SPATIAL ANALYSIS OF NEIGHBORHOOD SUSTAINABILITY

IN BIRMINGHAM, ALABAMA

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ABSTRACT

This research examined the geographical distribution of sustainability in the city of Birmingham, using sustainability indicators (SIs) applied at the neighborhood scale. The neighborhoods used in this project were those defined by the city's Department of Community Development. The indicators were developed by examination of previously developed sustainability rating systems and issues specific to the City of Birmingham; they addressed the three major dimensions of sustainability: economic, environmental, and social. The rating system was applied to all neighborhoods and geographical patterns were analyzed. This research is unique in its objective to evaluate sustainability of a city at the neighborhood scale. The neighborhood scale allowed the spatial patterns within the city to be analyzed. Neighborhood Sustainability Assessment (NSA) systems currently being used are applied only to new proposed developments. The ability to analyze sustainability of all areas within the city, not just new developments, provides information on which areas are performing well and which ones will require more attention in order for Birmingham to become a more sustainable city.

DEDICATION

This thesis is dedicated to my close friends and family who provided encouragement and support as I worked to complete this manuscript.

LIST OF ABBREVIATIONS AND SYMBOLS

APCA	Alabama Partners for Clean Air
ACS	American Community Survey
ANOVA	Analysis of Variance
BREEAM	Building Research Establishment Environmental Assessment Methodology
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CBD	Central Business District
CCT	Cell Crossing Time
DF	Development Footprint
DI	Dissimilarity Index
ECC	Earth Craft Communities
EPA	Environmental Protection Agency
ESDA	Exploratory Spatial Data Analysis
FLT	Freshwater Land Trust
GIS	Geographic Information System
GRCA	Green Resource Center for Alabama
HOPE	Housing Opportunity for People Everywhere
HUD	U.S. Department of Housing and Urban Development
LEED	Leadership in Energy and Environmental Design
LEED-ND	Leadership in Energy and Environmental Design for Neighborhood Development
LISA	Local Indicator of Spatial Association
NHD	National Hydrography Dataset

NLCD	National Land Cover Dataset
NSA	Neighborhood Sustainability Assessment
UAB	University of Alabama at Birmingham
UBEV	Unlawful Breaking and Entering of a Vehicle
USGBC	United States Green Building Council
SI	Sustainability Indicator
SSC	Sustainable Smart Cities
TIGER	Topologically Integrated Geographic Encoding and Referencing
UGB	Urban Growth Boundary
USGS	United States Geological Survey
WCED	World Commission on Environment and Development

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1.0 INTRODUCTION

In 1987, the World Commission on Environment and Development (WCED) realized the simultaneous need to protect the environment and promote economic growth in underdeveloped regions in order to increase quality of life for people living in those regions. The commission declared the need for sustainable development that meets the needs of the present (economic growth to increase equity) without compromising the ability of future generations to prosper (long-term environmental protection) (WCED, 1987). The concept of sustainable development has since caught on in a big way with people around the world. The problem is that it has proven to be very difficult to achieve or even define. The need to measure sustainability in order to track progress and set goals has been identified and multiple approaches have been developed, but the application of any particular method of sustainability assessment in all places may not be realistic because local problems often exist that need to be addressed in a local context. In the case of Birmingham, many sustainability problems have been identified in the Comprehensive Plan which was developed with input from the community (City of Birmingham, 2013). The problem to be addressed in this research is how to measure sustainability in Birmingham in a way that allows the city officials to identify problems and promote sustainable development. This research seeks to determine the level of sustainability of Birmingham neighborhoods, examine the spatial distribution of sustainability in Birmingham, and make recommendations on how to increase the sustainability of Birmingham. In order to accomplish these goals, this research developed and applied a neighborhood sustainability assessment (NSA) system to determine the current level of sustainability in Birmingham. The results of the NSA show which neighborhoods are doing well, which ones need improvement, and specifically what needs to be done to increase the sustainability of the city. It is important to measure progress in order to attain any goal, and sustainability is no exception. The specifics of the NSA system will be discussed in later sections.

1.1 Sustainability in Birmingham

Like most cities in the southeastern U.S., Birmingham is not usually thought of as a beacon of sustainability, but the city has recently made strides to promote sustainable development. Sustainability has become a major goal in the city's comprehensive plan; three chapters in the plan are specifically related to sustainability (City of Birmingham, 2013). This interest in sustainability seems to come from the citizens as well as from the planners and elected officials; many citizens expressed a desire for Birmingham to become a model of sustainability for Alabama in the visioning forum for the comprehensive plan.

Part of the reason that sustainability has become so important to the people of Birmingham is the fact that they can clearly see the negative impacts of the current form of development and the potential benefits of sustainable development. The impacts of pollution upon the city's economy and quality of life are obvious. Until recently the city was unable to attain minimum air quality standards required by the Environmental Protection Agency (EPA) and the Clean Air Act (APCA, 2014). Not achieving the minimum air quality standards has also meant restrictions on economic development in Birmingham. Perhaps part of the reason that Birmingham has finally achieved attainment status for clean air standards is that there has been a reduction in industrial jobs, and therefore a reduction of pollution associated with manufacturing activities, in the city. Although industry and manufacturing still has a large presence in the city, it is no longer the largest employer in the city. Education, medical, retail, and financial services each currently provide more jobs than manufacturing (U.S. Department of Labor, Bureau of Labor Statistics, 2012). This transition to more service and tech jobs could be very helpful in Birmingham's struggle to achieve the minimum air quality standards, however, it is important that those manufacturing jobs are replaced and the economy continues to grow in order to achieve sustainable development in which there are enough jobs and opportunity for the people of Birmingham. The new challenge for protecting air quality in Birmingham is controlling the mobile pollution from automobiles.

In addition to the support of the planning department, there are several groups within the city that support sustainability. Some of the most notable of these groups are the University of Alabama at Birmingham (UAB), The Green Resource Center for Alabama, the Freshwater Land Trust, and the U.S. Green Building Council of Alabama. UAB, one of the city's largest employers, has made a commitment to sustainability by establishing the Sustainable Smart Cities (SSC) Research Center. According to their website, the goal of the SSC is to "foster cross-disciplinary research, training, and outreach that integrate health, socio-economic impacts, and infrastructure design for the purpose of developing innovative solutions for sustainable smart cities and communities"(UAB Sustainable Smart Cities Research Center, 2014). Another organization supporting sustainability in the Birmingham area, the Green Resource Center for Alabama (GRCA), is a non-profit organization that provides guidance and resources for individuals seeking to live a 'greener' life. The GRCA provides people with news about sustainability in Birmingham and information on how to live a more sustainable lifestyle. The Freshwater Land Trust (FLT) is an organization that promotes conservation and environmental protection in the Birmingham area. The land trust has been developing a greenway trail system that will provide greater access to natural areas for recreation and increase the walkability of the entire Birmingham area. The U.S. Green Building Council (USGBC) of Alabama promotes green building practices in the Birmingham area. According to the USGBC website, there are 15 LEED certified green buildings in the Birmingham area (U.S. Green Building Council of Alabama, 2014). These organizations and many others show the great level of support for sustainability in the Birmingham area.

2.0 RESEARCH BACKGROUND

Issues of global climate change, environmental degradation, and increasing demand on natural resources due to a rapidly increasing global population have forced sustainability and sustainable development into the global spotlight. Hopwood, Mellor, and O'Brien (2005) suggest that this represents an "emphasis on human and environment interactions and a significant shift away from views of humanity as separate and superior to the environment". Governments at all levels have endorsed the concept of sustainable development and have been making pledges to improve sustainability within their jurisdictions (Purvis & Grainger, 2004; Chapin, 2012). This widespread support, however, has not necessarily translated into huge gains in sustainability (Leuderitz et al., 2013). Growing populations and growing demand for energy, natural resources, and development in general have slowed progress towards achieving sustainability. The global community has been unable to agree upon a standard definition of sustainability, making it even more difficult to determine how much progress has been made. In general, sustainable development should not consume natural resources at a rate that exceeds their replacement rate, contribute as little as possible to pollution of all kinds, not result in significant habitat destruction and biodiversity loss, and provide a high level of well-being for people today without negatively impacting the ability of future generations to have the same level of well-being. The big question is how can we accomplish this, and how do we measure our progress? In order to answer that question, we must first define sustainability.

Sustainability is often described as having three ‘pillars’ or overlapping circles, which include: environment, economy, and society (Giddings et al., 2002). It is important to fully understand the meaning of each of these pillars and how they interact with one another in order to understand and effectively measure sustainability. Environmental and economic sustainability are, in general, the most prominent of the three pillars in sustainability assessment while social sustainability is often overlooked or underemphasized (Giddings et al., 2002). The three pillars are also often seen as being in opposition to one another; one often sees arguments of environment vs. the economy (or jobs) or economic development vs. social equity. Campbell (1996) illustrates the sometimes opposing nature of the pillars when he describes the three pillars as a triangle with the pillars representing the corners of the triangle and the conflicts between the pillars representing the sides of the triangle. Between economy and environment is the “resources conflict”, between environment and society is the “development conflict”, and between society and the economy is the “property conflict” (Campbell, 1996). A major part of sustainability is reconciling these conflicts, and, in many cases, a proper balance between the three pillars benefits everyone involved. For example, preserving resources protects the environment while also ensuring resources for future economic activity that can benefit society for a longer period of time by providing long-term employment.

In order to better understand these conflicts and effectively resolve them, it is first important to understand the meaning of each pillar. The environmental pillar is the pillar that is focused on protecting the environment, in the form of conservation of natural resources, preservation of natural habitat and biodiversity, and limiting pollution. Economic sustainability is focused on promoting economic growth that can be sustained for long periods of time and does not cause excessive environmental damage. Social sustainability is often less understood; it is focused on equity, both inter-generational (between generations) and intra-generational (within generations). Issues of social equity often arise in the interplay of economic and environmental sustainability. Social equity depends upon adequate environmental standards for all people, as well as economic opportunity for all people and equal access to public services. While most sustainability research focuses on the inter-generational equity issues (preserving resources for future generations), there exist disparities between well-being of people in the current generation (Solow, 1991). By definition, sustainable development should provide well-being and equity for people now and in the future. The NSA system used in this research seeks to account for the well-being of the current generation while simultaneously promoting the well-being of future generations through environmental protection and long-term community investment.

2.1 Smart Growth and Sustainability

Of the many approaches to sustainable development, perhaps the most prominent is the smart growth movement. Especially in North America, smart growth has been growing rapidly in popularity since the mid-1990s. The term smart growth has, in some ways, become synonymous with sustainability. Tregoning, Agyeman and Shenot (2002) describes smart growth as a “new iteration” of sustainability. One reason that smart growth has become so popular is that it relates sustainability to issues that directly affect the average person instead of appealing almost exclusively to environmentalists as did most previous efforts to promote sustainability (Tregoning, Agyeman & Shenot, 2002). Smart growth has accomplished its high level of popularity and acceptance by “shifting the focus from self-sacrifice to self-interest” and redefining what constitutes “the good life”, showing people that smart growth is an alternative to sprawling development that can result in improvements in quality of life and sustainability

(Tregoning, Agyeman & Shenot, 2002). People around the country have realized the negative impacts of suburban sprawl and are ready to see changes in the way cities are developed that reduce those impacts. As Duany, Speck and Lydon (2010) puts it, “it is now clear that many current social, economic, and physiological ills are direct outcomes of the way we have built our communities since World War II”.

Smart growth is viewed by many as an approach to reduce urban sprawl and automobile dependence and improve quality of life; it is also believed by many county, regional, and state planning officials to slow down the loss of valuable agricultural land, open space, and natural areas and direct development toward existing communities already served by the necessary infrastructure (Mayer, Danis & Greenberg, 2002). For cities, the increased development of existing areas in urban centers that is promoted by smart growth enables them to benefit from a larger tax-base, more efficient provision of public services, and increased economic vitality (Mayer, Danis & Greenberg, 2002). Smart growth has gained acceptance from a wide range of interest groups, such as developers, planners, environmentalists, and everyday people, but each group tends to focus on the principles that best fit their goals. Downs (2001) outlined the principles that the various groups agree upon and those that tend to cause the most controversy. Most groups agree on the concepts of preserving open space, infill development, design innovation, less rigid zoning and development regulations, and a greater sense of community in neighborhoods, but they tend to disagree on the concepts of limiting growth (growth boundaries), methods of paying for infrastructure growth, reducing automobile dependency, resource sharing between municipalities in a region, and compact development (Downs, 2001). As a result of these disagreements, many smart growth initiatives pick and choose the concepts that will advance their cause and ignore the rest (Duany, Speck & Lydon, 2010). It seems that everyone wants smart growth but can't agree on how it is best accomplished, and there may be good reason for those differences of opinion. As Downs (2001) puts it, "what is 'smart' in New York may be 'dumb' in Phoenix". There will likely be a big difference in what actually works in each city or region, but most people can agree that sprawl must be kept under control and that smart growth can be the method of controlling it.

Duany, Speck and Lydon (2010) provide a detailed outline of smart growth principles from the regional level to the individual building level in their book *The Smart Growth Manual*; in the following paragraphs, the principles of smart growth, as described by Duany, Speck and Lydon (2010) will be outlined.

At the regional level, smart growth calls for cooperation and resource sharing among municipalities in order to develop an inter-city public transit system and limit growth outside of existing urban areas to protect natural areas, open space, and agricultural lands. Municipalities in a region should work together to develop regional development goals and direct growth to areas that are more desirable in order to limit traffic congestion and unnecessary environmental harm. Regional cooperation itself is generally agreed upon by most interest groups, but there is often disagreement about who should be making decisions and how resources (tax revenue) should be shared (Downs, 2001). One example of regional cooperation in smart growth practices can be seen in Portland, OR, where the urban growth boundary (UGB) has been in effect since 1979. In the case of Portland, a regional government authority, Metro, assumed responsibility for managing the UGB (Harvey & Works, 2002); the establishment of a regional authority may be the best option for creating regional cooperation in a way that doesn't give any one municipality more influence than others. In Birmingham, the Regional Planning Commission of Greater

Birmingham provides regional planning support, and would be a great asset in creating more cooperation between Birmingham and surrounding municipalities.

At the neighborhood level, smart growth emphasizes compact and mixed use neighborhoods where residents can find most of the things they need (retail, jobs, transit, parks and open space, etc.) within walking distance from their homes. In these neighborhoods, there should be a variety of housing options from single-family detached to high density multi-family housing in order to accommodate different lifestyles and income levels. Housing should be affordable to a wide variety of residents in order to create a diverse neighborhood environment, and affordable housing units should be available in all areas of the city in order to prevent the concentration of lower-income households in public housing projects in only a few locations around the city. When building these neighborhoods, smart growth encourages developers to leave the natural environment as natural as possible, meaning that natural drainage patterns should be preserved as well as the overall topography, and trees should be left standing as often as possible. Trees can serve a variety of functions within a smart growth development. They can provide aesthetic enhancement along the streets and sidewalks while simultaneously providing shade and protection to pedestrians (Duany, Speck & Lydon, 2010). They can also provide valuable ecosystem services by reducing CO_2 levels and preventing erosion. Housing densities in smart growth neighborhoods should be higher than those typical in other types of developments, but in order to compensate for the loss of private space (large backyards), there should be greater access to amenities, open space, and parks that increase the quality of life in the high density housing environment (Alexander & Tomalty, 2002). Housing density is one of the more controversial elements of smart growth, but it is also one of the most critical to promoting mixed use, walkability and preservation of open space; the benefits of increased housing density include: more efficient use of land and less pressure on natural areas, reduced automobile dependence, more mixed land use, more feasibility for public transit, reduced consumption of water and energy, improved quality of life due to increased walkability and open space, increased safety due to the “eyes on the street” concept, and a greater variety in housing types and prices (Alexander & Tomalty, 2002; Duany, Speck & Lydon, 2010). The smart growth principles for neighborhoods offer many potential sustainability indicators (SIs) for neighborhood sustainability assessment (NSA), including: housing density, walkability, mixed-use, parks and open space, and transit. The Leadership in Energy & Environmental Design for Neighborhood Developments (LEED-ND) assessment system is based on smart growth principles and also offers many examples of SIs that can be used for assessment.

The principles of smart growth also go beyond the neighborhood level to provide detailed guidelines for designing streets and individual buildings. In general, smart growth calls for slowing traffic on all roads except for major arterials and freeways and the creation of ‘complete streets’ which increase the safety and efficiency of other forms of transportation like walking and cycling. Planting of trees along roadways is also encouraged in order to create more attractive and safe areas for walking. On-street parking is encouraged in most areas to reduce the need for large parking areas made with impervious surfaces and to slow traffic to increase safety for pedestrians. In residential neighborhoods, parking is also encouraged on the street and in the rear alleys behind rows of houses. Buildings should be energy efficient, attractive, and diverse enough to meet the needs of a variety of residents.

The smart growth principles provide some guidelines for developing neighborhoods and regions sustainably. There are few examples of clear strategies for pursuing sustainable development, so it is no surprise that smart growth has been so successful. Birmingham, and any other city pursuing sustainable development, should strongly consider incorporating smart growth principles into their development strategies.

2.2 Sustainability Assessment

Academic research on the subject of sustainability has been complicated by the fact that there is no universally accepted definition of sustainability. There have been many interpretations of what sustainability actually means and how it can be measured, but the most accepted definition comes from the United Nations-sponsored World Commission on Environment and Development's (WCED) Brundtland Commission. The Brundtland Commission defined sustainable development as: "Development that meets the needs of current generations without compromising the ability of future generations to meet their needs." (WCED, 1987) The WCED's definition has been widely accepted, but it has also been criticized as being too general (Hopwood, Mellor & Brien, 2005). In other words, it does not necessarily mean the same thing to different people. A vague definition has helped to gain support for the concept, but it has also resulted in a lack of specific and universally accepted methods of assessment (Berardi, 2013). Because of this problem, there have been many different methods for measuring sustainability. Perhaps one of the most common is to identify "sustainability indicators" and determine an acceptable range of values, or "equilibrium", for these indicators (Bell and Morse, 1999 and 2003). The sustainability indicator method is quite common, but specific studies differ in the way they choose indicators and how they represent the results. One major issue is how to aggregate the values for different sustainability indicators; in some cases, combining different indicators into a single aggregated score, with each indicator having a different weight, can result in excessive tradeoffs between environmental and economic factors and a promotion of 'weak sustainability' (Berardi, 2013). Of course some tradeoffs are going to be necessary, but a proper balance must be maintained in order for a project to actually promote sustainability (Gibson et al., 2005). This research builds upon the existing literature by incorporating aspects of previous sustainability assessments, but adapting these methods to work on the existing neighborhood scale in the unique local context of Birmingham.

One of the most commonly applied NSA systems currently being used is the Leadership in Energy and Environmental Design (LEED) for Neighborhood Developments (ND) system. This system, like many other NSA systems, originated with a system for evaluating the sustainability of individual buildings. The neighborhood principles of LEED-ND were created with collaboration from the Congress for New Urbanism (CNU), meaning that new urbanism principles are reflected in many of the indicators of neighborhood sustainability (USGBC, 2009). The LEED-ND system evaluates neighborhoods based on three major categories: Smart Location and Linkage, Neighborhood Pattern and Design, and Green Infrastructure and Buildings; the system also gives bonus points for innovation and for addressing regional priority issues (USGBC, 2009). The LEED-ND system uses very detailed indicators of neighborhood design, including those based on the materials used to build homes and the energy efficiency of buildings in the neighborhood, but the system is not well suited for application to existing neighborhoods or a city-wide evaluation of neighborhoods. It would be nearly impossible to acquire all of the information needed to perform a LEED-ND assessment of all neighborhoods in a city. The LEED-ND system is actually intended to be applied by developers of new neighborhoods upon completion, or partial completion, of a planned neighborhood development; therefore, the LEED-ND NSA does not apply to the majority of neighborhoods in Birmingham or other U.S. cities. The focus on new developments is not unique to LEED-ND; other commonly used NSA systems, such as Earth Craft Communities (ECC), the British Building

Research Establishment Environmental Assessment Method (BREEAM), and Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), also focus on newly built, planned neighborhoods. In order to assess the sustainability of an entire city at a neighborhood scale, there must be a new system developed with more general indicators of sustainability; the NSA developed in this research is intended to provide an alternative to the LEED-ND and other NSA systems that are not well suited for city-wide neighborhood assessments.

In addition to not being well suited for existing neighborhoods or city-wide neighborhood assessments, many of the existing NSA systems neglect the social and economic categories of sustainability (Berardi, 2013; Sharifi & Murayama, 2012). This is not surprising when considering that many of the neighborhoods being assessed by these NSAs are just beginning to be occupied by residents, meaning that there is no real way to measure social or economic conditions in the neighborhood. Also, the NSA systems applied by developers in order to gain certifications (such as LEED-ND) are often only applied at the beginning of their development, and progress toward achievement of economic or social sustainability over time is never evaluated (Berardi, 2013). The ability to apply economic and social indicators is one major advantage to an NSA system that evaluates existing neighborhoods.

2.3 Importance of the Neighborhood Context

Most literature on the subject of sustainability and sustainability assessment agrees that urban areas and urban neighborhoods should be the focus of sustainability assessment. The focus on urban sustainability is due to the fact that the majority of the global human population is currently living in urban areas, and current estimates indicate that roughly two-thirds of the world population will be in urban areas by 2050 (Heilig, 2012). As the place where most people live, urban areas have become the areas where the majority of human activity takes place, and therefore have the largest impact on sustainability (Hiremath et al., 2013). The impacts of urban activities reach far and wide as most urban areas are net importers of products and resources (Berardi, 2013; Newman and Kenworthy, 1999). Despite the recent attention gained by sustainable development, the current urban form in most places is still considered to be unsustainable (Luederitz et al., 2013). There is, however, great potential for increased efficiency through sustainable design in urban areas. As the "building blocks of a city" (Searfoss, 2011), neighborhoods are the ideal places to begin working to increase urban sustainability. As Choguill (2008) puts it, "no single city can contribute to overall sustainability if its own component parts are found not to be sustainable". Despite the obvious importance of urban neighborhood sustainability, very little research has been completed on how to measure sustainability of existing urban neighborhoods or the spatial component of sustainability in urban areas. In their review of 22 sustainability assessment systems used in the U.S., Lynch et al. (2011) found that only 6 assessment systems evaluated sustainability at the neighborhood scale; the majority of the systems analyzed in their study evaluated sustainability at the city or metropolitan area scale. Berardi (2013) also found that the most commonly used NSA systems were applied mostly to new developments at the discretion of the developers and only at the beginning of the neighborhood development, not repeatedly throughout the life of the development. The observations of Lynch et al. (2011) and Berardi (2013) show that studies on sustainability of urban areas are often conducted on a city or metro area scale, and those NSA systems that are applied to neighborhoods are not comprehensive (covering all neighborhoods within a city) or capable of tracking results over time. The application of a neighborhood-scale assessment to all neighborhoods within Birmingham enables this research to reveal patterns within the city, something that the NSA systems currently in use cannot explain.

Neighborhoods may be the ideal unit of area for sustainability assessment in the urban environment because citizens can easily identify with neighborhoods and often take pride in their neighborhood. Because of the pride many citizens take in their neighborhoods, there could be an increased level of citizen participation when data are presented at the neighborhood level, and citizen participation can be a very powerful tool in sustainable development. Planners and geographers may be tempted to use units of area that are easier to obtain data and statistics for, such as census tracts or block groups, but these units are practically meaningless to the people that live within them. Neighborhoods have a sense of place which can be critical to providing inspiration for people to work together to improve their physical environment (Manzo & Perkins, 2006).

One major obstacle to conducting research at a neighborhood level is the difficulty of defining neighborhood boundaries. There have been many proposed methods of delineating neighborhoods, but ultimately, the neighborhood is defined by the people that feel attached to the neighborhood. According to the National Commission on Neighborhoods:

> "…each neighborhood is what the inhabitants think it is. The only genuinely accurate delineation of a neighborhood is one done by the people who live there, work there, retire there, and take pride in themselves as well as their community" (National Commission on Neighborhoods, 1979; Wilson, 2000).

The difficulty of delineating neighborhoods is avoided in Birmingham due to the fact that the Department of Community Development has already delineated the neighborhoods of the city. The neighborhoods were first delineated in the early 1970s and have been constantly changing ever since. Wilson (2000) described the neighborhood delineation process as follows:

> “Planners’ representation of neighborhood space in Birmingham consisted of the boundaries and names of ninety-one neighborhoods which residents were asked to confirm or correct through dialogue. This process led to the identification of tentative neighborhood boundaries. Next, staff members contacted other people residing on both sides of the tentative boundaries to identify boundaries upon which all could agree.”

Once the entire process was completed, there were 84 confirmed neighborhoods in Birmingham. After the delineation of the original neighborhoods, changes were made periodically at the request of the neighborhood groups. According to Wilson (2000), neighborhood groups requested more than thirty changes between 1974 and 1980. There are currently 99 neighborhoods in Birmingham according to the Department of Community Development.

3.0 METHODOLOGY

The methods for this research involved the development and application of a neighborhood sustainability assessment (NSA) system made up of a set of sustainability indicators (SIs) to measure sustainability of Birmingham neighborhoods and the use of that system to explain the spatial distribution of sustainability in the city. The SIs cover a wide range of criteria each monitoring achievement of one or more of the three types of sustainability: economic, environmental, and social.

3.1 Research Problem

The City of Birmingham has identified sustainability as a goal for the future of the city in its comprehensive plan, but, as of yet, there is no system for determining their progress. The establishment of a method to measure sustainability is a “prerequisite in any attempt for pursuing sustainable urban development” (Hiremath et al., 2013). The indicators developed for this research may not be able to fully explain every phenomena related to sustainability, but by definition, indicators are “simplifications of complex phenomena and provide only an indication of conditions or problems”, they should reduce the amount of data required to describe these phenomena, and indicate progress toward achieving sustainability as a policy goal (Hiremath et al., 2013). In order to develop an effective set of indicators it is necessary to understand the needs of the city and its citizens; for this research, the City’s comprehensive plan was be used to determine those needs. The planning department has identified problems that need to be addressed and collected data on what the citizens think are the most pressing problems, but the combination of all of these diverse factors are difficult to visualize in a spatial context. The development of a neighborhood sustainability rating system will allow for analysis of all of the contributing factors to sustainability in each neighborhood. This will enable the planners to make better decisions when allocating resources for achieving sustainable development.

3.2 Research Questions

The goal of this research is to examine the spatial distribution of sustainability in the city of Birmingham at the neighborhood scale. The first part of the research develops and applies a NSA system to Birmingham neighborhoods, the second analyzes geographical patterns of sustainability throughout the city, and the final section makes recommendations for improving sustainability in Birmingham neighborhoods. Although the methodology of this research is very important, the ultimate goal is to observe and explain the geographical pattern of sustainability in the city of Birmingham at the neighborhood scale. Evaluating the sustainability of the city at the neighborhood scale rather than at the city scale allows patterns to be identified and comparisons to be made between different neighborhoods. The specific research questions are:

1. What is the current level of sustainability in Birmingham neighborhoods?
2. What are the issues that negatively affect sustainability in Birmingham neighborhoods, and how can these issues be addressed by the planning department or other agencies?
3. What spatial patterns can be recognized for sustainability in Birmingham, and what do those patterns reveal about Birmingham neighborhood sustainability?

3.3 Research Methods and Data Acquisition

The City of Birmingham has made sustainability a major goal for the future. The comprehensive plan, which is the first comprehensive plan developed for the city since 1961, clearly expresses this goal in its "Vision and Principles" chapter. The vision of Birmingham in the year 2032 describes the city as, "diverse, prosperous, sustainable, and beautiful" (City of Birmingham, 2013). Community involvement is a critical component of planning, especially when setting goals for the future of a city or neighborhood. In the case of the Birmingham comprehensive plan, community feedback and guidance was used to shape all aspects of the plan (City of Birmingham, 2013). The information gathered by the planning department and used to develop the comprehensive plan was also used as the basis for the sustainability assessment system developed for this research. The Citywide Visioning Forum, which involved participation from over 200 Birmingham residents from all areas of the city, produced a list of issues about which residents were most concerned; table 3.1 below shows the most frequently mentioned issues.

The SIs for the NSA system of this research were developed based on the concerns expressed by the citizens of Birmingham in table 3.1 and the availability of data. The SIs, the issues they address, and the source of data for each are listed in table 3.2 below. The economic SIs give a basic understanding of the economic opportunities available to residents of the neighborhood; all of this data is derived from U.S. Census Bureau data collected at the Census Tract level. The environmental SIs are measures of how the built environment of the neighborhood affects the air and water quality of the area; this approach was chosen because data on air quality and water quality for each neighborhood was not available and would not be particularly useful for a neighborhood-scale project. Even if air and water quality measurements were used it would be impossible to determine the actual source of the pollution due to the fact that pollution in the urban environment comes largely from non-point sources, not necessarily located within the neighborhood in question. Finally, the social indicators deal with issues that affect the quality of life in the neighborhood, such as crime rate, access to public facilities, and access to fresh food.

Table 3.1
Issues most frequently mentioned in city-wide visioning forum

Issue ID	Issue of Concern	Number of Mentions
1	Lack of transportation alternatives: an inadequate transit system and few bike trails or marked routes	76
2	The public education system	54
3	Significant vacancies and blighted properties	36
4	Crime and the perception of crime/lack of safety	26
5	Lack of quality grocery stores/access to fresh food	23
6	Many parts of the city are not pedestrian friendly/walkability/issues with sidewalks	21
7	Pollution/clean air/environmental issues	19
8	Lack of business and jobs within city	18
9	Lack of connectedness	14
10	Lack of bike lanes and walking trails	12
11	Affordable housing	8
12	Social issues (addiction, homelessness, poverty)	8
13	Condition of Parks/Need for more Parks	5
14	Race relations/issues	3
15	Job Training	1

Table 3.2
Indicators and Data Sources

Indicator	Issues Addressed	Category	Data Source
Unemployment	Lack of Jobs	Economic	U.S. Census 2008-2012 ACS Estimates
Poverty	Lack of Jobs, Social Issues	Economic	U.S. Census 2008-2012 ACS Estimates
Vacant Housing	Vacancies and Blight	Economic	U.S. Census 2008-2012 ACS Estimates
Commute Time	Lack of Transportation Alternatives, Lack of Jobs	Economic	U.S. Census 2008-2012 ACS Estimates
Percentage of Population with High School Diploma	Public Education, Social Issues, Job Training	Economic	U.S. Census 2008-2012 ACS Estimates
Affordable Housing	Affordable Housing	Economic	U.S. Census 2008-2012 ACS Estimates
Proximity to Water Features	Pollution, Clean Air, Environmental	Environmental	USGS NHD and NLCD 2011 datasets
Impervious Surface	Pollution, Clean Air, Environmental	Environmental	USGS NLCD 2011
Intersection Density	Pollution, Clean Air, Environmental, Lack of Connectedness	Environmental	2014 TIGER/Line Shapefiles – All Roads
Development Footprint	Pollution, Clean Air, Environmental	Environmental	USGS NLCD 2011
Sidewalks and Bike Lanes	Lack of Bike Lanes and Walking Trails	Environmental	Google Maps – Google Streetview
Walkability	Walkability	Social	Walk Score website
Public Transit	Lack of Transportation Alternatives	Social	Google Earth
Access to Parks	Need for More Parks	Social	Digitized from Google Earth imagery
Access to Grocery Stores	Access to Fresh Food	Social	Google Maps; U.S. Census 2008-2012 ACS Estimates
Segregation	Race Relations, Social Issues	Social	U.S. Census 2008-2012 ACS Estimates
Crime Rate	Crime, Social Issues	Social	Birmingham Police Dept.

3.3.1 Data and Sources

The data for this research came from a variety of sources. The U.S. Census Bureau provided the the demographic and socio-economic data; with most of the data coming from the American Community Survey (ACS) 2012 5-year estimates. The data for roads, census tract boundaries, county boundaries, and city limits were obtained from the 2014 TIGER/Line shapefiles which also came from the Census Bureau website. Data for water features and land use came from the United States Geological Survey (USGS); the water was from the National

Hydrography Dataset (NHD) and the land use data from the National Land Cover Dataset (NLCD) 2011. Data that is specific to the City of Birmingham came from city departments. The Department of Planning, Engineering, and Permits provided GIS data for neighborhoods and communities, and the Birmingham Police Department provided crime data for 2013 by police beats and precincts. The remaining GIS data was digitized using imagery from Google Earth or ArcGIS Online. Finally, for the walkability SI, the Walk Score website was used; this site rates cities and individual addresses based on how easy it is to walk to most destinations. The Walk Scores are also a measure of the degree of mixed use in an area because the score is based on how many different types of businesses are located within walking distance of the address.

3.3.2 Area of Study

The study area for this research is limited to the city limits of Birmingham, AL. The neighborhoods as defined by the Department of Community Development are the specific areas of analysis. Figure 3.1 below shows the locations of the 99 neighborhoods of Birmingham. A more detailed map displaying the names of each neighborhood and community as well as major roads and surrounding municipalities can be found in the appendix of this paper.

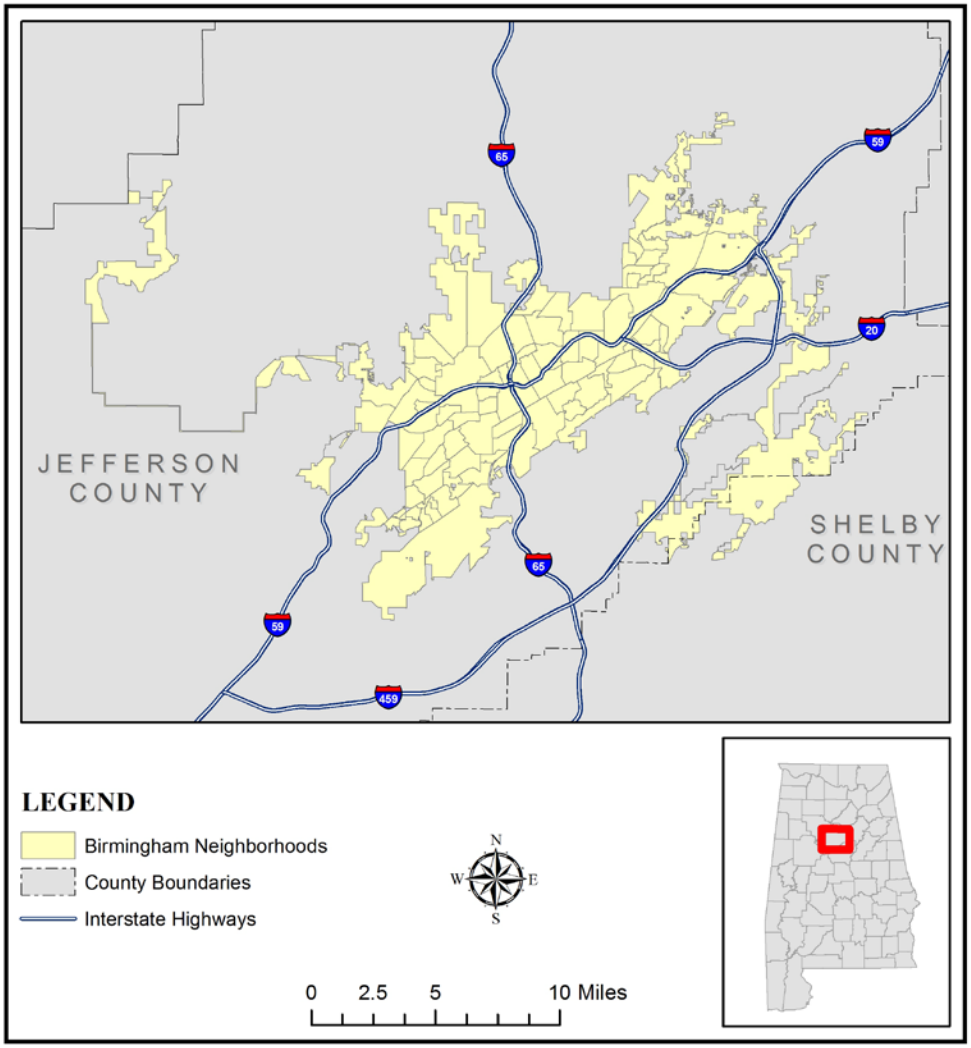

Figure 3.1 – Neighborhoods of Birmingham, AL

The City of Birmingham is located mostly in Jefferson County, but a small portion of the extreme southeastern part of the city lies in Shelby County. The city limits of Birmingham stretch across the center of Jefferson County in an east-west direction. The city is located in north-central Alabama and is the largest city in the state by population with 212,113 people in 2013 according to the U.S. Census Bureau (U.S. Census Bureau, 2014). Birmingham was founded in 1871, and was a major industrial center from the very beginning due to the availability of all the necessary ingredients to make steel. The city grew very rapidly in the late 19th and early 20th centuries reaching a peak population of 340,882 in 1960 before beginning to decline to a low of 211,441 in 2012 (Birmingham Public Library, 2014; U.S. Census Bureau, 2014). The racial composition of the city also began to change after 1960; the White population began to decrease as the African American population increased. In 1960, the city was 60.3% White and 39.6% African American, and in 2013 it was 22.3% White and 73.4% African American (Birmingham Public Library, 2014; U.S. Census Bureau, 2014).

3.3.3 Neighborhood Sustainability Assessment System

The NSA system developed for this research is comprised of seventeen indicators grouped into three categories: economic, environmental, and social. The indicators were normalized by assigning values of 1, 0, or -1 to each indicator. The method of assigning values to indicators differed depending on the unique characteristics of the indicator. The normalization of the indicator values allows them to be combined into total sustainability scores and allows tradeoffs between the different indicators when they are aggregated into total sustainability socres. Without normalization of the SI values it would be impossible to combine indicators such as unemployment, impervious surface area, food access, and segregation into total scores. After normalization, each category is worth six points each; one point for each indicator in the economic and social categories and 1.2 points for each indicator in the environmental category since there are only five environmental SIs. The fact that each category carries an equal weight in the NSA system ensures that there will not be excessive tradeoff between the categories.

For each indicator, a range of acceptable values was used to determine the score for each neighborhood. Depending on the nature of the indicator, the range of acceptable values may be based on how the indicator was used in other rating systems, previous research related to the indicator, or the distribution of the data for the indicator in Birmingham neighborhoods. For example, it is difficult to determine what the sustainable value should be for economic indicators like unemployment, but a range based on the distribution (standard deviations) of the unemployment data can be used to determine how the neighborhood compares to surrounding areas. In the case that an indicator's acceptable range of values is determined by the distribution of the data, the objective is to sort neighborhoods into the three possible scores (-1, 0, and 1) as evenly as possible. Using standard deviation as a method to sort neighborhoods into the three scores is relatively simple. Giving all neighborhoods that are more than 0.5 standard deviations away from the mean for the indicator a score of 1 or -1 (depending on the direction) and all neighborhoods that are within 0.5 standard deviations of the mean a score of 0 results in an almost evenly distributed set of scores for most indicators. This is based on the fact that, for normally distributed data, about 68% of all observations should fall within 1 standard deviation of the mean; therefore, about 1/3 (33-34%) of observations should fall within 0.5 standard deviations of the mean.

Once the values of all SIs have been determined for each neighborhood, the scores will be aggregated into a total sustainability score. Aggregation of different sustainability indicators and the application of different weights to indicators is one of the more contested topics in sustainability assessment literature (Sharifi & Murayama, 2012). Some would argue that aggregation of indicators results in excessive tradeoffs between the three pillars of sustainability (Berardi, 2013). The alternative to aggregation is displaying values for each indicator individually. For the purposes of this research, it was most useful to aggregate values to show overall sustainability of neighborhoods, but after neighborhoods with low values for sustainability have been identified, the values for individual indicators were used to determine how to improve sustainability for those neighborhoods.

The method for aggregating values in the NSA system used in this research was to normalize the values of the SIs by assigning values of -1, 0, and 1 for each SI in each neighborhood and combining those values together to form a total sustainability score. An SI value of -1 indicates that the neighborhood is below the acceptable value for the SI, a value of 0 indicates that the neighborhood has achieved the minimum acceptable value for the SI, and a value of 1 indicates that the neighborhood exceeds the minimum sustainable value for the SI. Similarly, when the normalized values for all indicators are combined together to form a total sustainability score, a neighborhood with a positive total sustainability score can be considered sustainable because it had sustainable values for the majority of the SIs. Using this simple method of aggregation, with each category having an equal weight, does not allow significant tradeoff between the three pillars of sustainability because negative scores in one category (indicating unsustainable values) take away from sustainability gained in other categories. For example, economically vibrant neighborhoods that are not environmentally or socially sustainable will have a negative aggregated value.

Economic Indicators. The economic indicators of the NSA include unemployment, poverty, vacant housing, commute time, high school diploma rate, and affordable housing. The data for all of these indicators was obtained from the U.S. Census Bureau ACS 2008-2012 dataset at the census tract level. The Areal Interpolation tool from the Geostatistical Analyst extension of ArcGIS was used to interpolate the data from census tracts to the neighborhood level. The Areal Interpolation tool allows users to take data aggregated at one spatial unit (census tracts, block groups, etc.) and predict values to another spatial unit. The tool works by using the method of kriging to create a prediction surface and then using the prediction surface to predict values at the new unit of area (see figure 3.1). Kriging uses the areas of observed values to predict values at unknown locations. The influence of observed values on the predicted values is determined by applying weights to all observed values within a specified distance of the predicted values' location. The weights are determined based upon a semivariogram, which is a model of the variance between observations at different locations; this can be thought of as a model of the degree of spatial autocorrelation depending on the distance between observations. Basically the assumption is that observations that are nearest to the predicted value will have the greatest influence on the predicted value. In figure 3.1, A is the data (white population) at the original areal unit, B is the prediction surface created by the areal interpolation tool, and C is the new predicted values for Birmingham neighborhoods.

Each of the economic indicators addresses at least one of the concerns mentioned by the citizens of Birmingham during the city-wide visioning forum (see tables 3.1 and 3.2). The city's economic problems are a significant barrier to sustainability in the city. As discussed earlier in the introductory sections, sustainability requires a balance of the economy, environment, and society, and if one of these are lagging behind then the city cannot be considered sustainable. According to the U.S. Census Bureau's QuickFacts page for the city, Birmingham has a poverty rate of 30.2% which is much higher than the average for the state of Alabama (18.6%) and the United States (15.4%) (U.S. Census Bureau, 2014).

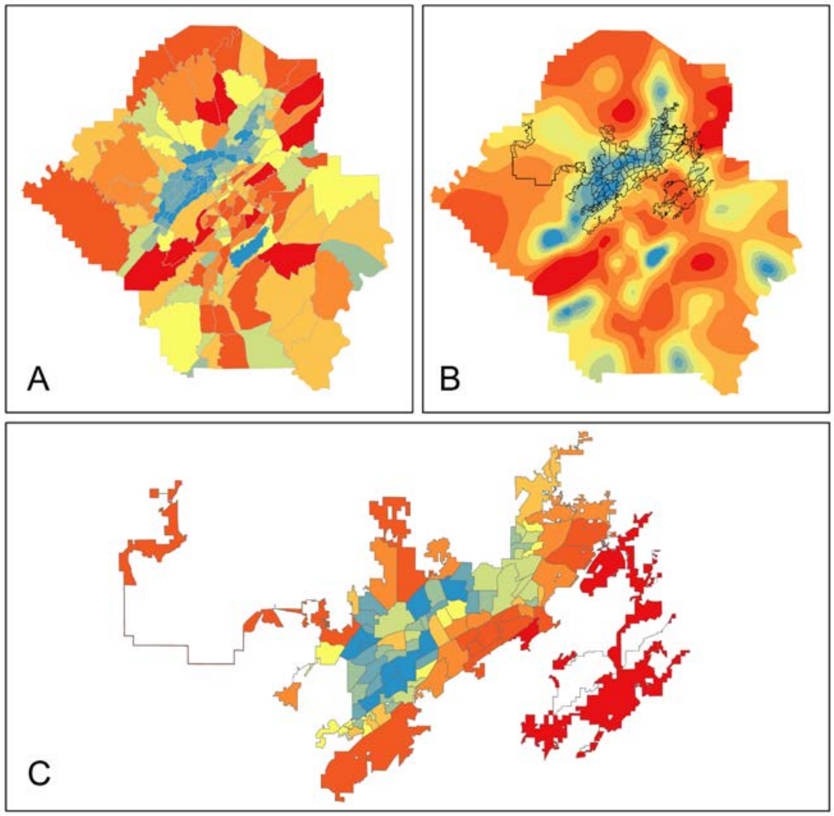

Figure 3.2 – Example of Areal Interpolation procedure in ArcGIS

The values for the economic indicators of unemployment, poverty, vacant housing, commute time, and percent with a high school diploma were calculated using the data from the U.S. Census directly. For affordable housing, the number of households paying greater than 30% of their income on housing in both the owner-occupied and renter-occupied households was divided by the total number of households sampled for that statistic. The threshold of 30% was used in order to comply with the definition of affordable housing provided by the U.S. Department of Housing and Urban Development (HUD) which describes families who pay more than 30% of their income on housing as “cost burdened” (U.S. Department of Housing and Urban Development, 2014). In addition to being a specific concern of the citizens of

Birmingham during the visioning forum, affordable housing has become a goal of HUD and a component part of smart growth strategies (Arigoni, 2001).

After the data for the economic indicators was interpolated from census tracts to neighborhoods, the distribution of the data was used to determine values for the indicator, using the method described earlier in the methods section. For the economic indicators, any neighborhood with a value within half of a standard deviation of the mean was given a 0; any neighborhood that was more than half of a standard deviation above the mean was given a 1, and any neighborhood that was more than half of a standard deviation below the mean was given a negative value. Using half of a standard deviation ensured that the neighborhoods were sorted almost evenly into the three possible values.

Environmental Indicators. The environmental indicators are the SIs most focused on the well-being of future generations. These indicators are concerned with biodiversity, air quality, and water quality, the natural resources that no society can live without. By focusing on how the built environment impacts the natural environment, these indicators promote environmental protection for future generations. Values for the environmental indicators were determined through examination of other rating systems and literature focused on each indicator. Each indicator in the environmental category is worth 1.2 instead of 1.0 because there are only five SIs in the category while the other two categories both have six.

Intersection density is an indicator of connectivity within the street network. This is important because a higher degree of connectivity enables drivers to take more direct routes to their destinations, using less fuel and contributing less to air pollution. Intersection density is used as an indicator in the Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) rating system, which is one of the most commonly used sustainability assessment systems for new neighborhood developments in the United States. The acceptable range of values for the intersection density SI in this research based upon those used by the LEED-ND system which recommends an intersection density of at least 120 intersections per square mile surrounding a neighborhood development in order to improve connectivity and accessibility (U.S. Green Building Council, 2009). Data for intersection density was derived from the Census Bureau's TIGER/Line shapefile for streets. The data was loaded into ArcGIS and the Intersect tool was used to place a point on each intersection. The points generated using the Intersect tool were then checked for duplicate values using the Delete Identical tool which deletes features with identical locations. Finally the number of intersection points for each neighborhood was divided by the area of the neighborhood to get the intersection density for each neighborhood. Neighborhoods with less than 120 intersections per square mile were given a value of -1, those with 120-200 intersections per square mile were given a value of 0, and those with more than 200 intersections per square mile were given a value of 1.

Proximity to water features is another indicator that is used in LEED-ND and other rating systems. It is important to set aside a buffer around water features in order to reduce runoff and allow vegetation to filter pollution from urban areas and to protect biodiversity. According to Ch. 4, "Natural Resources and Environmental Constraints", of the Comprehensive Plan, there are 26 endangered species in Jefferson County (City of Birmingham, 2013). Protecting these endangered species as well as the ecosystem as a whole should be a priority, and it will be critical in order for Birmingham to become a sustainable city. The acceptable range of values for the proximity to water features SI was determined through an examination of planning literature. In their review of literature relating to stream buffers, Castelle, Johnson and Conolly (1994) found that stream buffers of less than 5-10m offered little protection and buffers of 15-30m should be the minimum in order to protect water quality of streams; based on their findings, neighborhoods which have development within 15 meters of a stream feature received negative values for the proximity to water features SI. Water features data used for this indicator came from the USGS National Hydrography Dataset, and data for developed areas was taken from the National Land Cover Dataset (NLCD). The NLCD dataset was reclassified to display only developed versus undeveloped land, and a simple buffer analysis was used to determine if a neighborhood had adequate stream buffers. The Intersect tool was used to identify developed areas that were located within the stream buffers of 15 meters and 30 meters; these areas were then split by the neighborhood boundaries using the Split tool in ArcGIS. The results of the Split tool were then exported to a table and analyzed in Microsoft Excel. Neighborhoods which had no development within the 30 meter buffer received a value of 1 for the indicator, those with development within the 15 meter buffer received a -1, and those with development within the 30 meter buffer but not the 15 meter buffer received a 0.

Impervious surfaces have also been shown to have a significant impact on the quantity and quality of storm water runoff and to cause damage to the natural environment (Arnold & Gibbons, 1996; Brabec, 2002). The acceptable range of values for the impervious surface indicator was determined through examination of other rating systems and literature on the impact of impervious surface on water quality. According to Arnold and Gibbons (1996) watersheds with 10% or less of impervious surface coverage can be considered protected; impervious surface begins to have a real impact on water quality when impervious surfaces cover more than 10% of the land area, and water quality becomes noticeably degraded when impervious surface coverage exceeds 30%. Impervious surface coverage for each neighborhood was estimated based on the NLCD dataset which defines urban classes based upon the percentage of impervious surface coverage. In order to estimate total impervious surface in each neighborhood, the NLCD dataset was converted to a vector format and split by neighborhood boundaries in ArcGIS. The area of the polygons was then calculated and multiplied by the impervious surface percentages associated with the developed land use classifications of the NLCD dataset to get an estimate of impervious surface within the polygons. The total of estimated impervious surface area within each neighborhood was then divided by the total area of the neighborhood in order to get impervious surface coverage by neighborhood. In accordance with Arnold and Gibbons (1996), neighborhoods with less than 10% impervious surface area received a score of 1.2 for this SI while those with greater than 30% received a score of -1.2; all neighborhoods with 10-30% impervious surface coverage received a neutral value of 0.

The Development Footprint (DF) is a ratio of developed land area to population in thousands; it is an indicator of how large the physical footprint is for an individual has that lives in the neighborhood. Basically, the DF can be thought of as an indicator of population density, although it accounts for the land area occupied by all development in the neighborhood instead of just the area occupied by housing. It is important to keep the amount of space occupied by development as low as possible to ensure that the natural environment and prime agricultural land is preserved. DF is measured by dividing the developed land area (acres) by thousands of people. Rashed-Ali (2012) used the DF indicator in the neighborhood sustainability assessment of San Antonio with values of 40.0 (0.04 acres per capita) and 400.0 (0.4 acres per capita) as the upper and lower thresholds; in this NSA the thresholds for DF were 100.0 (0.1 acres per capita) and 300.0 (0.3 acres per capita) because these numbers better represented the City of Birmingham which has very few neighborhoods with a DF higher than 400. DF was calculated using Block-level data from the 2010 U.S. Census and the NLCD 2011 land cover dataset. The block data was used to determine the total population of neighborhoods. Blocks are the smallest available unit of area that population estimates are made for by the U.S. Census Bureau, and they are especially small in urban areas like Birmingham. The blocks were assigned to neighborhoods using a spatial join, and the populations were totaled for each neighborhood. The NLCD data was then used to determine the amount of developed area within the neighborhoods using the same method that was used to calculate impervious surface coverage. The DFs for each neighborhood were calculated by dividing the developed area of the neighborhood by the total population within the neighborhood. Neighborhoods with a DF lower than 100 received a score of 1.2 for the SI while those that had a DF of 300 or more received a score of -1.2, and all neighborhoods with a DF of 100-300 received a neutral score of 0.

The availability of sidewalks and bike lanes is used as an indicator of how easy it is for neighborhood residents to use active forms of transportation, contributing less to air pollution associated with the use of motor vehicles. GIS data for sidewalks and bike lanes was not available from the City of Birmingham's GIS department, so it was necessary to take a random sample of points from each neighborhood and check for the availability of sidewalks and bike lanes at those locations. The random sample of points was generated in ArcGIS; it consisted of 990 points (10 for each neighborhood) which were then checked for sidewalk and bike lane coverage using Google Maps Street View imagery. The percentage of randomly sampled points having sidewalks or bike lanes was used to determine the SI value. Neighborhoods with less than 50% coverage of sidewalks received a value of -1.2, those with 50-75% coverage received a value of 0, and those with 75-100% coverage received a value of 1.2.

Social Indicators. The social indicators are those that are focused on the quality of life offered by each neighborhood. They include accessibility to necessities like grocery stores and public transit as well as accessibility to parks and the degree of mixed use and walkability. Social issues like segregation and crime are also addressed by the indicators in this category.

Walkability is important for social sustainability for several reasons. Living in a walkable neighborhood has been shown to have a positive impact on public health (Frank et al. 2009; Sallis et al., 2009), and it also increases the overall quality of life in a neighborhood. The values for the walkability SI were based on the walk scores of the neighborhood centroids. Walk scores are calculated based on the amount of time it takes to walk to destinations like restaurants, grocery stores, retail stores, etc. from a particular address. The address receives the maximum amount of points for destinations that are located within 0.25 miles and less points for destinations that are farther away depending on distance (Walk Score, 2014a). The walk score is a measure of how walkable an area is as well as a measure of mixed-use. The walk score website separates neighborhoods into three different categories based upon their walk score. Neighborhoods with a walk score of 0-49 are considered to be “car-dependent”, meaning that almost all trips require a car. Neighborhoods with a walk score of 50-69 are “somewhat walkable”, those with a walk score of 70-89 are “very walkable”, and those with a walk score of 90-100 are “walker’s paradise” (Walk Score, 2014b). Aside from areas of downtown, such as Central City, Southside, and Five Points South neighborhoods, most of Birmingham has a very low walk score. The average score for the City of Birmingham is only 33, meaning that the city as a whole is “car-dependent” according to the walk score system (Walk Score, 2014a). Because of the low values for walk scores in Birmingham, the SI scores were based on the distribution of the data using the same strategy employed for the economic SIs. The walk score for each neighborhood was retrieved by entering the coordinates of the neighborhood centroid into the walk score website and recording the walk score at the address nearest the centroid.

Access to public transit is another important social indicator because without public transit, people who are very young, very old, or very poor are at a severe disadvantage. The value for this SI was determined based upon the average walking time from a bus stop within each neighborhood. Bus stops were digitized from the Google Earth's transportation layer, and the walk times were determined through the use of a cost-distance tool that uses minutes of travel as the cost accumulator. In order to determine walking speed in the cost-distance tool, Tobler's Hiking function was used. Tobler's Hiking Function is a non-isotropic geographic modeling technique that uses slope to estimate walking speed (Tobler, 1993). The formula for Tobler's Hiking function is as follows:

$$W = 6 * \exp \{-3.5 * \mathrm{abs}\ (S + 0.05)\}$$

Where W is the walking velocity (km/h) and S is the slope of the terrain expressed in degrees. The cost-distance tool was created for this project and was based upon a methodology developed in Juliao (1999) which allows for travel off of the street network. The formula used for cell crossing time (CCT) in the cost-distance tool is as follows:

$$CCT = \frac{P \times 60}{TS \times 1000}$$

Where P is the size of the pixel and TS is the travelling speed (km/h). In the tool, walking speed is highest when walking along local streets (excluding major highways) on the street network; off-network walking speed was determined by multiplying the speed provided by Tobler's Hiking Function by 3/5, as suggested by Tobler (1993). The output of the cost-distance tool is a raster image in which each pixel's value is the amount of time it takes to walk to a source feature from that location. In the case of the public transit SI, the source features are bus stops. Figure 3.3 shows the output of the cost-distance tool for the public transit SI. The values for the cost-distance tool were averaged for the populated areas of each neighborhood using the Zonal Statistics tool in ArcGIS, and these averages were used to determine the value for the SI. Neighborhoods with average walk times of 5 minutes or less received a 1, those with walk times of 5-15 minutes received a 0, and those with greater than 15 minutes received a -1.

Access to public parks is another important social indicator. While it is not as critical as some other indicators, parks can have a significant impact on the quality of life for a neighborhood. The City of Birmingham's comprehensive plan states that they strive to have a public park or green space within a 10 minute walk of all residents within the city. The same cost-distance tool used in the public transit access SI was used for this SI. In accordance with the goals of the City, neighborhoods with average walk times of less than 10 minutes received a 1, those with walks of 10-15 minutes received a 0, and those with walks greater than 15 minutes received a -1.

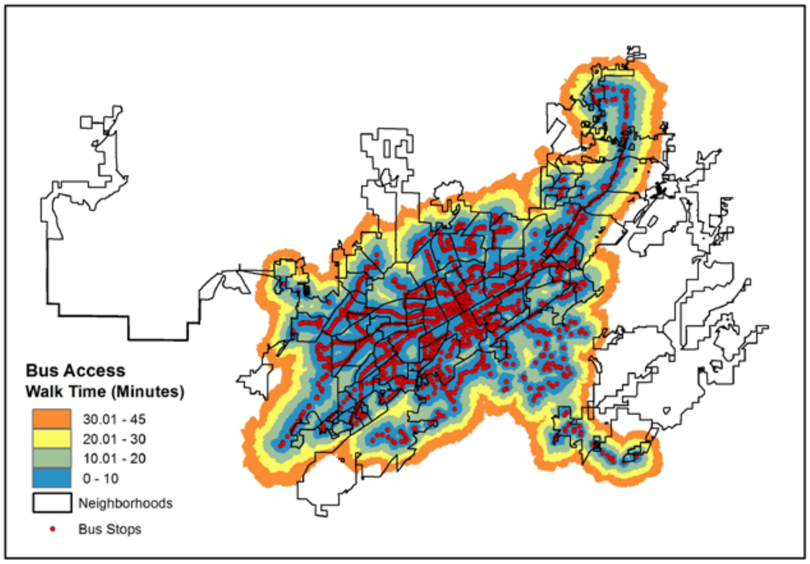

Figure 3.3 – Access to Public Transit (cost-distance example)

Access to grocery stores is one of the most important social indicators. Access to fresh, healthy, and affordable food has a serious impact on public health and well-being. For the grocery store access SI, the definition of a food desert was used to determine acceptable values. A food desert is a low income area with limited access to stores that offer affordable healthy food (Jiao et al., 2012). Based on the work of Jiao et al. (2012), food deserts can be identified as areas with more than 20% of households in poverty and more than one mile away from a grocery store. Therefore, poverty is a prerequisite for an unsustainable value for grocery store access; more wealthy neighborhoods received an acceptable value of 0 if there were no grocery stores within two miles because they have the means to overcome the distance. In order to determine which neighborhoods were located in a food desert, grocery stores were identified and mapped in Google Earth. One and two mile buffers were then placed around the grocery store points and those neighborhoods with centroids falling inside the one mile buffer received a 1, those falling between the one and two mile buffers received a 0, those falling outside the two mile buffer and having a poverty rate less than 20% also received a 0, and those falling outside the two mile buffer and having poverty rates greater than 20% received a -1. Figure 3.4 shows the locations of grocery stores, the buffers used to determine grocery store accessibility, and the score received by each neighborhood for the grocery store access SI.

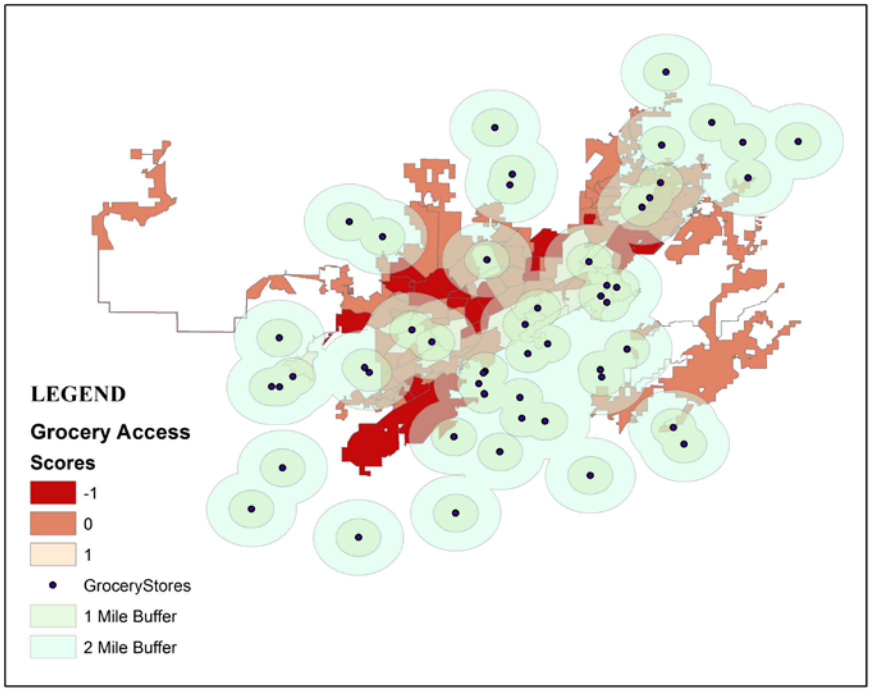

Figure 3.4 – Grocery store access example map

Another social indicator, segregation, has been a source of civil unrest in Birmingham's history. The City had a racial zoning code in place longer than any other city in the U.S. (Connerly, 2000). Although the city has come a long way since the days of racial zoning and the Civil Rights Movement, it is still plagued by racial issues like segregation. The racial makeup of the city has changed dramatically since the Civil Rights Movement in the 1960s; the city has been losing population since the 1960s, and the proportion of the population that is white has been falling drastically from a high of 60.1% in 1960 to a low of 24.1% in 2000 (Birmingham Public Library, 2014). The acceptable value for segregation will be determined by the city's Dissimilarity Index (DI). The DI is a measure of how different the racial makeup of the neighborhood is from the racial makeup of the city as a whole. For example, if the city was 50% white and 50% African American and every neighborhood had exactly the same proportion of the two races, the DI would be 0; however, if every neighborhood was 100% white or 100% African American, the DI would be 100. The formula for DI is as follows:

$$DI = \frac{1}{2}\sum_{i=1}^{N}\left|\frac{b_i}{B} - \frac{w_i}{W}\right|$$

Where b_i = is the black population at the i^{th} area, B is the total black population of the city, w_i is the white population of the i^{th} area, and W is the total white population of the city. The DI for the Birmingham metropolitan area is 77.4 according to Social Science Data Analysis Network (2009), making it the 15^{th} most segregated metropolitan area in the country. In order to determine the value of the DI indicator, the city DI was calculated by assuming all neighborhoods have the same racial makeup as the neighborhood in question; the scores for each neighborhood was determined by comparing the DI of the neighborhood with the distribution of the data, using the same methods that were employed with the economic indicators.

The final social indicator, crime rate, was one of the issues mentioned specifically by citizens in the Citywide Visioning Forum for the Birmingham Comprehensive Plan (2013). Crime is an important social indicator because it influences how safe people feel in the neighborhood. Crime data was supplied by the Birmingham Police Department for robbery, homicide, rape, burglary, theft, unlawful breaking and entering of a vehicle (UBEV), auto theft, and assault by precinct and police beats. Police beats were digitized in ArcGIS and the data from the Birmingham Police Department was joined to the shapefile. Areal interpolation was used to get estimates of total population in each police beat, and crime rate was calculated by dividing the total number of the crimes in the data by the number of people living in the police beat. The crime rates were then interpolated from the police beat unit of area to the neighborhood unit using the Areal Interpolation tool in ArcGIS. Values for the crime rate SI were determined by comparing the crime rates of neighborhoods to the distribution of the crime rate data. Neighborhoods with crime rates less than 0.5 standard deviations from the mean were assigned a value of 1, those within 0.5 standard deviations from the mean were assigned a value of 0, and those more than 0.5 standard deviations from the mean were assigned a -1.

3.4 Exploratory Spatial Data Analysis

The results of the NSA were analyzed in an exploratory manner, looking for patterns in the dataset that could provide some insight into the distribution of sustainability among Birmingham neighborhoods. The distribution of the data was first observed in a histogram and basic statistics were calculated for the total sustainability scores as well as the totals for each category. An analysis of variance (ANOVA) test was performed on the data to test for statistically significant differences between the three sustainability categories. After viewing the data in tables and graphs, choropleth maps were created in ArcGIS in order to visually examine the spatial distribution of sustainability scores and, following the process of Exploratory Spatial Data Analysis (ESDA), measures of spatial autocorrelation both global and local were calculated and visualized.

The process of ESDA was used to analyze the spatial patterns in the results of the NSA applied in this research. The ESDA process can be described as:

> "a set of techniques aimed at describing and visualizing spatial distributions, at identifying atypical localizations or spatial outliers, at detecting patterns of spatial association, clusters or hot spots, and at suggesting spatial regimes or other forms of spatial heterogeneity" (Le Gallo & Ertur, 2003).

ESDA may lead to insights that were not identified through other methods of analysis; for example, a choropleth map could reveal that one of the low outliers is surrounded by areas of high values or vice versa, indicating an unusual situation that may require further inquiry

(Fatheringham & Charlton, 1994). A simple choropleth map can be a powerful tool for identifying spatial patterns, but there are many other methods that can reveal more complex relationships and patterns.

Spatial autocorrelation, the phenomenon in which objects with similar locations (being located near one another) also have similar values, is central to the ESDA process (Anselin, 1998). The Moran's I statistic, a statistic used to indicate the degree of spatial autocorrelation within a dataset, can be used to determine whether there is significant clustering of high or low values within a spatial dataset (Murray et al., 2001). A dataset that is significantly clustered is one in which areas located near one another have similar values; datasets could also have a negative spatial autocorrelation in which high values are located near low values, or they could also have no spatial pattern at all. The Moran's I statistic is a measure of global spatial autocorrelation which summarizes the overall pattern of spatial autocorrelation into a single indicator. The equation for the Moran's I statistic is as follows:

$$\mathrm{I} = \frac{n \sum_i^n \sum_j^n w_{i,j} z_i z_j}{(n-1) \sum_i^n \sum_j^n w_{ij}}$$

Where n is the total number of features, z_i is the deviation of an attribute for feature *i* from its mean, and w_{ij} is the spatial weight between features *i* and *j*.

The numerator of the equation is the key to understanding how the Moran's I statistic works. In the numerator, z-values (difference from the mean) for the two features being considered are multiplied together. If the z values are similar (both above the mean or both below the mean) then the numerator will be positive, and if the values are different (one above and one below), then the numerator will be negative. The spatial weights (w_{ij}) are also important in understanding the Moran's I equation. The spatial weights are a measure of the proximity of features *i* and *j*. The spatial weights can be defined several different ways, but perhaps the most common method is one of binary connectivity (Rogerson, 2010). Using the binary connectivity method, features that share a boundary with one another are given a spatial weight of 1, and features that do not share a boundary are given a spatial weight of 0. This method ensures that areas that are nearest one another are given the highest spatial weights. The value for the Moran's I statistic can range from +1 to -1. Values that are near +1 indicate a strong spatial pattern and clustering of similar values in the dataset while values near -1 indicate a strong negative spatial autocorrelation with high values being located near low values (Rogerson, 2010). Values of 0 indicate that there is no spatial pattern, or in other words, a random distribution within the data. The results of the Moran's I equation can be evaluated using a simple z-test to determine whether the value of the Moran's I is statistically significant.

Global measures of spatial autocorrelation, like the Moran's I statistic, can reveal the overall spatial pattern in a dataset, but they offer no information about how spatial autocorrelation varies through space within the dataset and are therefore not very meaningful for examining spatial patterns (Anselin, 1998). In order to determine the spatial patterns within the neighborhood sustainability dataset, it is necessary to use local indicators of spatial autocorrelation (LISA) such as the Local Moran statistic. The Local Moran is used to identify areas with dissimilar values (areas of local instability) and areas of similar values (clusters); this reveals which areas contribute most to spatial autocorrelation within the dataset (LeGallo & Ertur, 2003). The equation for the Local Moran statistic is as follows:

$$I_i = z_i \sum_{j}^{n} w_{i,j}\, z_j$$

Where z_i is the deviation of feature i from the mean, $w_{i,j}$ is the spatial weight between features i and j, and z_j is the deviation of feature j from the mean. The Local Moran statistic is similar to the Moran's I statistic in that it involves multiplying the difference from the mean of the feature *i* with the difference from the mean of the surrounding features. If the values of the surrounding features are similar to the feature *i*, then the value for the Local Moran statistic will be high, but if the values are different, the statistic will be low; this is the same concept that was described in the numerator of the Moran's I statistic in the paragraph above. A very high Local Moran statistic indicates that the feature shows a strongly positive relationship with the surrounding features, whereas a very low Local Moran statistic indicates that the feature shows a strongly negative relationship with surrounding features. The significance of the Local Moran statistic can also be evaluated using a z-test.

The Getis-Ord GI* statistic is another LISA statistic that can be used to identify hotspots (significant clusters of high values) and coldspots (significant clusters of low values) within a spatial dataset. In this research both the Local Moran and the Getis-Ord GI* statistics were used to examine the spatial distribution of sustainability in Birmingham neighborhoods. Understanding these spatial patterns within the neighborhood sustainability scores dataset will help planners and city officials better understand how the sustainability of neighborhoods are related to one another and will help them make better, more informed decisions. The formula for the Getis-Ord GI* statistic is as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}}$$

Where S is the sample standard deviation of the attribute values, $\overline{X}$ is the mean of the attribute values, x_j is the attribute value for feature j, and $w_{i,j}$ is the spatial weight between features i and j. The equation for the Getis-Ord GI* statistic compares the weighted value of *x* in the region of *i* (region determined by the search distance defined by the user) to the expected value if the region was average (Rogerson, 2010). The Getis-Ord GI* statistic is a z-value, so the values can be used to determine the significance of the observation. A significantly positive value indicates a hotspot, and a significantly low value indicates a coldspot.

4.0 RESULTS AND DISCUSSION

The results of the NSA show that very few neighborhoods scored well in all three categories of sustainability. The average sustainability score in the assessment was 0.11, which is a positive number but still very low; the possible range of scores was -18 to 18. The highest value was 9 and the lowest value was -9.4. The histogram (figure 4.1) shows the distribution of the sustainability scores. The distribution appears to be negatively skewed and not significantly peaked, with the majority of values falling between -4 and 5.

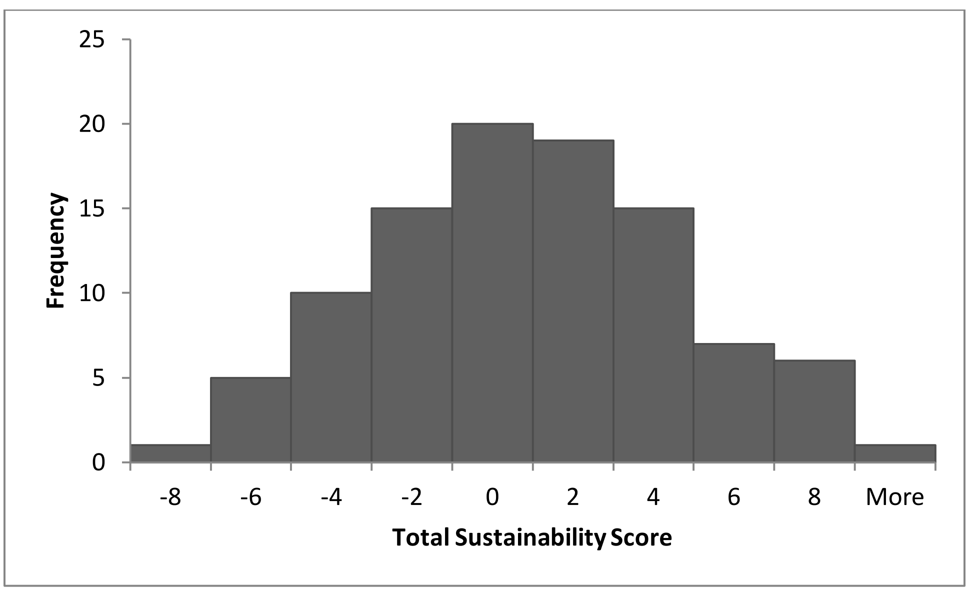

Figure 4.1 – Histogram of total Sustainability scores

Overall neighborhoods scored best in the social category and worst in the economic category. The average score for the economic indicators was -0.15, for the environmental indicators the average was -0.12, and the average for social indicators was 0.38. Table 4.1 shows descriptive statistics for total sustainability score as well as the three categories.

Table 4.1
Descriptive statistics for NSA score categories

Category	Mean	Median	Mode	Standard Deviation	Kurtosis	Skewness
Total	0.11	0.20	-4.20	4.08	-0.78	-0.11
Economic	-0.15	0.00	-3.00	2.97	-0.96	0.28
Environmental	-0.12	0.00	-1.20	1.85	-0.50	0.17
Social	0.38	0.00	0.00	2.09	-0.84	0.09

As table 4.1 shows, the scores were very low for all three categories of sustainability. Only seven neighborhoods received positive scores in all three categories, and 17 neighborhoods failed to receive a positive score in any of the three categories. These numbers reveal that an overwhelming majority of neighborhoods in Birmingham cannot be considered sustainable and have significant problems in at least one of the three categories of sustainability.

An ANOVA test was used to determine if there were significant differences between the values of the economic, environmental, and social sustainability scores. The results of the ANOVA test showed that there was not a significant difference between the scores in the three categories. In other words, although the neighborhoods seemed to score better in the social category than the economic and environmental categories, the difference between the three was not statistically significant.

4.1 Exploratory Spatial Data Analysis Results

In this section, the results of the ESDA of the sustainability data will identify the spatial patterns within the NSA results, and reveal the spatial relationships between neighborhoods. The first step in the ESDA process was to create choropleth maps of the total sustainability scores for each neighborhood, the economic category scores, the environmental category scores, and the social category scores in order to visualize the spatial distribution of sustainability. The first choropleth map (figure 4.2) shows Birmingham neighborhoods grouped into three classes: neighborhoods with total sustainability scores less than -1, neighborhoods with total sustainability scores between -1 and 1, and neighborhoods with sustainability scores greater than 1. Grouping the neighborhoods into these three categories shows which neighborhoods received very low scores, which ones scored close to zero, and which ones received positive scores for the majority of the sustainability indicators. Overall, 38 neighborhoods scored less than -1, 37 scored greater than 1, and 24 scored between -1 and 1. The map revealed that most of the high-scoring neighborhoods were located close to the edges of the city, especially the southern edge. There is a linear pattern of low scores that appears to closely follow the path of Interstate 20 and the major industrial areas just north of the interstate.

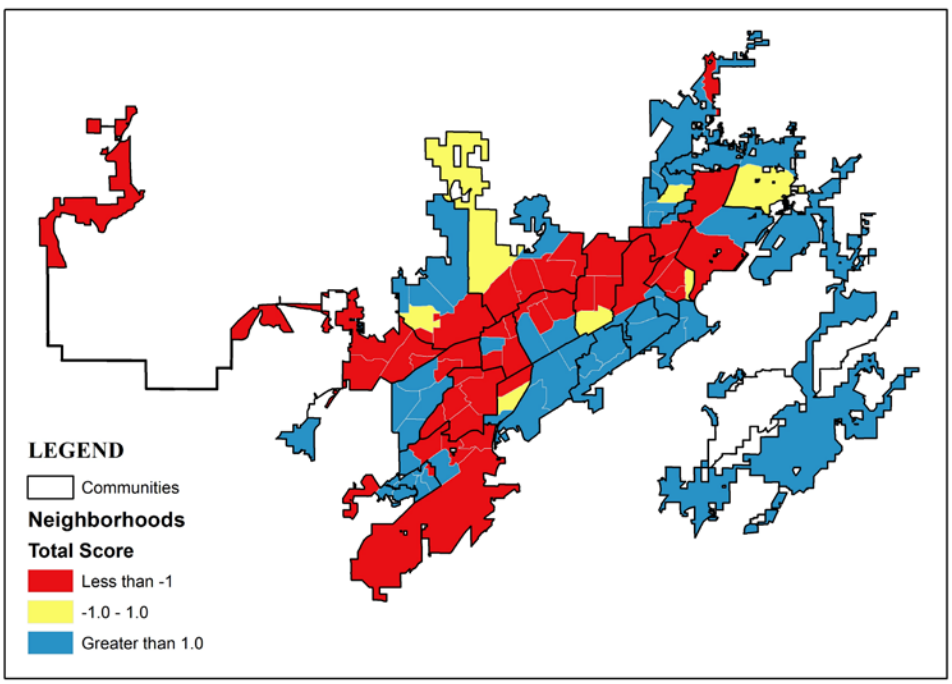

Figure 4.2 – Map of total sustainability scores by neighborhood

The maps of the economic, environmental, and social category scores showed a less obvious pattern. The map of the economic scores (figure 4.3) closely resembles the map of the total scores, but the environmental (figure 4.4) and social scores (figure 4.5) maps appear to be more randomly distributed. The neighborhoods scoring lowest in the environmental categories were the ones with predominantly industrial land uses followed by the neighborhoods furthest away from the city center. The lower environmental scores for the outer-most neighborhoods was likely due to the fact that they were less likely to have sidewalks or easy access to parks and public transit than the older, more centrally located neighborhoods. The higher environmental scores in the downtown area show the many advantages of the central business district (CBD) urban form. These areas are high density, meaning a low DF; they also have nearly 100% sidewalk coverage and a very dense street network. The only drawback to the CBD in the environmental category is the high percentage of impervious surface coverage, but converting some parking lots and other concrete surfaces to parks and open space could limit the impervious surfaces coverage. The downtown area certainly offers a great opportunity to create a more sustainable urban environment. The social scores map was by far the most randomly distributed of the three maps; there were no obvious spatial patterns that could be observed from the choropleth map of social scores. This is likely due to the differing spatial patterns of the SIs used for the social category. The accessibility to public services indicators show a pattern of having high values in and around the CBD while the SIs for crime and segregation show the opposite pattern.

The next step in the ESDA process after the visual interpretation of the choropleth map was to examine the spatial autocorrelation within the NSA results. The Moran's I statistic as calculated by the Spatial Autocorrelation tool in the Spatial Statistics toolbox of ArcGIS for the variable of total sustainability score was used to determine the degree of spatial autocorrelation. The result of the Spatial Autocorrelation tool was a Moran's Index of 0.426323 with a Z-score of 7.07 and a P-value of less than 0.01, revealing that the total sustainability score showed a high degree of spatial autocorrelation and was significantly clustered. The Spatial Autocorrelation tool was also used to determine the degree of spatial autocorrelation of the values of the total economic, environmental, and social sustainability scores. The results of the Spatial Autocorrelation tool for the three categories revealed that the economic and environmental categories were also significantly clustered, but, as observed in the analysis of choropleth maps, the social category was randomly dispersed.

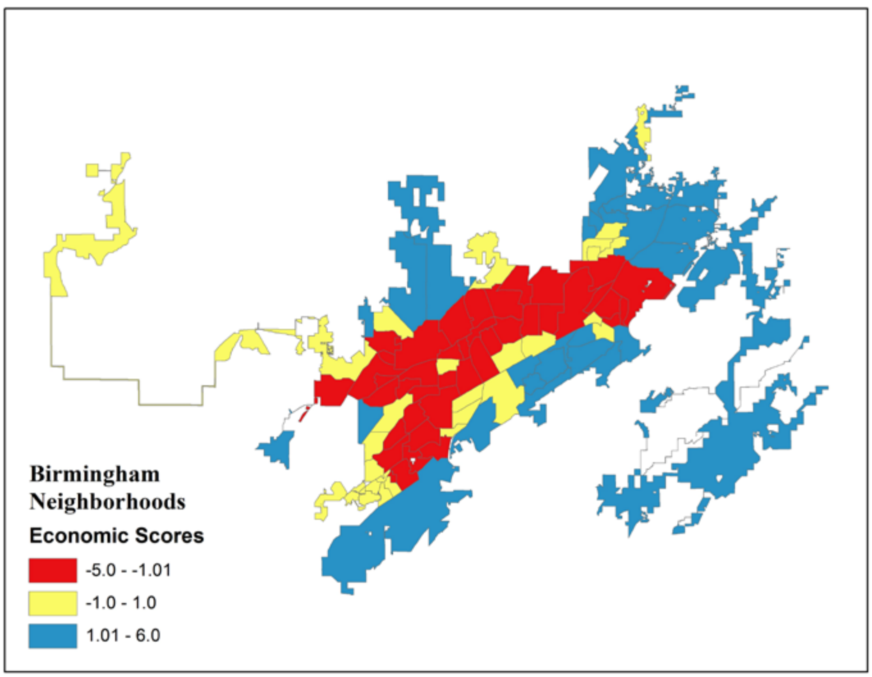

Figure 4.3 – Economic scores choropleth map

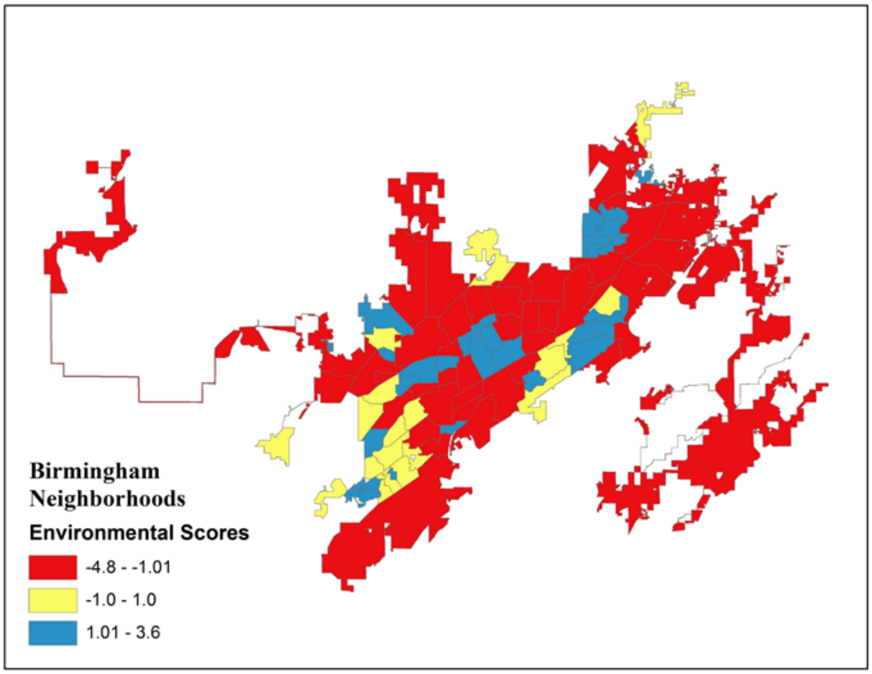

Figure 4.4 – Environmental scores choropleth map

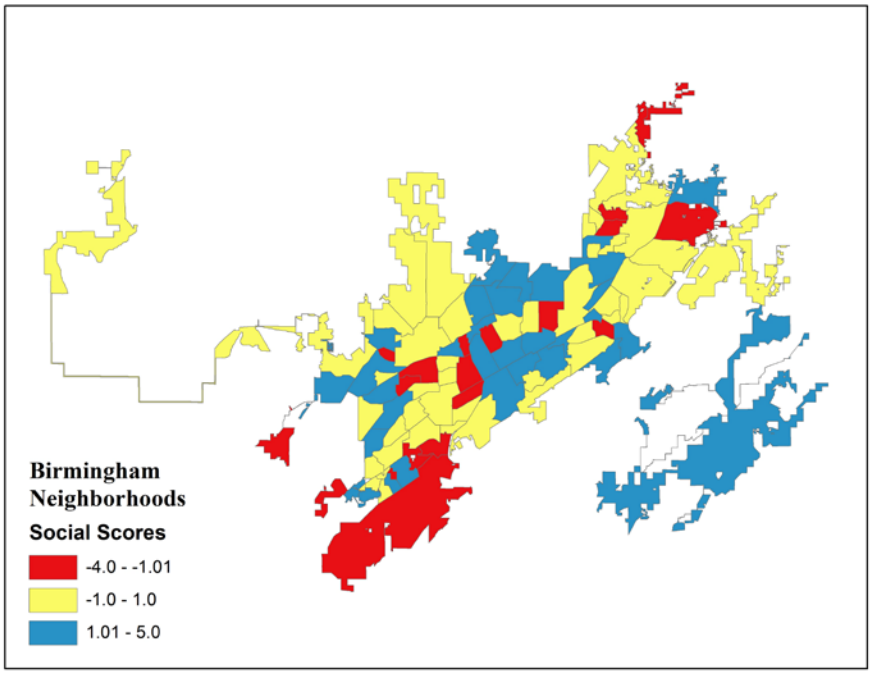

Figure 4.5 – Social scores choropleth map

Upon closer examination, the indicators within the social category, individually, did not have a random distribution. The social SIs each exhibited a clustered pattern, but their patterns were different enough from one another that, when combined, the totals for the social category were randomly distributed. The walkability, public transit, and parks access indicators all tended to be positive in the more centrally located neighborhoods. The segregation and access to grocery stores SIs had the most random distribution of the social indicators, but each had some degree of clustering. The crime rate and segregation indicators both had clusters of high values in the downtown and central neighborhoods with clusters of low values in the neighborhoods in the southern part of the city. The fact that the SIs in the social category had differing spatial patterns resulted in a random distribution for the social category scores. This demonstrates the loss of information on the spatial patterns of the individual SIs associated with the combination of the SI values in to category scores and total scores. However, the combination of the SI values enables observation of the phenomena of sustainability, to which the SIs contribute.

The Moran’s I statistic is a measure of global spatial autocorrelation, meaning that it yields one result for an entire dataset. Global spatial autocorrelation measures are useful for determining the degree of spatial autocorrelation within an entire dataset, but in order to see relationships within the dataset, it is necessary to use local indicators of spatial autocorrelation (LISA) statistics. The Spatial Statistics toolbox of ArcGIS offers several tools for examining patterns of local spatial autocorrelation. The Cluster and Outlier Analysis tool uses the Local Moran’s I statistic to identify clusters of similar values within the dataset, which contribute greatly to the global spatial autocorrelation, and spatial outliers (values that are significantly different from surrounding values) which exhibit a low degree of spatial autocorrelation. Another tool that can be useful for examining local spatial autocorrelation is the Hot Spot Analysis tool which uses the Getis-Ord GI* statistic to identify hot spots and cold spots within the dataset. Using the Getis-Ord GI* statistic, one neighborhood having a high value does not necessarily constitute a hot spot; with the Hot Spot Analysis tool, a neighborhood can only be considered a hot spot if it is also surrounded by other neighborhoods that have a high value. When calculating the LISA statistics, the method of defining spatial weights was the contiguity (edges and corners) method in which polygons which share a boundary or corner are used in the calculations.

The results of the Cluster and Outlier Analysis tool for total sustainability scores showed that there were no significant spatial outliers and four areas of significant clustering. There were two clusters of low values and two clusters of high values. The low clusters were located near the interstates and industrial areas in the western part of the city and the airport in the eastern part of the city. The high clusters were located in the southeastern part of the city around the Red Mountain and Crestwood communities and in the western-most part of the city between the Grasselli and Brownville communities. The results of the hot spot analysis mirrored the results of the cluster and outlier analysis except that the P-values were slightly higher, meaning that the hot spots and cold spots are slightly larger than the clusters identified in the cluster and outlier analysis. Figure 4.6 shows a map of the Cluster and Outlier results, and figure 4.7 shows a map of the Hot Spot analysis results.

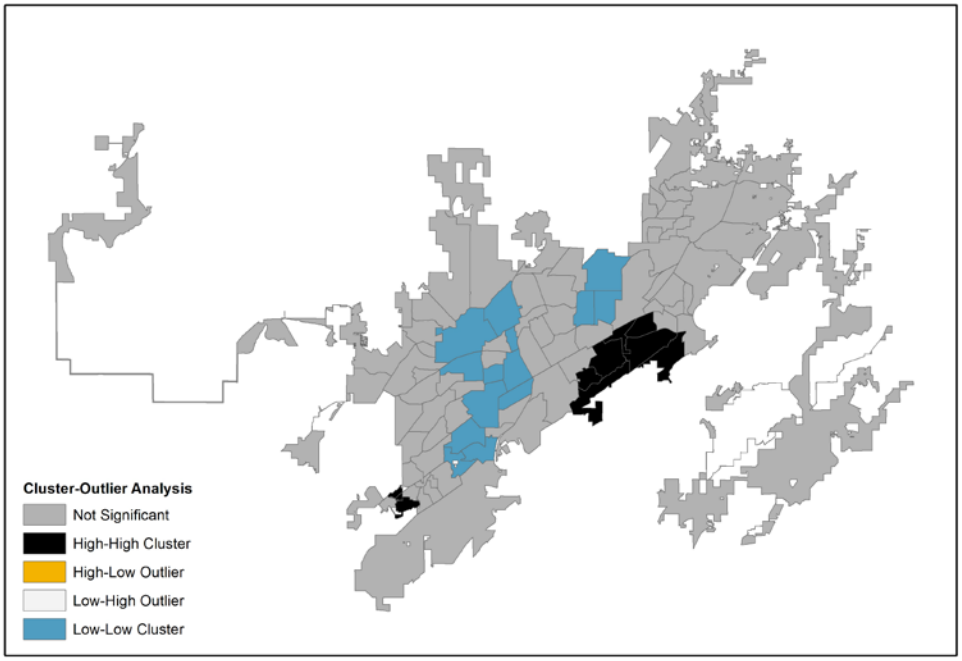

Figure 4.6 – Cluster and Outlier Map

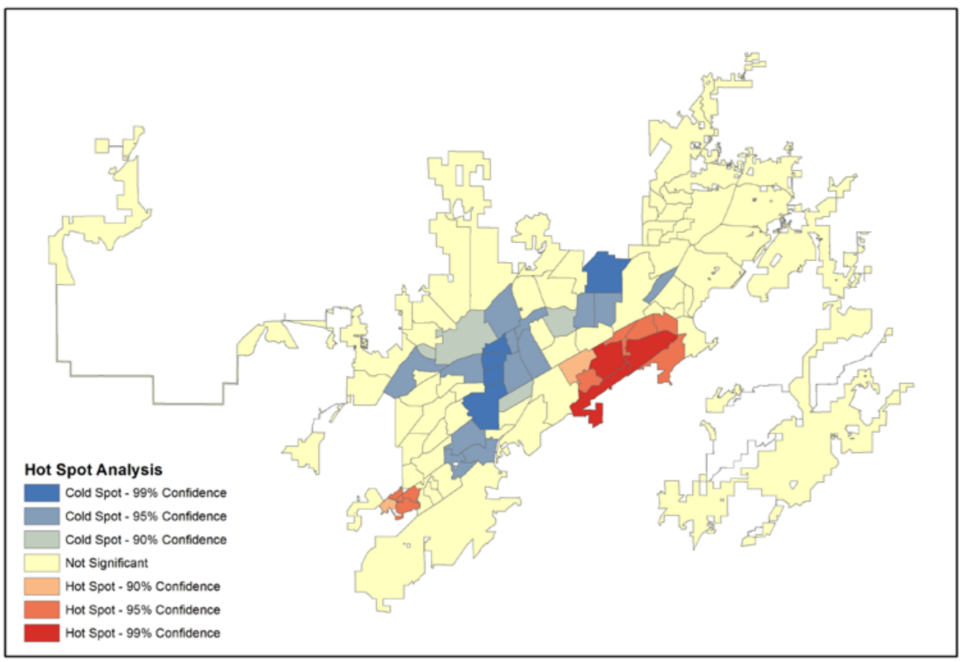

Figure 4.7 – Hot Spot Map

4.2 Discussion and Recommendations

The results of the hot spot analysis helped to identify areas of low sustainability scores that need improvement in order for Birmingham to achieve its goal of becoming a sustainable city. Further examination revealed that the neighborhoods located within the statistically significant cold spots scored worst in the economic category of sustainability. The majority of these neighborhoods received negative scores for the poverty rate, vacant housing, high school diploma percentage, and affordable housing indicators. The neighborhoods also scored poorly in the environmental category, especially on the indicators of proximity to water features, walkability, and impervious surface. Based on the hot spot analysis, these neighborhoods should be a high priority in allocating resources for improving sustainability in Birmingham, and work that improves the indicators listed above would most effectively improve sustainability in those neighborhoods.

The neighborhoods located in the small hot spot in the southwestern part of the city, in the Grasselli Heights, Hillman, Hillman Park, East Brownville, and West Brownville neighborhoods appears to be an almost entirely residential area. The neighborhoods have a relatively high population and housing density with a lot of tree cover. There are also many small forested areas within the neighborhoods. These neighborhoods seem to have achieved their high scores due to their environmental sustainability. The neighborhoods all did very well with the impervious surface, development footprint, and proximity to water features SIs. Their scores in the economic category were all close to 0, and the scores in the social category were mostly positive. The homes in these neighborhoods tend to be modest and simple, but most of them are well taken care of and in good condition. With a little improvement in the economic category and an increase in mixed use, these neighborhoods could be a great model for sustainable communities in Birmingham.

One of the more interesting observations that can be taken from the hot spot analysis is that the largest hotspot, the one located south and east of downtown, is an area where significant gentrification is occurring. These neighborhoods, located in the Southside, Red Mountain, Crestwood, Crestline, and Woodlawn communities, were once some of the earliest suburbs of Birmingham. Today there is a trend of people moving into these once prominent neighborhoods and returning the homes/neighborhoods to their former glory. This is the result of the initially low real estate prices in these areas and the desire for many younger people to live a more urban lifestyle. These neighborhoods also offer a lot of traditional charm, such as the beautiful parks, like Avondale Park, that were built early in the history of the suburbs. In the next section, the concept of gentrification will be reviewed, including its positive and negative impacts and its implications for sustainability of Birmingham neighborhoods.

4.2.1 Gentrification and Birmingham Neighborhood Sustainability

According to Lees, Slater, and Wyly (2008), gentrification can be defined as “the transformation of a working-class or vacant area of the central city into middle-class residential and/or commercial use”. Gentrification can also be viewed as a reversal of the process of neighborhood decline; in fact, neighborhood decline and falling real estate prices are necessary in order to begin the process of gentrification. Gentrification involves an influx of higher-income, often white, households into poorer areas of the city. The “gentrifiers” often move into these areas because of a desire to live a more urban lifestyle in a more culturally diverse neighborhood. When these higher-income households move into the neighborhood and make improvements on their homes, real estate prices, public services, safety, and political action in the neighborhood tend to increase. The fact that the gentrifying areas of Birmingham scored so well on the sustainability assessment warrants further examination of the process of gentrification and its implications for neighborhood sustainability. There are, however, both positive and negative impacts that result from the process of gentrification; these impacts will be reviewed in the following paragraphs.

The term gentrification was first coined by Ruth Glass in her 1964 book, *London: Aspects of Change*. Glass (1964) used the term with a negative connotation when describing the process by which working-class people were displaced by higher-income people in a neighborhood. This negative aspect of gentrification still remains a prominent area of research. Negative impacts of gentrification include: displacement through rent/price increases, psychological costs of displacement, community resentment and conflict, unsustainable speculative property price increases, homelessness, and loss of social diversity (Lees, Slater & Wyly, 2008). The most often cited negative impact of gentrification is the displacement of the previous, lower-income, residents of the gentrifying neighborhoods and the impact of displacement on the everyday lives of the displaced residents. Marcuse (1985) describes this displacement as highly destructive, saying “at worst it leads to homelessness, at best it impairs a sense of community”. Residents that are displaced by gentrification lose their sense of community and the social connections that they developed as residents of the gentrifying neighborhood. Betancur (2002) describes the loss of community and social connections as “the destruction of the elaborate and complex community fabric that is crucial for low-income, immigrant, and minority communities”. The housing needs of the displaced also place increased strain on the affordable housing supply in other areas of the city. Many policy-makers seem to ignore or underestimate these negative impacts of gentrification, and, in many cases, develop policies that promote gentrification (Betancur, 2002; Marcuse, 1985).

The literature on gentrification is not all negative. Several papers and books have been published which promote gentrification as being positive for the city as a whole and sometimes even for the lower-income inhabitants of gentrifying neighborhoods. Byrne (2003), in particular, highlights the positive impacts of gentrification stating that "increasing the number of residents who can pay taxes, purchase local goods and services, and support the city in state and federal political processes" benefits the city. Byrne (2003) further argues that the negative impact of displacement is not directly caused by the process of gentrification, but, rather, is often a result of the "persistent failure of government to produce or secure affordable housing". Others, such as Freeman and Braconi (2004), have observed that the amount of displacement caused by gentrification may be exaggerated. In their surveys in the 1990s, Freeman and Braconi (2004) found that low-income households in gentrifying areas were actually less likely to move than their counterparts in more impoverished areas of the city; their results suggest that low-income households, in many cases, desire to live in the gentrifying areas due to the increase of public services and job opportunities and find some way to afford the increases in rent. Due to the potential for urban revitalization, Byrne (2003) argues that "prohibiting poor people from being succeeded by more affluent people dooms the neighborhood, and perhaps, the city to poverty". This argument that gentrification is a positive force for urban revitalization can be described as "positive gentrification" (Chaskin & Joseph, 2013).

As mentioned before, some urban policies can be seen as supporting gentrification in order to spur urban revitalization. The opponents of gentrification claim that these policies ignore or underestimate the negative impacts (Lees, Slater & Wyly, 2008). One argument that has been used by urban policy-makers to support gentrification for urban redevelopment is that gentrification reduces the social isolation of low-income households and reduces the concentration of poverty in the inner city. Deconcentration of poverty in the inner city has been a major theme of urban policy and public housing in recent years (Chaskin & Joseph, 2013). The arguments for reducing the concentration of poverty are based on observations made by scholars like Wilson (1987) who first described the destructive and self-perpetrating nature of social isolation and concentrated poverty. Wilson (1897) described an "urban underclass culture" in many inner city neighborhoods that had weak connections to the labor market, high rates of welfare receipt, high rates of teen pregnancy, single-female-headed households, violent crime, and drug use (Popkin et al., 2004). The underclass culture was attributed to the isolation and concentration of poverty in the inner city and the absence of "middle- and working-class residents to serve as role models and to support local institutions such as schools and stores" (Popkins et al., 2004). HUD's Housing Opportunity for People Everywhere (HOPE VI) program is a good example of a housing and urban development policy that aims to reduce the concentration of poverty through mixed-income development. HOPE VI projects demolish older (often high density) distressed public housing projects and replace them with higher quality, lower density developments that contain public housing units, subsidized housing units, and market-rate housing units. The HOPE VI program seemed to have some success at providing high quality housing to low-income households and reducing the concentration of poverty, but the developments are often criticized for not replacing all of the units demolished, displacing families during the construction period, and not being able to offer all of the previous residents housing in the new development (Popkin et al., 2004; Joseph, Chaskin & Webber, 2007). Other than the gentrification-like displacement of many former public housing residents, the HOPE VI program can be viewed as largely successful. The purpose of the HOPE VI program was to get rid of those public housing projects that were distressed and replace them with the high quality, low density, and mixed-income developments; therefore, the main focus was to improve the quality of public housing, not the total replacement of all housing units from the older projects. Byrne (2003) approves of the HOPE VI program, citing its proven ability to spur development in new areas and calling the program "the first successful government program to integrate residential neighbourhoods by income".

Although HOPE VI has been criticized by some, the concept of mixed-income development is generally viewed in a positive light in the literature. It would appear that the main problem with HOPE VI is the reduction of affordable housing, therefore, it seems that promoting mixed-income development, not to replace older public housing units but, instead, to increase diversity in gentrifying areas could help provide high-quality public housing in neighborhoods that are revitalizing. Joseph, Chaskin and Webber (2007) provides a good overview of the objectives of mixed-income development; according to their article, mixed-income is adopted as an urban policy objective for two reasons: (1) to address urban poverty; and (2) as a general strategy for urban redevelopment. Mixed-income development is thought to address urban poverty in the following ways: (1) enabling low-income households to build social networks and social capital with higher-income households; (2) social control: increased pressure for community order and safety; (3) role modeling: lower-income residents using higher-income residents as role models; and (4) political economy of place: increased spending power and homeownership makes neighborhood more attractive for investment (Joseph, Chaskin & Webber, 2007). In their analysis for the evidence behind the four ways that mixed-income development addresses urban poverty, Joseph, Chaskin and Webber (2007) found that placing low-income households in close proximity to higher-income households did not necessarily result in increased social interaction between those households. Mixed-income development certainly results in a better environment for low-income households, but in terms of more direct benefits such as employment gains, opportunity, and well-being, mixed-income development is unlikely to provide immediate gains; however, the residents may benefit indirectly through increased investment in the community, greater safety and order, and better public services (Joseph, Chaskin & Webber, 2007). The literature suggests that mixed-income development can be somewhat effective at improving the lives of low-income households, but that it cannot be the one and only method for poverty reduction. Joseph, Chaskin and Webber (2007) recommend that:

> "In addition to these structural factors, fully addressing poverty among low-income residents of mixed-income developments will require serious investments in education, job readiness, training, and placement; attention to instrumental barriers such as transportation and substance abuse; and attention to more fundamental structural barriers that shape unequal access to opportunity."

Mixed-income development offers a potential solution to many of Birmingham's sustainability problems. If used correctly, it could increase the supply of affordable housing, reduce the concentration of poverty, revitalize neighborhoods, increase investment and tax base in the inner city, and decrease vacant and abandoned housing.

4.2.2 Recommendations

The NSA results revealed that the majority of Birmingham neighborhoods cannot be considered sustainable. The spatial analysis further revealed that there was a large cluster of neighborhoods with high sustainability values in the gentrifying southeastern portion of the city, and a large cluster of low sustainability values in the largely industrial areas of the city. Further examination of the concepts of gentrification and mixed-income development revealed a possible solution to redeveloping declining areas of the city and increasing sustainability in Birmingham. Gentrification produces more sustainable communities by improving the real estate market, bringing in more commercial development, increasing demand for public services and the tax base, and providing pressure for greater safety and social order in the neighborhood. The downside to gentrification is the displacement of low-income residents and a reduction in the affordable housing supply, however, the problem of displacement can be addressed by providing mixed-income development in gentrifying areas. Instead of using mixed-income developments to replace the public housing supply, as was done with the HOPE VI program, mixed-income development can be used to integrate neighborhoods based on income level. In addition to providing mixed-income development in the gentrifying areas, the city should continue to improve and increase the supply of public housing throughout the city in order to minimize the impact on affordable housing in the city. Although mixed-income development will help to alleviate poverty by reducing the spatial concentration of poverty and the negative environment it creates, it cannot be the only solution. In addition to the strategy of mixed-income development, the city should address poverty through improvements in public transportation, education, and job training. Addressing poverty should be a major priority in the City's plan to increase sustainability.

Overall, neighborhoods received the worst scores in the economic sustainability category. Increasing the economic sustainability of Birmingham neighborhoods should be the first priority because improving the economy will enable the city to more easily address social and environmental sustainability issues. The strategy of mixed income development and the revitalization that it will help generate will increase the tax base and the demand for improvements of public transportation, sidewalks, bike lanes, parks and open space. Because the city is also facing problems with vacant and abandoned housing, there is an opportunity to use some of these underutilized areas for the redevelopment. According to the City's comprehensive plan, approximately 18% of housing in Birmingham is vacant, and 7% of housing units are both vacant and out of the market, meaning they are neither for sale or rent. The plan also states that a total of 11.5% of residential properties in the city are tax-delinquent. A strategy including the establishment of a redevelopment authority and land bank, as suggested in chapter 8 "Community Renewal" of the comprehensive plan, could be used to acquire some of these vacant and tax-delinquent properties for the purposes of redevelopment. Of course not all of the land currently occupied by vacant and abandoned housing will be suitable for mixed-income development, but those properties could be converted to new parks and open spaces that could make the neighborhoods more attractive. Urban agriculture, in the form of community gardens, would also be a good use of the abandoned properties and would help to resolve the problem of food access. The city should be very selective of where it tries to implement the mixed-income development strategy. Brophy and Smith (1997) emphasize the importance of having an adequate number of market-rate housing units and an adequate demand for those units in order to have a successful mixed-income development, therefore, these developments should be placed in areas where there is already some demand for market-rate housing units. The areas of the central city with good access to public transit and a good commercial base would be good target areas for such developments. Placing mixed-income developments in these high-demand areas with good access to public services would allow low-income families to live in areas with a positive environment and high levels of opportunity as well as ensuring that the supply of affordable housing in the gentrifying areas does not disappear with increasing real estate prices and property taxes.

The City also has much room for improvement in the environmental category. The majority of neighborhoods received negative scores in both the proximity to water features and impervious surfaces SIs, indicating a need to better protect the water resources in the city. The City should work on expanding stream buffers and planting appropriate vegetation in those buffers to limit the damage of storm water runoff. The Freshwater Land Trust (FLT) has been working to improve these stream buffers by acquiring conservation easements around the streams in the Birmingham area. The FLT has also been using some of these easements to build a network of greenways and urban walkways that will contribute to walkability and hopefully encourage more residents to walk or bike instead of driving and contributing to air pollution in the city. The City should continue to work with the FLT to improve the stream buffers and improve water and air quality. Impervious surfaces, another concern for water quality, could be reduced by removing some of the structures and parking lots that are no longer in use; these areas could be replaced with new parks, community gardens, and open space that would reduce the percentage of impervious surface coverage. Another method for reducing impervious surfaces would be to use pervious concrete for new sidewalks and parking lots or simply incorporating more open space and vegetation into areas currently covered by imperious surfaces. Finally, the City needs to improve existing sidewalks and bike lanes and add them where they are missing in order to encourage more walking and cycling and reduce mobile source air pollution.

Although the social category was the category in which neighborhoods performed best, there is still much room for improvement. The walkability indicator, in particular, was one in which most neighborhoods performed very poorly. Walkability could be an extremely important driver of economic growth and rejuvenation in Birmingham. Speck (2012) identified a number of positive effects of increases in walkability including increased real estate prices and the ability to attract young professionals to a city. Improving damaged sidewalks and installing new ones where they are lacking will go a long way in improving walkability in Birmingham neighborhoods, but another way to improve walkability is to provide more mixed-use areas. In order to be walkable, neighborhoods not only need to have sidewalks but also destinations that people want to walk to in close proximity to residential neighborhoods. According to Speck (2012) people will only choose to walk instead of drive if the walk is useful, enjoyable, and safe; this means that there must be an appropriate mix of destinations in close proximity to a person's home, the area should be attractive and interesting, and there must be appropriate safety measures (adequate lighting, sidewalks, traffic buffers, etc.). Therefore, in addition to adding sidewalks the city should consider promoting mixed-use development, providing important safety features to protect walkers from the dangers of automobile traffic and crime, and making the sidewalks more attractive perhaps by planting trees and gardens or adding statues and artworks along major walkways.

Of course the City should strive to improve all indicators, but the indicators listed in the paragraphs above should receive the highest priority. They are the indicators in which neighborhoods consistently performed poorly. The purpose of this research was to aid in the decision-making and resource allocation process in order to improve sustainability in the City of Birmingham. The results of the NSA system provide a starting point by identifying the hot and cold spots for sustainability within the city and the SIs for which the neighborhoods performed the worst. The city should use this information to continue to make progress towards sustainability, and, eventually, this assessment should be performed again in order to determine how much progress has been made. When the assessment has been performed again, the result of this assessment can be used as a baseline, and meaningful estimates of progress can be made. The NSA process is one that is meant to monitor progress and therefore should be performed on a regular basis, perhaps as often as once per year. The majority of SIs used in this NSA system are based on data that is easily attained on a yearly basis, making it a realistic model for continued assessment of sustainability in Birmingham.

In addition to seeking to improve the indicators used in this system, the City of Birmingham should strive to make good decisions going forward with new developments. If the city is going to become the sustainable city that its citizens and city officials have envisioned in the 2013 Comprehensive Plan, every decision made for further growth should be analyzed with sustainability in mind. The economic, environmental, and social costs of each decision should be weighed before any development can occur. This paper has largely focused on improving the existing neighborhoods, but inevitably the city will change and new neighborhoods will be added, whether in completely new areas or within existing areas of the city. Going forward, the city should have a strategy for building sustainable communities, and there should be a theoretical framework for creating those communities. One source for such a framework could be the smart growth concept which includes principles for building sustainable communities. According to Duany, Speck and Lydon (2010), smart growth is a strategy to reduce urban sprawl and automobile dependence and improve the sustainability and livability of communities. The adoption of smart growth principals has become increasingly common in local and regional development strategies across the country in recent years (Krueger & Gibbs, 2008). Central to the concepts of smart growth are regional planning, mass transit, mixed-use, mixed-income, walkability, high density, and preservation of agricultural and natural areas (Duany, Speck, & Lydon, 2010).

Planning with smart growth principles provides several advantages for the City of Birmingham. Smart growth emphasizes the concepts of infill development and redevelopment in urban areas, and there are many areas of great opportunity for these types of developments in Birmingham. Smart growth also emphasizes planning at the regional scale and cooperation between municipalities within a region to accomplish long term goals. The region is the real scale of people's lives, so it makes sense to plan for development of communities and transportation infrastructure at the regional scale (Duany, Speck, & Lydon, 2010). In reality, people do not stay within one municipality, but instead move throughout a region in their daily lives; planning at the regional scale allows municipalities to work together and share resources to accomplish regional goals. Goals for regional development in the Birmingham area should include urban infill and revitalization, and the development of a well-balanced transportation system that enables people to move throughout the region and between the various municipalities without necessarily having to rely on personal automobiles. The City of Birmingham should work with surrounding municipalities to develop communities with these goals in mind. This means improving the public transportation system of the region for longer trips, and designing communities that promote alternative forms of transportation, such as walking and cycling, at a more local scale. Also, based on the principles of smart growth, the areas of Birmingham that offer an opportunity for infill development near the urban center should be priority areas for new development. A regional plan that directs new growth to areas of Birmingham that are ideal for infill development would reduce traffic congestion caused by people commuting into the city from surrounding municipalities and could offer benefits to all municipalities in the region.

Smart growth offers guidelines for development of regions, neighborhoods, streets, and buildings, all with a focus on the concept of sustainability. The City of Birmingham would be wise to adopt many of the principles of smart growth to help them accomplish their goal of becoming a sustainable city. The LEED-ND sustainability assessment system, which was mentioned in the research background section of this paper, evaluates neighborhoods based on these principles. The NSA system developed for this research was needed to evaluate existing neighborhoods, but NSA systems like the LEED-ND system could be a valuable tool for evaluating the sustainability of new and planned developments in the city. The LEED-ND system, and others like it, are much more comprehensive and detailed because they are performed by people with access to all of the information necessary for such a detailed assessment. It would be very beneficial to use these NSA systems in cooperation with the NSA system developed in this research to continue to improve sustainability in the City of Birmingham.

5.0 CONCLUSION

The goal of this research was to provide information about the sustainability of Birmingham neighborhoods and the spatial distribution of sustainability in Birmingham through the application of a NSA system. The specific research questions were:

1. What is the current level of sustainability in Birmingham neighborhoods?
2. What are the issues that negatively affect sustainability in Birmingham neighborhoods, and how can these issues be addressed by the planning department or other agencies?
3. What spatial patterns can be recognized for sustainability in Birmingham, and what do those patterns reveal about Birmingham neighborhood sustainability?

In the following paragraphs each of the research questions will be answered. First, the current level of sustainability in Birmingham is not very high. The City of Birmingham's current level of sustainability can be evaluated through the results of NSA system applied in this research. The results showed that the average score for Birmingham neighborhoods was 0.13 out of a possible 18.0. While 0.13 is a positive number, it shows that, at best, there were about as many neighborhoods with negative scores as there were neighborhoods with positive scores. Also, there was a total of 17 neighborhoods that didn't receive a positive score in any of the three categories in the assessment. The economic category appears to be the area that needs the most improvement; 47 neighborhoods received negative scores in the economic category compared to 44 in the environmental category and 37 in the social category. In order for Birmingham to be considered truly sustainable, there will need to be significant improvements in all three categories of sustainability.

The second research question asked what issues negatively affect sustainability in Birmingham, what is currently being done to address those issues, and what should be done to address those issues going forward. In the results section of this paper, a few SIs were identified as being the ones that needed the most improvement. There is room for improvement in all of the SIs, but the economic SIs were those most in need of improvement. Poverty, unemployment, vacant housing, and affordable housing are all indicators that will need significant improvement in order for Birmingham to reach its goal of becoming a sustainable city. The scores for the economic indicators do not accurately reflect the seriousness of the economic problems of Birmingham due to the fact that the neighborhoods were scored based on how they compared to all other neighborhoods; many of the neighborhoods that received a positive score for these indicators are still not doing as well as they should be, but because they are better than most neighborhoods in the city, they received a positive score. For example, the poverty rate in Birmingham is 30.2%, compared to only 15.4% for the United States and 18.6% in Alabama (U.S. Census Bureau, 2014). Because of the very high poverty rate in Birmingham, a neighborhood with a high poverty rate could receive a positive score in the assessment because, although it has a high poverty rate, it may have a lower poverty rate than the majority of Birmingham neighborhoods. As discussed in the results section, mixed-income development could be used as a method to reduce poverty in the city and improve the economic indicators in Birmingham neighborhoods. However, it is important that the city continues to improve its public housing stock and not attempt to replace all public housing with mixed-income development. As seen with HUD's HOPE VI project, replacing traditional public housing with mixed-income development can result in a significant reduction in the total public housing stock, which could displace low-income households and reduce the availability of affordable housing in the city.

In addition to the economic problems in the city, proximity to water features, sidewalks, and walkability are also SIs that showed a need for improvement. These environmental and social issues are being addressed by the Freshwater Land Trust (FLT) with its efforts to acquire conservation easements around streams in the Birmingham area. The FLT is mostly focused on conserving these areas for endangered species and biodiversity, but their efforts benefit the city and its people in many ways. Some of the land being managed by FLT is currently being used to create a system of greenways throughout the city which will help with the sidewalks and walkability issues. The City currently needs to focus on the economic issues and continue to support organizations like FLT that are trying to improve the environment. Projects like the FLT's greenway trail system provide a good opportunity to improve sustainability in all three categories. The trail system will provide people the opportunity to traverse the city by foot or bicycle, hopefully resulting in less vehicle miles traveled, lower emissions, better public health, and possibly some urban revitalization as people realize the value of the trail system. Environmentally, the city should be trying to reduce emissions and improve air quality in any way they can. Improving sidewalks, walkability, and public transportation would all be good ways of reducing the mobile air pollution caused by automobiles.

The third and final research question asked about the spatial patterns of sustainability in Birmingham neighborhoods. The spatial analysis of this research revealed that there were, in fact, some recognizable spatial patterns for sustainability in Birmingham. The sustainability scores data was shown to be spatially clustered with a large high cluster in the southeastern part of the city and a large low cluster in the central city. These spatial patterns revealed some interesting details about sustainability in Birmingham. The large cluster of high scoring neighborhoods in the southeastern part of the city, which is a gentrifying area of the city, revealed that redevelopment and revitalization could be the key to improving sustainability in the city. Further research on gentrification revealed that mixed-income development could be used to eliminate some of the negative impacts of gentrification-induced revitalization.

The main goal of this research was to provide some insight into the state of sustainability in Birmingham neighborhoods, and provide information on how the City can reach its goal of becoming more sustainable. The NSA system applied in this research used a wide variety of indicators covering economic, environmental, and social issues. The results showed that neighborhoods have room for improvement in all three categories, but that economic problems are perhaps the most concerning. The poverty rate in the city is much higher than surrounding areas, and, in order to become a sustainable city, Birmingham must first improve the social and economic conditions in the city. If people cannot achieve an acceptable quality of life now, it is unrealistic to spend very much time focusing on the well-being of future generations. Improving the economic sustainability of Birmingham must be the top priority for the near future, but improving the economy does not mean that the environment or society must be sacrificed. The City must consider all environmental and social impacts when making decisions to improve the economy. Making good decisions going forward and working to fix problems that currently exist is the way that Birmingham must approach the goal of improving sustainability. One way to ensure that good decisions are made in the future is to adopt the principles of smart growth, as discussed in the recommendations section of this paper. Smart growth principles provide guidelines for developing sustainable communities that reduce environmental impacts, urban sprawl, and automobile dependence while improving the quality of life of neighborhood residents.

The City should also take advantage of the new trend of higher-income households moving back into the inner city. This process is often called gentrification, and it has been criticized in academic literature as displacing lower-income households and causing as much harm as benefit. However, there are also many positive side effects of gentrification, including lower crime rates, improved real estate market, more public and private investment, and more tax revenue for the city. Because the gentrifying neighborhoods performed so well in the NSA system applied in this study, gentrification and its benefits should not be overlooked. The main negative issue associated with gentrification is the displacement of lower-income households, but this does not necessarily have to occur. The City has a major problem with vacant and abandoned properties, clearly indicating that there is room for more people in the inner city, but it is not just an issue of having enough housing; it is also important that there is an adequate supply of affordable housing available for people at all income levels. Birmingham could use a strategy of requiring a certain amount of affordable housing in any new housing development in the city (or certain areas of the city), ensuring that new developments are not exclusive to lower-income households and do not strain the affordable housing supply in the city. Using this strategy to limit the negative impact of gentrification could help Birmingham improve the economy of its inner city and reduce its very high poverty rate. Once the economic situation has improved there will be more resources available to address the environmental and social issues and more political pressure to do so, and Birmingham will be well on its way to becoming a sustainable city.

The results of this study have provided some information that Birmingham can use to move forward with its plan to become a more sustainable city, but it is important that the City continues to perform this type of assessment in order to track its progress. It would be very useful to use the same indicators in future assessments in order to see how they improved on specific issues, but it would also be good to add new indicators as new issues arise in the city and more data becomes available. This assessment provides a baseline estimate of sustainability in Birmingham neighborhoods and reveals the spatial patterns of sustainability within the City of Birmingham. With this information, city officials will be able to identify which neighborhoods to focus on and what specific issues need to be addressed in those neighborhoods. The results of this assessment can also be used to determine how much progress has been made when future assessments are completed.

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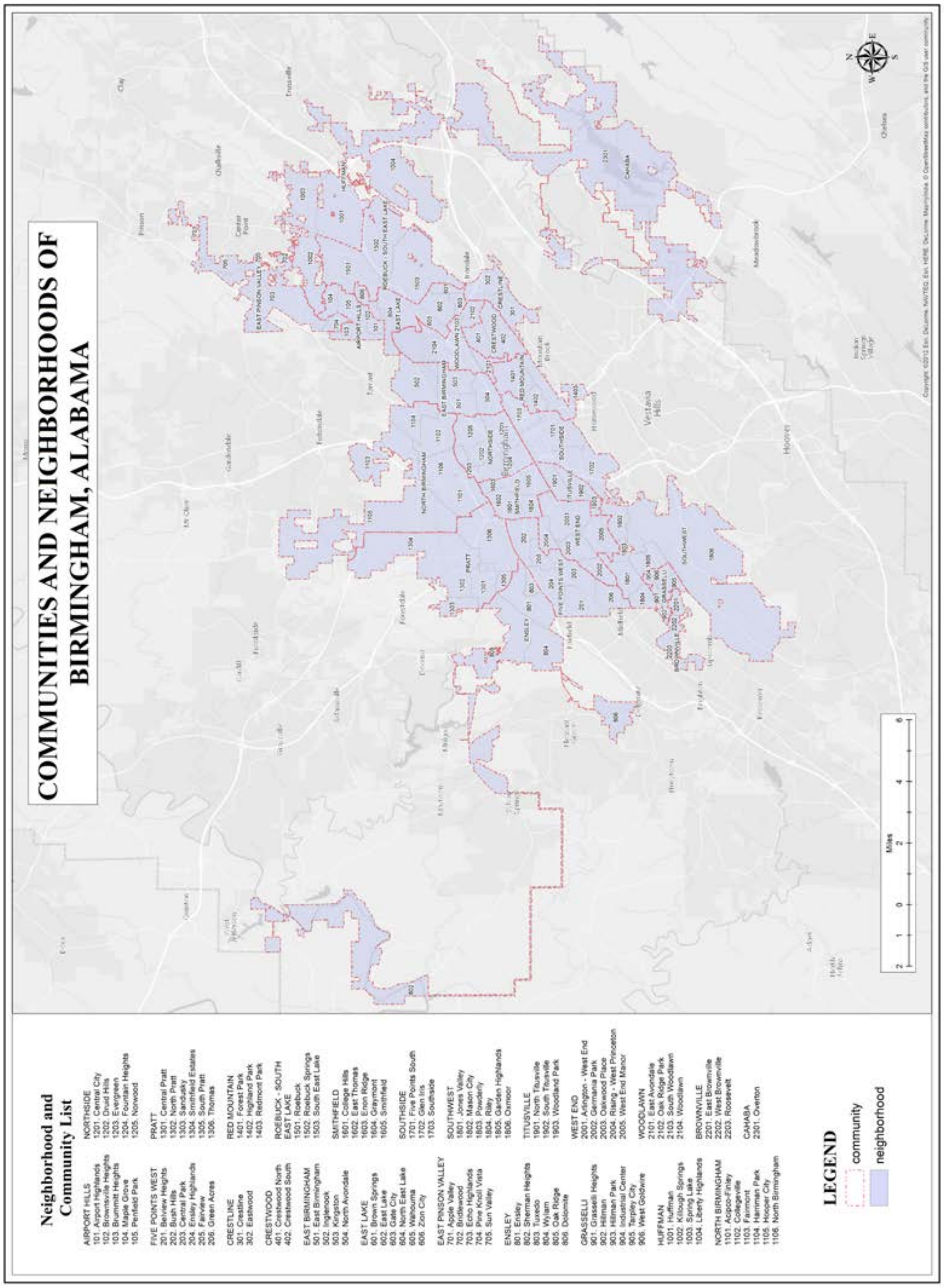
Appendix A – Detailed Neighborhood and Community Map



Appendix B – Neighborhood List with Sustainability Scores

Neighborhood Name	Economic Score	Environmental Score	Social Score	Total Score
Acipco-Finley	-3.0	-2.4	0.0	-5.4
Airport Highlands	1.0	2.4	0.0	3.4
Apple Valley	3.0	0.0	-2.0	1.0
Arlington-West End	-2.0	-1.2	-1.0	-4.2
Belview Heights	3.0	0.0	1.0	4.0
Bridlewood	4.0	2.4	1.0	7.4
Brown Springs	-3.0	3.6	-1.0	-0.4
Brownsville Heights	1.0	2.4	2.0	5.4
Brummitt Heights	3.0	2.4	-1.0	4.4
Bush Hills	-2.0	1.2	-3.0	-3.8
Central City	-1.0	1.2	2.0	2.2
Central Park	0.0	-1.2	5.0	3.8
Central Pratt	-2.0	0.0	2.0	0.0
College Hills	-1.0	2.4	-1.0	0.4
Collegeville	-3.0	-3.6	3.0	-3.6
Crestline	6.0	-1.2	2.0	6.8
Crestwood North	5.0	2.4	0.0	7.4
Crestwood South	6.0	1.2	-1.0	6.2
Dolomite	3.0	0.0	-2.0	1.0
Druid Hills	-5.0	1.2	-2.0	-5.8
East Avondale	5.0	0.0	4.0	9.0
East Birmingham	-3.0	-1.2	0.0	-4.2
East Brownville	1.0	2.4	2.0	5.4
East Lake	-3.0	0.0	-1.0	-4.0
East Thomas	-2.0	-1.2	2.0	-1.2
Eastwood	4.0	-1.2	2.0	4.8
Echo Highlands	4.0	-2.4	-1.0	0.6
Enon Ridge	-4.0	1.2	-3.0	-5.8
Ensley	-4.0	-2.4	3.0	-3.4
Ensley Highlands	-2.0	0.0	4.0	2.0
Evergreen	-5.0	1.2	2.0	-1.8
Fairmont	1.0	0.0	3.0	4.0
Fairview	-3.0	3.6	-2.0	-1.4
Five Points South	1.0	-2.4	3.0	1.6

Neighborhood Name	Economic Score	Environmental Score	Social Score	Total Score
Forest Park	4.0	0.0	3.0	7.0
Fountain Heights	-2.0	1.2	2.0	1.2
Garden Highlands	-2.0	0.0	4.0	2.0
Gate City	-3.0	1.2	0.0	-1.8
Germania Park	-2.0	0.0	1.0	-1.0
Glen Iris	4.0	-1.2	0.0	2.8
Grasselli Heights	-1.0	3.6	1.0	3.6
Graymont	-2.0	-1.2	-1.0	-4.2
Green Acres	0.0	1.2	2.0	3.2
Harriman Park	-3.0	-3.6	2.0	-4.6
Highland Park	4.0	1.2	-1.0	4.2
Hillman	1.0	2.4	2.0	5.4
Hillman Park	1.0	3.6	0.0	4.6
Hooper City	2.0	-1.2	-1.0	-0.2
Huffman	3.0	-1.2	-2.0	-0.2
Industrial Center	-2.0	1.2	-3.0	-3.8
Inglenook	-4.0	-1.2	2.0	-3.2
Jones Valley	-2.0	0.0	0.0	-2.0
Killough Springs	4.0	-1.2	-1.0	1.8
Kingston	-4.0	-2.4	-2.0	-8.4
Liberty Highlands	6.0	-2.4	0.0	3.6
Maple Grove	2.0	1.2	-3.0	0.2
Mason City	-3.0	-1.2	-2.0	-6.2
North Avondale	0.0	-2.4	2.0	-0.4
North Birmingham	-4.0	-1.2	4.0	-1.2
North East Lake	-4.0	-1.2	3.0	-2.2
North Pratt	1.0	1.2	0.0	2.2
North Titusville	-1.0	-2.4	-3.0	-6.4
Norwood	-4.0	-1.2	1.0	-4.2
Oak Ridge	-1.0	2.4	4.0	5.4
Oak Ridge Park	0.0	3.6	-3.0	0.6
Oakwood Place	-2.0	0.0	1.0	-1.0
Overton	4.0	-2.4	3.0	4.6
Oxmoor	3.0	-2.4	-3.0	-2.4
Penfield Park	1.0	1.2	-3.0	-0.8
Pine Knoll Vista	3.0	1.2	-1.0	3.2
Powderly	-4.0	0.0	-2.0	-6.0
Redmont Park	6.0	0.0	0.0	6.0
Riley	1.0	0.0	0.0	1.0
Rising-West Princeton	-3.0	-1.2	0.0	-4.2
Roebuck	2.0	-2.4	-1.0	-1.4

Neighborhood Name	Economic Score	Environmental Score	Social Score	Total Score
Roebuck Springs	3.0	-1.2	1.0	2.8
Roosevelt	-1.0	0.0	-2.0	-3.0
Sandusky	2.0	2.4	-1.0	3.4
Sherman Heights	1.0	-1.2	-1.0	-1.2
Smithfield	-3.0	-2.4	-4.0	-9.4
Smithfield Estates	2.0	-1.2	1.0	1.8
South East Lake	-3.0	-1.2	-1.0	-5.2
South Pratt	-4.0	1.2	-2.0	-4.8
South Titusville	1.0	-2.4	1.0	-0.4
South Woodlawn	0.0	1.2	4.0	5.2
Southside	2.0	-1.2	2.0	2.8
Spring Lake	2.0	-2.4	3.0	2.6
Sun Valley	1.0	0.0	-2.0	-1.0
Tarpley City	0.0	0.0	1.0	1.0
Thomas	-3.0	-4.8	1.0	-6.8
Tuxedo	-5.0	-1.2	-1.0	-7.2
Wahouma	-4.0	-2.4	4.0	-2.4
West Brownville	0.0	1.2	3.0	4.2
West End Manor	-4.0	-1.2	0.0	-5.2
West Goldwire	0.0	0.0	2.0	2.0
Woodland Park	1.0	1.2	0.0	2.2
Woodlawn	-3.0	-2.4	0.0	-5.4
Wylam	-3.0	-1.2	2.0	-2.2
Zion City	1.0	3.6	0.0	4.6