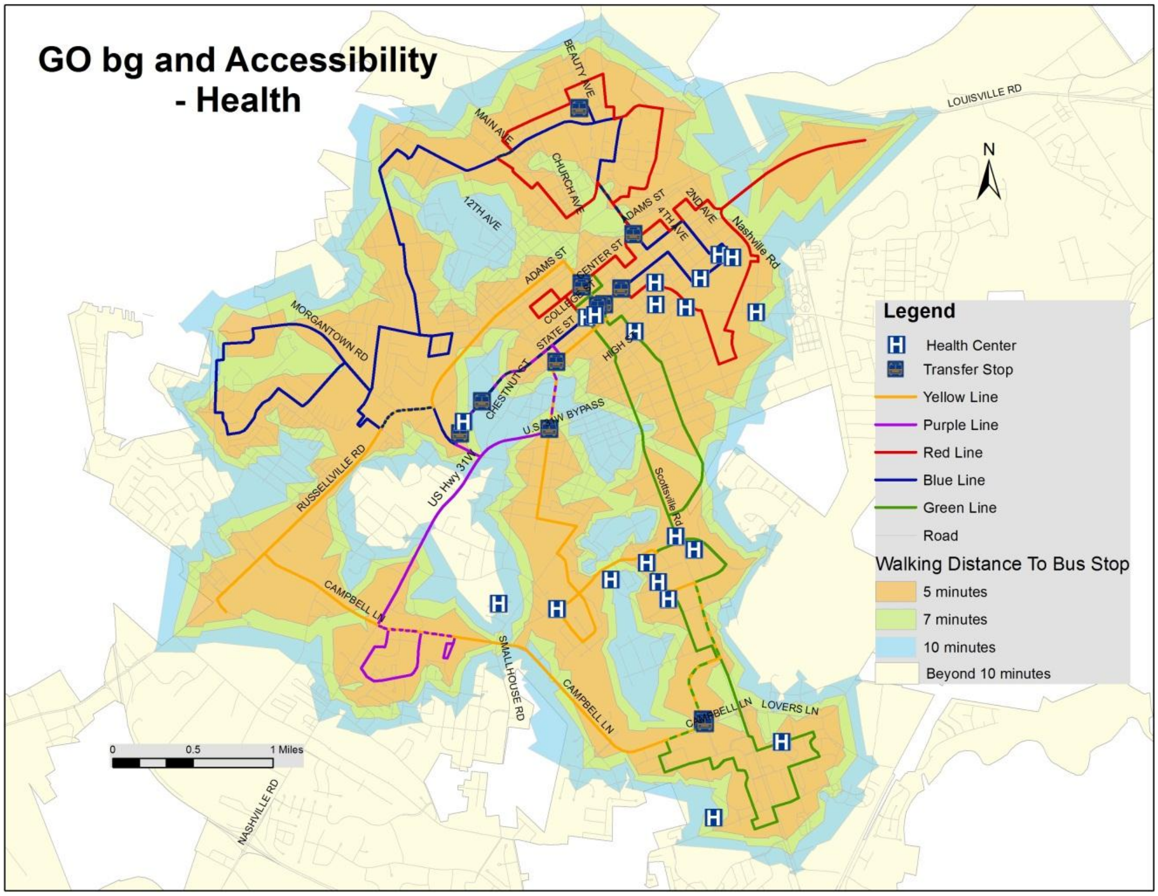


Figure 5.11: Accessibility to Major Health Centers.
Source: U.S. Census (2010c); CASOKY (2013).

the city shows that the majority of them are located to the east and south of Bowling Green, and most of them are within a five-minute walk of a transit stop (Figure 5.11). Figure 5.11 show that different routes serve the various facilities across the city. As a result, although one may have direct access to a certain transit route, riders would have to switch over to another route en route to their destinations. This is where transfer points become vital within a transit system. A bus transfer point allows passengers to switch routes at designated places. While the Medical Center of Bowling Green is only serviced by the Blue line, people whose journey to that facility originates from locations served by the other routes can transfer to the Blue line in order to reach the Medical Center. The other notable health facilities within the city include Greenview Regional Hospital, Bowling Green Medical Clinic, Western KY Diagnostic Imaging, WKU Health Services, and Fairview Community Health Center. As Figure 5.11 shows, all the above mentioned health facilities are all within a five-minute walk from a *GO bg* transit stop. It is also worth pointing out that people who live in the north and west of the city are likely to make longer trips when visiting one of the major health facilities, as a result of the spatial distance away from these facilities as well as the number of transfers that may be involved.

Some of the main grocery stores in the study area include Wal-Mart, Kroger, ALDI, IGA, Save-A-Lot, and Dollar General. Figure 5.12 shows the distribution of grocery stores across the city. Unlike health-care facilities, grocery stores show a more balanced distribution throughout the city. The GO bg transit service has at least one route directly leading to a main grocery store. This means less travel is involved for grocery shopping. Figure 5.12 also shows that most of the major grocery stores are within the five-minute walking zone.

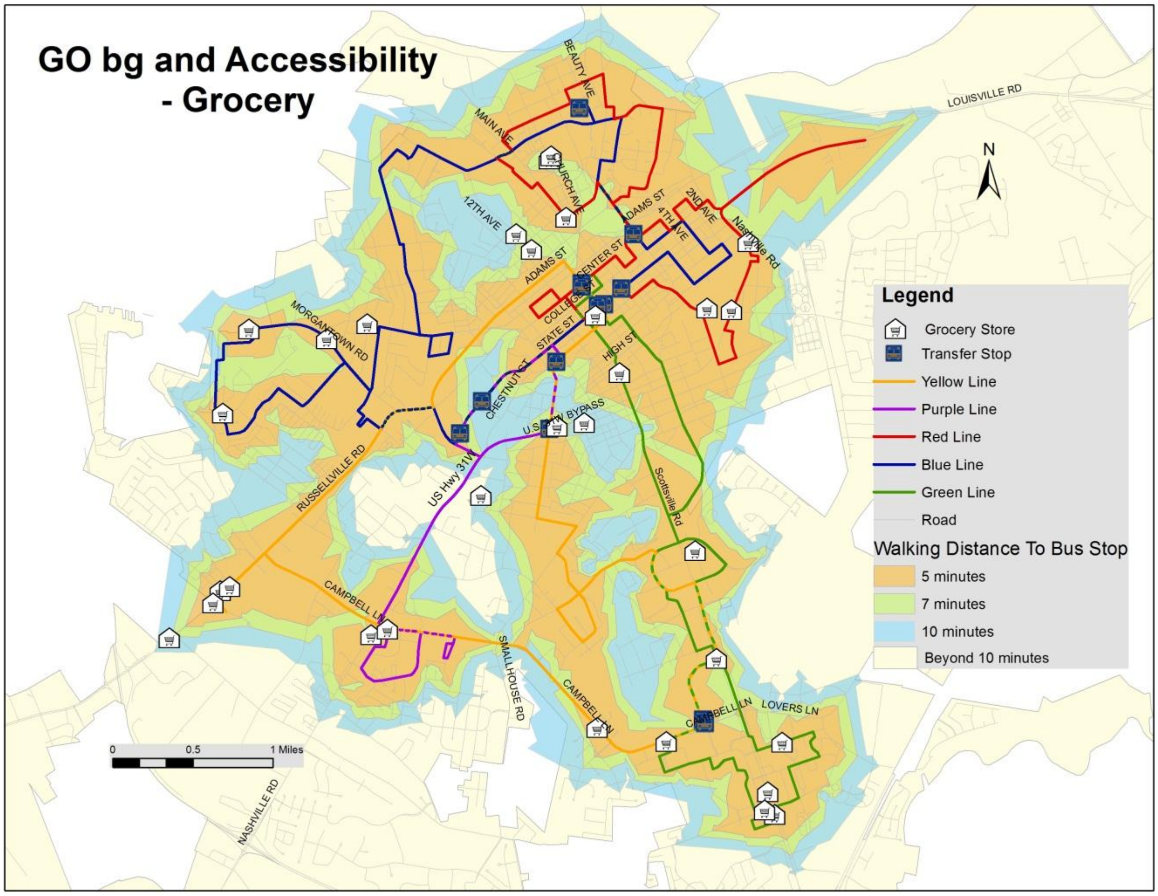


Figure 5.12: Accessibility to Grocery Stores.
Source: U.S. Census (2010c); CASOKY (2013).

General shopping is another theme discussed in this section and this includes the major department stores (Figure 5.13). The map also indicates that the majority of these stores are located towards the southern part of Bowling Green. With the exception of Sam's Club, the rest are within a five-minute walk from a transit stop. Again, as noted in the earlier discussion, people coming from the northern region would have to transfer in order to reach their destinations. They are likely to spend a longer time travelling than those living in the southern portion.

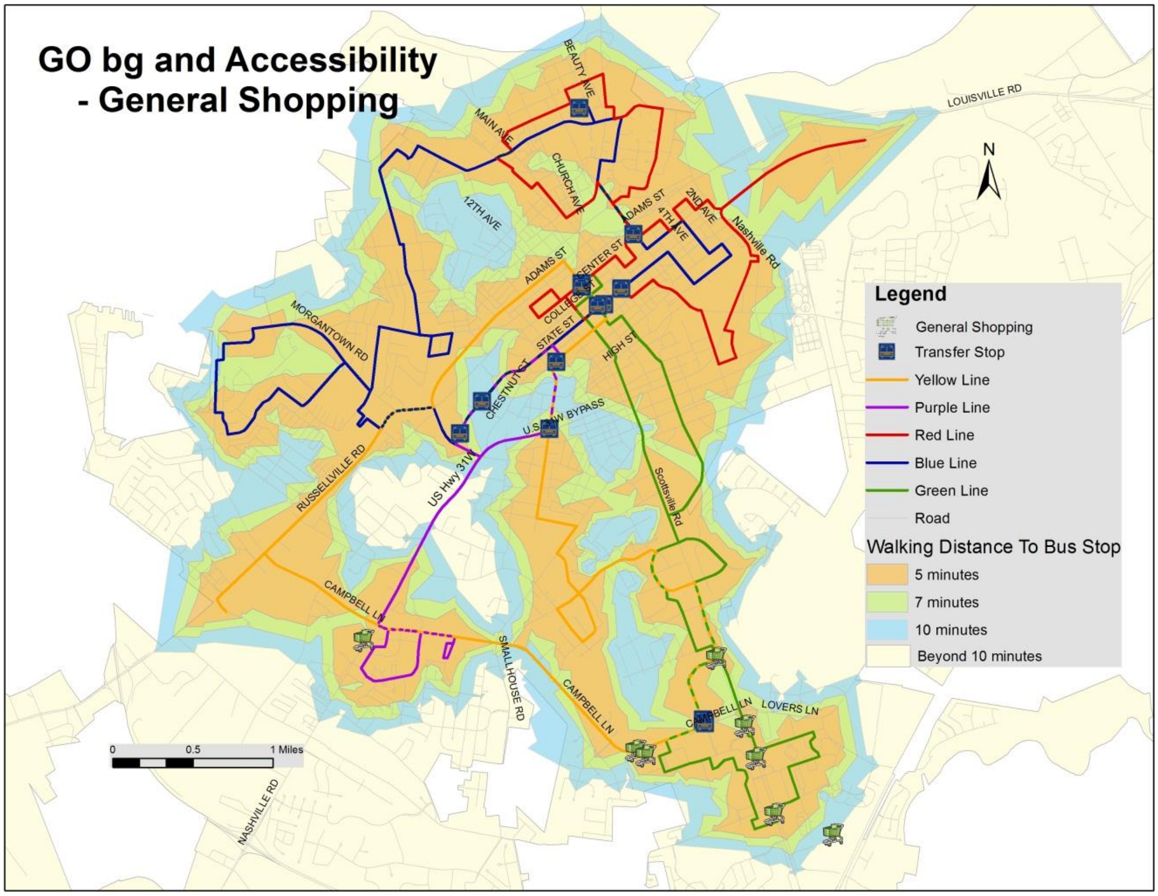


Figure 5.13: Accessibility to General Shopping.
Source: US Census (2010c); CASOKY (2013).

Figure 5.14 shows the spatial distribution of educational institutions. Since school buses pick up k-12 school students, accessibility to higher educational institutions and public libraries is the only consideration when examining transit service to educational facilities. WKU, SKYCTC, and Daymar Institute are the major institutions of higher learning in the city. With the exception of Daymar, the rest are within a five-minute walk from a *GO bg* transit stop. The location of Daymar Institute lies within the seven-minute zone and people accessing the bus from that institution must walk slightly longer than those from WKU and SKYCTC. The Warren County Public Library (WCPL), which provides computers and Internet access, as well as other educational facilities, also lies within the five-minute walking zone.

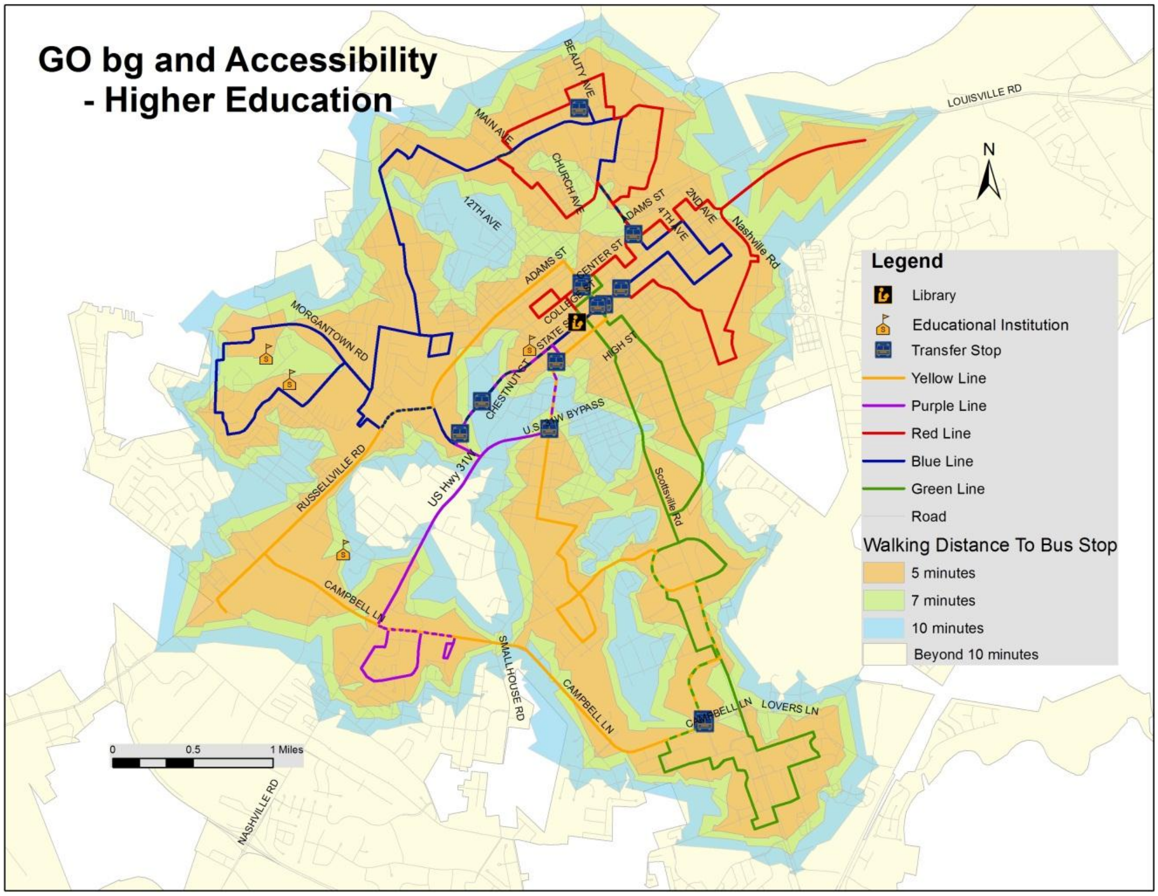


Figure 5.14: Accessibility to Education Institutions.
Source: U.S. Census (2010c); CASOKY (2013).

Another accessibility theme under discussion is recreation. Some of the recreation locations mapped include the city parks, movie theatres, gyms, bowling alleys, and museums, as shown in Figure 5.15. The map shows that numerous recreational opportunities are available using the transit service. The two major movie theaters and museums in the study area are both within a five-minute walk from a transit stop. The movie theaters are located mainly in the southern portions of the city, meaning that people coming from the north would likely have to transfer to another route before reaching their destination. This can prolong their journey and, therefore, could limit the number of trips they would make. Most of the gyms and parks are also within close proximity of a five-minute walk to a bus stop.

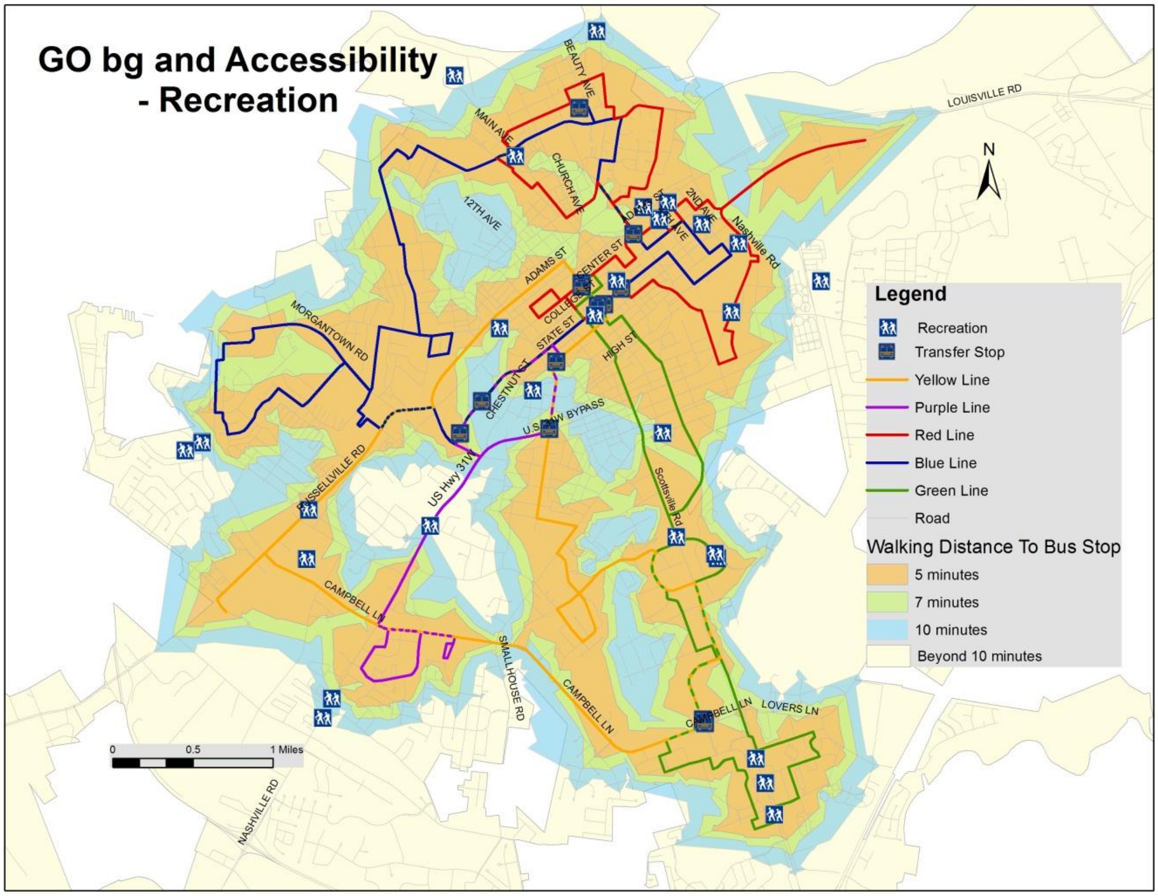


Figure 5.15: Accessibility to Recreation Sites.
Source: US Census (2010c); CASOKY (2013).

There are other places of interest where people would normally go to take care of other needs but which could not be classified under the themes discussed above, such as the post office, courthouse, and family support center. Figure 5.16 shows the location of these places. Most of them are in close proximity to each other around the central part around the downtown of the city and where multiple *GO bg* bus routes converge.

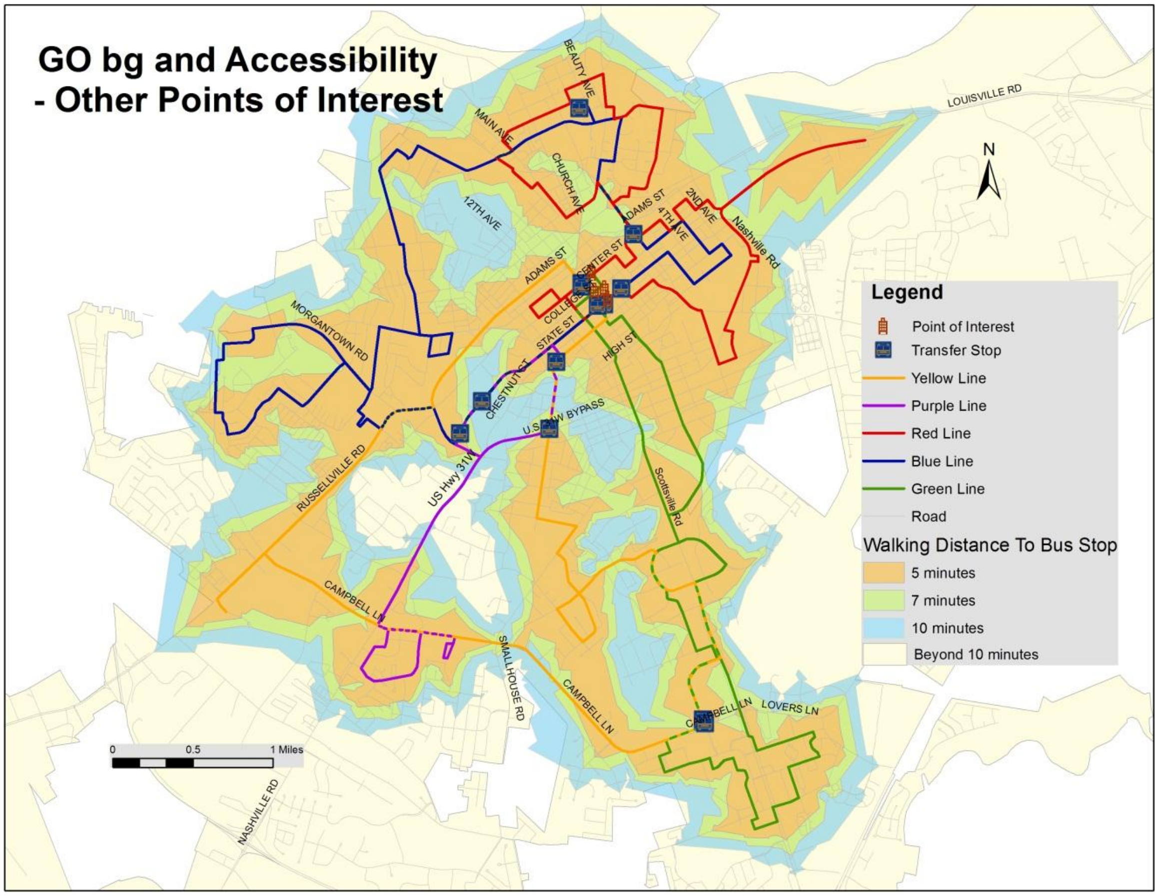


Figure 5.16: Accessibility to Other Points of Interest.
Source: U.S. Census (2010c); CASOKY (2013).

CHAPTER 6: CONCLUSIONS AND FUTURE RESEARCH

6.1. Conclusions

The objective of this study has been to understand access to the *GO bg* public transit system within the City of Bowling Green as it relates to the spatial distribution of demographic subgroups such as African Americans and Hispanics, people of low income status, and persons aged 65 and above. The analysis was conducted based on the routes and stops of the *GO bg* transit service. Using a number of methods, including thematic mapping of the population under study, transit demand analysis, and service area analysis, the study demonstrates the extent to which the *GO bg* transit system serves the local population. It was found that a considerable population with potentially high transit demand and ridership tend to concentrate in the north, north-west, and south-central part of the study area. It is also worth noting that there is a similarity in the spatial distribution of African Americans, Hispanics, and the population below the poverty line. Unfortunately, the reality in many parts of the U.S. is that poverty is often associated with minority groups, particularly African Americans and Hispanics. This is perhaps the reason why many studies have found that these two minority groups have disproportionately greater percentages of public transit ridership (Pucher and Renne, 2003), as discussed in the Section 2.3.

Weighted demand mapping proved to be useful to show where the areas with potential high transit demand are located. An overlay of the existing transit routes with the demand map shows an acceptable coverage of *GO bg* transit service. To understand fully the spatial access to the transit system, service area analysis was then conducted to show how well the total population and selected demographic subgroups with high potential transit ridership have access. It was found that within a seven-minute walking distance, over 50% of all population subgroups under investigation can have access to the transit service, except for people aged 65 and above. A simple point overlay was also conducted to determine the accessibility of various basic human activities available to the transit riders. It was determined that the *GO bg* transit service provides access to basic needs, although land-use patterns play a major role in determining who gets to a destination faster and more conveniently. Given the fact that, in the U.S., automobile dependency is so high, it is reasonable to conclude that the *GO bg* transit service is doing a relatively good job in terms of providing spatial coverage.

It must also be noted that, although this study focused mainly on the actual service coverage of *GO bg* transit, there is also a greater awareness of a shift towards a more green lifestyle so as to safeguard our environment. Consequently, enhancing mobility and accessibility through public transit should return greater benefits for society in general.

6.2. Future Research

There is further research that can be conducted to examine public transit services in small cities like Bowling Green. First, there is a need for further analysis of the ridership at the various stops to determine what kind of spatial ridership pattern, if any, can be found. This could validate (or disprove), in terms of consistency with the results of this study, the weighted demand mapping method where certain areas were identified as having greater demand for public transit. This would require more detailed ridership data at every stop.

Another factor that should be considered in future analysis is the relationship between employment centers and transit access within the city. Unfortunately, employment data with needed geographic details, though available, are not comprehensive enough and might not produce reliable results. Moreover, this study can be repeated frequently as the *GO bg* transit service expands and grows. Had this study taken place three to five years ago, the results would likely have been different. This is due to the fact that the transit services removed and added some stops and also added and redesigned some routes. For instance, the new extension of the red line to old Louisville Road became effective in the first quarter of 2013. Also, although the purple line was implemented in 2009, it was redesigned in the first quarter of 2013 as well. It would be interesting to know how the coverage has been impacted. In addition, the approach used in this study could also be applied to other study areas with a similar size throughout the nation. It would be interesting to compare how the findings may differ across the U.S.

Although *GO bg* transit did not use GIS directly for planning, the study shows that the transit service does provide reasonably good spatial coverage. It is evident that *GO bg* operators have determined the routes and stops using local understanding of the city and its census data. There are still a lot of areas that could be improved, and GIS and other information technologies should be used in the future in order to further optimize routes and minimize walking distance while increasing the accessibility of the system's patrons.

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