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Context-Based Neighborhood Sustainability Assessment in Birmingham, Alabama

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Abstract: Sustainability assessment is widely used to monitor public policy toward sustainable development (SD). However, such tools have been less developed at the local level. This research examined sustainability indicators (SIs) applied at the neighborhood scale. The indicators were developed by examination of previously developed sustainability rating systems and issues specific to the City of Birmingham, Alabama, USA. The indicators of Neighborhood Sustainability Assessment (NSA) systems addressed the three major dimensions of sustainability: economic, environmental, and social. The rating system was applied to all neighborhoods, and geographical patterns were analyzed. The ability to analyze the sustainability of all neighborhoods within the city provides information on which areas are performing well and which areas need more attention to become more sustainable.

Keywords: sustainability assessment; neighborhood sustainability; sustainability indicators

1. Introduction

1.1. Defining Sustainability

Hopwood, Mellor, and O'Brien [1] suggest an “emphasis on human and environment interactions and a significant shift away from views of humanity as separate and superior to the environment”. 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 question is how can we accomplish this, and how do we measure our progress? To answer that question, there is a need for defining sustainability.

Sustainability is often described as having three “pillars” or overlapping circles, which include the environment, economy, and society [1]. The environmental pillar is the pillar that focuses on protecting the environment, in the forms of conservation of natural resources, preservation of natural habitat and biodiversity, and limiting pollution. Economic sustainability focuses 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 focuses 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 among well-being of people in the current generation [2].

1.2. Sustainability Assessment

The existing literature 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" [3]. The WCED's definition has been widely accepted, but it has also been criticized as being too general [1]. In other words, it does not necessarily mean the same to different people; people in developed countries tend to focus more on environment and inter-generational equity issues while developing countries focus more on development and intra-generational equity issues. A vague definition has helped gain support for the concept, but it has also resulted in a lack of specific and universally accepted methods of assessment [4]. In consequence, 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 [5,6]. 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" [4]. Some tradeoffs are going to be necessary, but a proper balance must be maintained for a project to promote sustainability [7]. 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 Neighborhood Sustainability Assessment (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 [8]. 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 [8]. 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 in existing neighborhoods or a city-wide evaluation of neighborhoods. It would be difficult to acquire all 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 [4,9]. 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. In addition, 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 [4]. Economic and social indicators are needed to be included in an NSA system that evaluates existing neighborhoods.

1.3. 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 [10]. 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 [11]. The impacts of urban activities reach far and wide as most urban areas are not importers of products and resources [4,12]. Despite the recent attention gained by sustainable development, the current urban form in most places is still considered to be unsustainable [13]. There is, however, great potential for increased efficiency through sustainable design in urban areas. As the “building blocks of a city” [14], neighborhoods are the ideal places to begin working to increase urban sustainability. As Choguill [15] 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 the sustainability of existing urban neighborhoods or the spatial component of sustainability in urban areas.

Lynch et al. [16] reviewed 22 sustainability assessment systems used in the U.S. and 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 [4] 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. [16] and Berardi [4] 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 [17].

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” [18,19].

The difficulty of delineating neighborhoods is avoided in Birmingham because 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 [19] 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 neighborhood groups. According to Wilson [19], neighborhood groups requested more than thirty changes between 1974 and 1980. There are currently 99 neighborhoods located within 23 communities according to the Department of Community Development.

1.4. Objective of the Study

The aim of this research is to develop an NSA system to examine the spatial distribution of sustainability in the city of Birmingham at the neighborhood scale. The intention of the study is to reflect issues specific to the city of Birmingham, Alabama, USA to identify indicators in neighborhood assessment. The ability to analyze the sustainability of all neighborhoods within the city provides information on which areas are performing well and which areas need more attention to become more sustainable.

2. Materials and Methods

2.1. Birmingham-Based 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” [20]. 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 were used to shape all aspects of the plan [20]. 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 1 below shows the most frequently mentioned issues.

2.2. Data Sources

The data for this research came from a variety of sources. The U.S. Census Bureau provided the demographic and socioeconomic 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 data was from the National Hydrography Dataset (NHD) and the land use data

from the National Land Cover Dataset (NLCD) 2011. Data that are 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 were digitized using imagery from Google Earth or ArcGIS Online. Walk Score [21,22] was used for walkability.

Table 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

2.3. Study Area

The study area for this research is the city limits of Birmingham, AL. The neighborhoods as defined by the Department of Community Development of the city are the specific areas of analysis. Figure 1 below shows the locations of the 99 neighborhoods of Birmingham. 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 [23]. 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 77.4% African American [23].

2.4. Neighborhood Sustainability Assessment System

A comprehensive review on the existing NSA systems including the LEED-ND, BREEAM, CASBEE, ECC and CASBEE, was conducted to identify a pool of relevant indicators. In addition, we evaluated the concerns expressed by the citizens of Birmingham in order to consider our case study's local context. The NSA system developed for this research is comprised of seventeen indicators grouped into three categories: economic, environmental, and social. Table 2 shows the categories, indicators, data sources, and related issues from the citizens of Birmingham.

2.4.1. Indicators and Scoring

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 deviation) of the unemployment data can be used to determine how the neighborhood is doing in relation 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.

Figure 1. Neighborhoods of Birmingham, AL.

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 these indicators were obtained from the U.S. Census Bureau ACS 2008–2012 dataset at the census tract level. For scoring, a standard deviation method was used for economic indicators. 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.

Table 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.

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 Department of Housing and Urban Development (HUD), which describes families who pay more than 30% of their income on housing as “cost burdened” [24]. 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 [25].

Environmental Indicators: indicators in this category include proximity to water, impervious surface, intersection density, development footprint and sidewalks and bike lanes. Values for the environmental indicators were determined through examination of other rating systems, and literature focused on each indicator.

Proximity to water features is important to set aside a buffer around water features to reduce runoff and allow vegetation to filter pollution from urban areas and to protect biodiversity. The acceptable range of values for the proximity to water features SI was determined through an examination of the planning literature. In their review of the literature relating to stream buffers, Castelle, Johnson and Conolly [26] found that stream buffers of less than 5–10 m offered little protection and buffers of 15–30 m should be the minimum in order to protect water quality of streams. Neighborhoods which had no development within the 30 m buffer received a value of 1 for the indicator, those with development within the 15 m buffer received a −1, and those with development within the 30 m buffer but not the 15 m 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 [27,28]. According to Arnold and Gibbons [27] watersheds with 10% or less of impervious surface coverage can be considered protected; when impervious surfaces cover more than 10% of the land area, the impervious surface begins to have a real impact on water quality, and beyond 30% impervious surface coverage, the water quality becomes noticeably degraded. Impervious surface percentage for each neighborhood was estimated based on the NLCD dataset, which defines their urban classes based upon the percentage of impervious surface coverage. In accordance with Arnold and Gibbons (1996), neighborhoods with less than 10% impervious surface area received a score of 1 for this SI while those with greater than 30% received a score of −1; all neighborhoods with 10–30% impervious surface coverage received a neutral value of 0.

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. The acceptable range of values for the intersection density SI in this research is based on 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 [8]. 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.

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 that lives in the neighborhood. 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 for the SI while those that had a DF of 300 or more received a score of −1, 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 were not available from the City of Birmingham's GIS department. 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, those with 50–75% coverage received a value of 0, and those with 75–100% coverage received a value of 1.

Social Indicators: the social indicators are those that are focused on the quality of life offered by each neighborhood. They include walkability, accessibility to public transit, accessibility to parks, and the degree of mixed use, segregation, and walkability. 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 [29,30], 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 how far away they are [21]. 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 a “walker's paradise” [22]. 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. Using standard deviation, neighborhoods are scored into the three possible scores (−1, 0, and 1) as evenly as possible.

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 Google Earth's transportation layer, and the walk times were determined with a cost-distance tool that uses minutes of travel as the cost accumulator. Neighborhoods with average walk times of 5 min or less received a 1, those with walk times of 5–15 min received a 0, and those with greater than 15 min 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-min 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 min received a 1, those with walks of 10–15 min received a 0, and those with walks greater than 15 min received a −1.

Access to grocery stores is one of the most important social indicators. 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 [31]. 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. 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.

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. [32]. The acceptable value for segregation was determined by the city's Dissimilarity Index (DI). The DI is a measure of how different the racial makeup of the neighborhoods is from the racial makeup of the city. The formula for DI is as follows:

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

where:

b_i = the black population at the i^{th} area;

B = the total black population of the city;

w_i = the white population of the i^{th} area;

W = the total white population of the city.

The DI for the Birmingham metropolitan area is 77.4 according to the Social Science Data Analysis Network [33], making it the 15th most segregated metropolitan area in the country. In order to determine the value of the DI indicator, the city's DI was calculated by assuming all neighborhoods have the same racial makeup as the neighborhood in question; the scores for each neighborhood were 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 [20]. Crime is an important social indicator because it influences how safe people feel in the neighborhood. Crime data were 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 were joined to the shapefile.

Areal interpolation was used to obtain 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. Neighborhoods with crime rates more than 0.5 standard deviations from the mean were assigned a value of 1, those within a standard deviation from the mean were assigned a value of 0, and those more than 0.5 standard deviations from the mean were assigned a -1 .

2.4.2. Normalization, Weighting, and Aggregation of the Indicator Scores

The indicators are normalized by assigning values of 1, 0, or -1 to each indicator where higher positive values reflect greater sustainability. The method of assigning values to indicators are different depending on the unique characteristics of the indicator. 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 SIs in that category. The fact that each category carries an equal weight in the NSA system ensures that there will not be an excessive tradeoff between the categories. Tradeoffs between the economy, environment, and society have been identified as a major issue in sustainability assessment [4,7].

Once the values of all SIs have been determined for each neighborhood, the scores were 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 [9]. Some would argue that aggregation of indicators results in excessive tradeoffs between the three pillars of sustainability [4]. 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 the 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 areas.

2.5. Exploratory Spatial Data Analysis

To interpret the results of this research, an exploratory spatial data analysis (ESDA) technique was used. ESDA 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 hotspots, and at suggesting spatial regimes or other forms of spatial heterogeneity” [34].

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 [35]. To determine the spatial patterns within the neighborhood sustainability dataset, it is necessary to use local indicators of spatial autocorrelation (LISA). The Getis-Ord G_i^* 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 G_i^* 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 each neighborhood is related to one another and will help them make better, more informed decisions. The formula for the Getis-Ord G_i^* statistic is as follows:

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

where:

$$S = \sqrt{\frac{\sum_{j=1}^n x_j^2}{n} - (\bar{X})^2} \quad (3)$$

$\bar{X}$ = the mean of the corresponding attribute;

x_j = the attribute value for feature j ;

$w_{i,j}$ = the spatial weight between feature i and feature 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 [36]. 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. Hotspot analysis was performed in ArcGIS with the hotspot analysis (Getis-Ord GI^*) tool.

3. Results

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 . 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 3 shows descriptive statistics for the total sustainability score as well as the three categories. (see more detailed Information in Supplementary)

Table 3. 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 3 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.

The first map (Figure 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 most 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. The second map, illustrating the average total sustainability scores by community, showed a similar pattern with the northern and western portions of the city having lower scores than the southeastern portions.

The maps of the economic, environmental, and social category scores showed a less obvious pattern. The map of the economic scores (Figure 3) closely resembles the map of the total scores, but the environmental (Figure 4) and social scores (Figure 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.

Figure 2. Total sustainability scores by neighborhood.

Figure 3. Economic scores by neighborhood.

The lower environmental scores for the outmost neighborhoods were likely because these neighborhoods 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 shows a pattern of having high values in and around the CBD, while the SIs for crime and segregation show the opposite pattern.

Figure 4. Environmental scores by neighborhood.

Figure 5. Social scores by neighborhood.

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 (Figure 6).

Figure 6. Hot spots of total sustainability score.

4. Discussion

The result of the study presented the spatial distribution of sustainability in Birmingham through the application of an NSA system. 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 the 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. In addition, there was a total of 17 neighborhoods that did not 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. For Birmingham to be considered truly sustainable, there will need to be significant improvements in all three categories of sustainability.

The results of the hotspot analysis helped to identify areas of low sustainability scores that need improvement for Birmingham to achieve its goal of becoming a sustainable city. Further examination revealed that the neighborhoods located within the statistically significant coldspots scored worst in the economic category of sustainability. Most 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 hotspot 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.

One of the more interesting observations that can be taken from the hotspot 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 beautiful parks, like Avondale Park, that were built early in the history of the suburbs.

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 the investment and tax base in the inner city, and decrease vacant and abandoned housing.

Overall, neighborhoods received the worst scores in the economic sustainability category. Increasing the economic sustainability of Birmingham neighborhoods should be the priority because improving the economy will enable the city to address social and environmental sustainability issues more easily. 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 nor rent. The plan also states that a total of 11.5% of residential properties in the city are also 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.

The city also has much room for improvement in the environmental category. Most 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 impervious surfaces. Finally, the city needs to improve existing sidewalks and bike lanes and add them where they are missing 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 was one in which most neighborhoods performed very poorly. Walkability could be an extremely important driver of economic growth and rejuvenation in Birmingham. Speck [37] identified several 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.

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 to improve sustainability in the City of Birmingham.

5. Conclusions

To date, sustainability assessment tools have been less developed at the local level. This paper demonstrated sustainability indicators applied at the neighborhood scale in the City of Birmingham, Alabama, USA.

This research contributes to the literature in two ways. One contribution of the study is the incorporation of stakeholder perspectives. Indicators were based on the Citywide Visioning Forum, which involved participation from over 200 Birmingham residents from all areas of the city. 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 second contribution of the research is to provide a local level sustainability assessment tool. The results of the NSA system provided 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. This assessment could be performed again to determine how much progress has been made. The majority of SIs used in this NSA system are based on data that are easily attained on a yearly basis, making it a realistic model for continued assessment of sustainability in Birmingham.

There are a few limitations in the study. First, we acknowledge that additional aspects are needed to be considered (e.g., access to hospitals and the food desert). The second limitation is the subjectivity of normalization and the weighting system. Fuzzy techniques and sensitivity can be applied to reduce the subjectivity level. Lastly, direct replicability in a different context may be challenging as local context is a basis for indicator development.

While in its limitations, context-based neighborhood sustainability assessment has a potential to help planners and policy makers understand locally adoptable sustainable policies. 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.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2071-1050/12/22/9426/s1>. Detailed Neighborhood and Community Map and Neighborhood List with Sustainability Scores

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