QUANTIFYING URBAN DIVERSITY: A CASE STUDY IN THE DISTRICT OF COLUMBIA

by

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ABSTRACT

QUANTIFYING URBAN DIVERSITY: A CASE STUDY IN THE DISTRICT OF COLUMBIA

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As more and more people begin living in urban areas the role the built environment plays in creating a livable urban space is increasingly important. This research examines Jane Jacobs' four generators of urban diversity, as presented in *The Death and Life of Great American Cities* and attempts to quantify them in a meaningful way. This paper presents a methodology for assessing each of the four generators – dwelling density, block length, mix of building age, and mix of uses – as well as a new composite Urban Livability index that combines all four generators. The methods presented here are intended to create a framework that may be applied to any U.S. city in order to assess the built environment and provide useful information to city planners and policy-makers. The District of Columbia is used as a case study for the application and testing of this methodology.

INTRODUCTION

Urban structure is complex and multi-faceted. With more Americans living in cities than ever before, the effect that the built environment has on the 'livability' of urban spaces deserves an increasing amount of consideration. In the United States, the concept of 'new urbanism' has been gaining favor among modern city planners. New Urbanism can trace the origins of some of its concepts to the work of Jane Jacobs. In her first, and perhaps most influential, work *The Death and Life of Great American Cities*, Jacobs focuses much of her time on detailing what she describes as the four generators of urban diversity. These are: a fine-grained mix of primary uses; short block lengths; a fine-grained mixing of building age; and sufficient dwelling density to support urban vibrancy (Jacobs 1992, 150-151). Many of these elements have been incorporated into the design principles of new urbanism, which has largely been the impetus behind the modern ideas that create what has been described as 'livable' urban spaces.

In the Charter of the New Urbanism, the Congress for the New Urbanism states, "we stand for the restoration of existing urban centers and towns within coherent metropolitan regions, the reconfiguration of sprawling suburbs into communities of real neighborhoods and diverse districts, the conservation of natural environments, and the preservation of our built legacy" (Anon. 1996). The Charter goes on to co-opt each of Jacobs' four generators, stating in principle number 11, "neighborhoods should be compact, pedestrian-friendly, and mixed-use," in principle number 13, "interconnected networks of streets should be designed to encourage walking, reduce the number and length of automobile trips, and conserve energy," in principle number 15, "appropriate building densities and land uses should be within walking distance of transit stops, permitting public transit to become a viable alternative to the automobile," and in principle number 27, "preservation and renewal of historic buildings, districts, and landscapes affirm the continuity and evolution of urban society" (Anon. 1996). With such clear adoption of Jacobs' ideas, it is easy to see why studying Jacobs remains a relevant topic of research.

Increasingly there is a movement among federal, state, and local governments to invest resources into communities in the interest of creating more 'livable' environments. While there is latitude as to what precisely constitutes a livable urban space, most definitions include at least three of Jacobs' generators of urban diversity; namely, dwelling density, short (or frequent) blocks, and mixed primary uses. Often, it is clear to those that are familiar with the many communities within a city as to which locations need the greatest investment in one or all of these generators. The difficulty for policy-makers is to be able to present these decisions in a defensible manner to the public at large. The justification for these decisions is often presented though a quantitative analysis. While the qualitative approach to this work does hold value and Jacobs' work was almost exclusively qualitative in nature, the key elements that she describes are certainly quantifiable. This paper seeks to quantify the four generators that Jacobs describes in the form of a single index and four sub-indices in order to create a quantitative analysis of the livability of different communities within an urban environment; here, Washington D.C. has been chosen as a case study.

While there has been considerable research into one or more of Jacobs' four generators of diversity, as shown in the following section, there does not appear to be any research that has considered all four dimensions in combination. Furthermore, nearly all research has been conducted using boundaries that do not necessarily reflect areas that constitute a neighborhood (such as traffic analysis zones, which are delineated by state or local officials specifically for the purposes of studying traffic volumes) or have been conducted at too coarse a level of detail (such as an entire Metropolitan area). In addition, the existing research has largely been conducted in suburban locations, rather than true urban environments. In her introduction, Jacobs clearly states "I hope no reader will try to transfer my observations into guides as to what goes on in towns, or little cities, or in suburbs which still are suburban. Towns, suburbs, and even little cities are totally different organisms from great cities…to try to understand towns in terms of big cities will only compound confusion" (Jacobs 1992, 16). This paper seeks to apply Jacobs' four generators of diversity to a truly urban environment at a fine-grained level. In this paper Jacobs four generators are examined both individually and in concert at the Census block group level within the boundaries of Washington, DC, utilizing data from the city government.

This research does not seek to prove or disprove Jacobs' four generators, but rather to create a methodology that allows for their examination. While the validity of Jacobs' theories cannot be overlooked and this methodology will be useful in examining the viability of Jacobs' diversity parameters, more importantly, it allows for the investigation and targeted investment by policy-makers into the success of city neighborhoods. Whether Jacobs' ideas are fully functional or not, they have been incorporated into the tenets of New Urbanism, Smart Growth, and Transit-Oriented Design. Given the popularity of these ideas among modern planners, it is important to create useful methods for their examination.

The following section presents a review of previous research in the area of livability, this is followed by a description of the data used to conduct this case study. Next, a detailed description of the methodology is presented, followed by the results of the case study, the conclusions that can be drawn from this case study, as well as possible future research. The final section of this paper presents a list of the references utilized throughout this paper. Please note that the quotations from *The Death and Life of Great American Cities* presented in this paper are from the 1992 edition of the book, although the original was published in 1961.

LITERATURE REVIEW

When *The Death and Life of Great American Cities* was first published it was rightfully seen as an unfavorable critique of modern city planning. In the first sentence of the book Jacobs states explicitly, “This book is an attack on current city planning and rebuilding” (1992, 3). Throughout the book, Jacobs names not only the planning concepts to which she objects, but also those that she sees as their authors and proponents. Among the parties she identifies on numerous occasions as having had a detrimental effect on the city is Lewis Mumford, a contemporary of hers and a respected planner to this day. Perhaps due in part to inflammatory statements by Jacobs (see above), the level of discord between Jacobs and Mumford has been somewhat exaggerated. In reviewing the relationship between Jacobs and Mumford, Mellon (2009) found that while Jacobs’ and Mumford’s ideas for what constituted a healthy, diverse, livable urban environment differed, they both strove for the same goal; Mumford is even noted as having encouraged Jacobs to write *Death and Life*.

While the friction between Mumford and Jacobs may have been embellished by history, there is no doubt that she saw futility in the city planning efforts of the time (again, see earlier quote). However, the critique that she presented in *Death and Life* was not considered by many to be objective in nature (Laurence 2006), especially when compared to the physical sciences being studied at the time. However, in the final chapter of *Death and Life*, Jacobs discusses the scientific theories of Warren Waver and notes "cities happen to be problems of organized complexity, like the life sciences" (1992, 433). This suggest that if we change the way that cities have been studied in the past, it is possible to arrive at methods that produce master plans dramatically different than those that Jacobs railed against. This is the void which the research presented in this paper attempts to begin filling.

The research presented here is related to other research in the fields of livability and quality of life. Other authors have recently reviewed much of the previous literature relating to these subjects from a broad perspective. These reviews find that the definitions of livability are wide-ranging and note that "concepts such as livability, living quality, living environment, quality of place, residential-perception and satisfaction, the evaluation of residential and living environment, quality of life and sustainability do overlap, and are often used as synonyms – but every so often are contrasted" (van Kamp et al. 2003). It can be noted that some of these concepts, such as quality of life, are usually studied by examining the perceptions of groups of people rather than examining quantitative data that represents the built environment, as is being done in the research presented here. Pacione (2003) also examines a large volume of literature in the field, and comes to many of the same conclusions as van Kamp, et al. (2003), viewing quality of life and livability studies as having many sub-domains related to the researcher's approach to the problem (objective vs. subjective, scale of the study, etc.). Pacione makes the case for the power of planning, noting that "markets (for labor, finance, goods and services) are not created by natural or divine forces but are the product of values, institutions, regulations and political decisions that govern them" (2003).

Two examples of the broad ranging nature of quality-of-life and livability studies include the work of Doi, Kii and Nakanishi (2008) and the work of Wood, Frank and Giles-Corti (2010). The research of Doi, et al. (2008) examines quality of life indicators in Takamatsu, Japan, and includes the sweeping statement that "if individuals are enabled to make rational choices about their location over the long term, they can ensure the highest [quality of life] performance all the time." This statement highlights the perceptive nature of this particular study, which ignores the fact that individuals are capable of making (and frequently do make) decisions that are irrational, causing perceptive studies to potentially arrive at irrational conclusions. While these types of studies are important (what use is a safe neighborhood if everyone in the community perceives it to be crime-ridden?), it is necessary to include non-perceptive qualitative studies in the literature as well. Wood, et al. (2010) attempts to fill this gap by examining the effects of the built environment on sense of community. However, this particular study used a study area that was largely homogenous in nature, something acknowledged by the authors; "the extent of urban form variation was also limited by the fact that the Atlanta study region was very auto-oriented with limited public transport" (Wood, Frank, and Giles-Corti 2010). Again, more robust studies are needed to bolster the understanding of the built environment and its role in livability.

As noted earlier, many of the concepts that Jacobs introduced in *Death and Life* have been incorporated into the New Urbanist movement. As such, much of the modern criticism of these ideas comes under the umbrella of critiquing the New Urbanist and Smart Growth planning ideals. Kristen Day (2003) argues that in New Urbanist design, "diversity is not regarded as an existing characteristic of communities…the assumption breaks down, however, when New Urbanism is applied to urban neighborhoods in which diversity already exists." This is an important statement, in that it reflects how the ideas of Jacobs differ from how they have been incorporated into New Urbanism. Jacobs actually sees the situation as the reverse of the New Urbanists, stating that, "to be sure, a good city neighborhood can absorb newcomers into itself, both newcomers by choice and immigrants settling by expediency, and it can protect a reasonable amount of transient population too" (1992, 137-138). Here, Jacobs sees the diversity as inherent in the good neighborhood, with the ability to adapt and absorb, as opposed to a diversity that needs to be created. To be fair, she also indicates that diversity is not inherent, and thus proposes the four characteristics that she sees as necessary for the creation and sustainability of diversity. In the chapter entitled "Gradual money and cataclysmic money" she warns against sudden infusions of money that "[pour] into an area in concentrated form, producing drastic changes" (Jacobs 1992, 293) which may produce challenges because, according to Jacobs, "All city building that retains staying power after its novelty has gone and that preserves the freedom of the streets and upholds citizens' self-management, requires that its locality be able to adapt, keep up to date, keep interesting, keep convenient, and this in turn requires a myriad of gradual, constant, close-grained changes" (1992, 294). The distinctions between Jacobs' original work and its incorporation into the New Urbanist movement are important, since much of the existing research and critique has focused on the principles of the New Urbanists, rather than the original ideas of Jacobs.

Many of the critics of Jacobs and the New Urbanist ideals focus on evaluating them from a single perspective, such as traffic reduction. The research of Filion and Hammond (2003) is an excellent example. The authors question the wisdom of neo-traditional (i.e. New Urbanist) design, noting that they do not “necessarily enhance pedestrian accessibility rates” and “are not as effective at diverting through traffic away from residential streets as those of newer neighborhoods” (Filion and Hammond 2003). Jacobs would likely take this statement as an example of the flawed reasoning of the authors, as they focus on segregating uses (residential streets versus commercial corridors) and travel modes. Jacobs herself did not see automobiles as an enemy; “we blame automobiles for too much” (1992, 338). Instead, she views automobile use as a necessary, though over-used, means of transport – and as especially critical for conducting commerce. “To concentrate on riddance as the primary purpose, negatively to put taboos and penalties on automobiles as children might say, ‘Cars, cars go away,’ would be a policy not only doomed to defeat but rightly doomed to defeat” (Jacobs 1992, 360). The conclusions of Filion and Hammond are likely due to their decision to approach the research from a perspective that differs from Jacobs’ with regard to the separation of travel modes and uses.

Similarly, much of the research into Jacobs’ four generators of diversity has focused on only one or two of the generators in isolation. A number of studies have been conducted into the effects of mixed-use development. Grant (2002) found that “mixed use districts are becoming more segregated by class, and affordability has not improved. Efforts to mix uses have not stanched the loss of economic vitality for most Canadian cities." However, this research focused on mixed-use in the suburban context, a location where Jacobs' (as noted earlier) had no intention of her ideas being utilized. Some research has focused on the level of physical deterioration of structures (as a proxy for the success or failure of the community) within a mixed-use context, finding that there are increased levels of deterioration in mixed-use neighborhoods (Taylor et al. 1995). The research of Wansborough and Mageean (2000) looks at mixed-use in slightly broader terms, focusing on its role in cultural regeneration. Their conclusion differs from Taylor, et al. (1995), finding that "the encouragement of ground-floor uses in mixed-use schemes has helped to improve surveillance and soften the boundary between public and private space" (Wansborough and Mageean 2000). Hirt (2007) explores the differences in zoning between the U.S. and German systems finding that, "under the German approach each city block may end up in a different land use category, and this is conducive to a much more fine-grained diversity of uses." The research goes on to note that U.S. zoning techniques, "reduce the idea of the mixed-use city, which Jane Jacobs so eloquently advocated, to a small mixed-use part of the city" and "assume that single-family residential areas are inevitable, quite unlike what we find in Germany. This is precisely one of the reasons why Jane Jacobs criticized new urbanism" (Hirt 2007). This is further evidence that while the New Urbanists found inspiration in Jacobs' work they have not strictly adhered to her philosophy.

There have also been studies that have focused on the density aspect of the four generators of diversity in isolation from the others. Bramley and Power (2009) explored the connection between density and social sustainability within communities, and note the trade-offs that occur with increased density. "…Compact forms worsen neighborhood problems and dissatisfaction, while improving access to services" and "policy must therefore think in terms of trade-offs between social objectives" (Bramley and Power 2009). Similarly, Nasar (2003) found that, "the more condensed pattern of development and reduced use of auto did not yield a higher sense of community: residents in [neo-traditional developments] and [standard suburban developments] showed no difference in sense of community." With these two studies, it is not clear just how large of a role self-selection has played in the results. How many of the residents have chosen to live in a particular neighborhood for specific reasons, as opposed to those that live there as a compromise, or through lack of alternative options? A resident that is present in a neighborhood as part of a deliberate locational choice is likely to respond differently than a resident that is there due to a lack of alternatives. This uncertainty strengthens the argument that, as noted earlier, perception is only one aspect that should be evaluated when considering the four generators of diversity.

In contrast to density and mixed-use, there has been significantly less research conducted regarding street length and mix of building age in the context of livability. Cozens and Hillier (2008) conducted a review of literature regarding cul-de-sacs and grid street networks (which can be considered a moderately useful proxy for short street segments) and concluded that "the evidence to support New Urbanism's advocacy for permeable street networks is unfounded or largely inconclusive at best." The authors suggest that cul-de-sacs have fallen out of favor due to their association with the Garden City movement; the planning idea against which New Urbanism is sometimes considered a reaction. However, as noted later in this paper, it is not strictly the connectedness of a street layout that is in question with Jacob's work, it is actually the physical length of the network segments. For this reason, Cozen and Hillier's conclusions must be taken in context, and cannot be seen as a refutation of Jacobs' ideas about block length. Along with the limited research into the street length – livability dynamic, there is virtually no current research available that examines the role of building age mixes with regard to livability and diversity.

In addition to the research that has been conducted focusing on a single one of the four generators of diversity, there have been a limited number of studies that have attempted to include elements of at least three of the generators (again, building age mix is absent from inclusion in these studies). Miles and Song (2009) examined Portland, Oregon which has utilized many of Jacobs' ideas in its planning and found that the city "has been successful in creating neighborhoods at several economic scales that feature not only the connectivity, accessibly, mixed land use and access to public transit that characterize 'good' neighborhoods from a physical perspective, but also 'good' social environment indicative of strong ties and collective efficacy." This finding echoes the earlier research of Song (2005) who examined three different communities that have utilized 'smart growth' policies and found that "only when all these dimensions – connectivity, density, mixed land uses, accessibility, and pedestrian walkability – are combined can they create synergy by having amenities that complement one another." Regarding the four generators of diversity, Jacobs herself writes, "all four in combination are necessary to generate city diversity; the absence of any one of the four frustrates a district's potential" (1992, 151). Cervero (2002) also examines multiple parameters, this time strictly from the perspective of travel mode choice. Utilizing Traffic Analysis Zones, he found that "drive-alone and group-ride automobile travel fell relative to transit riding as gross densities increased at both the trip origin and destination. And land-use mixture at both trip ends lowered the probability of driving alone or ride-sharing versus taking a bus or train, ceteris paribus" (Cervero 2002). These papers all underscore the wide-ranging impact that Jacobs' ideas about density, land-use, and street networks can have on the livability of the urban environment.

A number of researchers have emphasized the importance of scale when studying the built environment. Tesfazghi, Martinez, and Verplanke (2010) illustrated how having areas of aggregation that are too large can mask the variability that exists at a lower level. This reinforces the work of Openshaw and what he described as the 'modifiable areal unit problem', noting that "the definition of these geographical objects is arbitrary and (in theory) modifiable at choice; indeed, different researchers may well use different sets of units" (1983). This highlights the importance of utilizing small, yet standardized units of aggregation, such as Census defined block groups. Martinez (2009) chose to study quality of life indicators at a block group level stating that, "when indicators are generated at high levels of aggregation they can give a misleading idea of the problem they address and quantify." Apparicio, Seguin and Naud (2008) who examined a mix of subjective and objective quality of life parameters at an intra-urban level note that, “since individuals’ daily lived environment is not on a metropolitan scale, it is important to find the appropriate scale so that the indicators can express the heterogeneity of the conditions faced by urban residents.” The research presents a convincing argument to carefully account for the level of detail at which a study is undertaken. For this reason, block groups have been chosen as the primary unit of aggregation for this study.

In light of the previous research conducted in the area of livability and the built environment, the research presented here hopes to fill the gap by creating a methodology that effectively quantifies each of Jacobs’ four generators of diversity in a manner that may be applied to any large U.S. city, as well as creating a single Urban Livability index which combines all four parameters into a single easy to understand ranking. By creating a single index as well as four supporting indices, the methodology presented will assist city officials in decision making during the urban planning process, as well as provide a repeatable framework for other researchers in the area of livability.

DATA

For this study, the data is from two sources. The first source is the U.S. Census Bureau, from which the block group geography is obtained. These serve as the primary units of aggregation and examination for the study. The second source is the Washington, DC, city government that provided data for street centerlines as well as land ownership data that includes a number of important attributes. All data were projected in the Maryland State Plane Coordinate System (the official coordinate system for the Washington, DC city government), which utilizes a specific implementation of the Lambert Conformal Conic projection to minimize the distortion of all measurements within the study area.

The block group file contains 433 block groups and covers the entire city, including areas owned and operated by the federal government, such as the National Mall. The street centerline file includes 34,138 street segments (including freeways, alleyways, driveways and access ramps) across the entire city, again, including areas under federal jurisdiction, such as Rock Creek Parkway. The ownership file is a point file that contains a single point for each ownership record within Washington, DC. This file contains a detailed land-use code for each point that corresponds to a list of 109 possible land-use types designated by the city government. This file was appended with data for building construction, renovation and addition dates for commercial and residential properties, also obtained from the city government. This information was not available for some buildings, such as educational and health care facilities. The greatest challenge with the ownership data is the different treatment that condominiums and rental units receive. While condominiums in the same building are each represented as a unique point, an apartment building for which a single owner rents all the units only contains one point in this file. This represented a potential difficulty for calculating dwelling densities. However, the same file that contained information on building date also contained information on the number of units in each structure. Thus, apartments units that are represented by a single point for multiple dwellings had the information on the number of units appended to them.

METHODOLOGY

The basic method of research for this study consists of the creation of four individual indices for each of Jacobs' four generators of diversity, as well as a single composite index comprised of the results of each of the four individual indices. All four of the individual indices utilize data that is rescaled to range from 0 to 1. This facilitates the computation of the final index by giving all four parameters equal weights. Other methods, such as the utilization of a z-score were considered, but this tends to force the parameter values into artificial distributions which may or may not hold true between different cities and require differing transformations, limiting the portability of the methodology. By utilizing rescaled values, this methodology may then be applied to different cities and begin to allow for analysis based on data from different regions.

For the first parameter, dwelling density, each of the ownership points is assigned to a block group, and the area for each block group is calculated in acres. Next all points defined by their use code as residential (see Table 1) are selected. For properties where a single dwelling is represented by a single point (single-family homes, condominiums, etc.), a value of '1' is assigned to that point. For properties where multiple dwellings are represented by a single point (such as rental apartments), a value corresponding to the total number of dwellings is assigned to the point. These values are then totaled for each block group and a density is calculated from these totaled values. Finally, these values are then rescaled from 0 to 1 utilizing the equation:

Equation 1

$$V_r = \frac{(V_i - V_{\min})}{(V_{\max} - V_{\min})}$$

Where V_i equals the value to be rescaled, V_{min} equals the lowest density calculated, and the V_{max} equals the highest density calculated. This results in all values being scaled from 0 to 1, with values closer to 0 having a lower density than values closer to 1. This also maintains the natural distribution of the dataset.

Table 1 - List of Residential Uses for Dwelling Density

Use Code	Description
003	Residential-Transient
011	Residential-Row-Single-Family
012	Residential-Detached-Single-Family
013	Residential-Semi-Detached-Single-Family
015	Residential-Mixed Use
016	Residential-Condo-Horizontal
017	Residential-Condo-Vertical
019	Residential-Single-Family-Misc
021	Residential-Apartment-Walk-Up
022	Residential-Apartment-Elevator
023	Residential Flats-Less than 5
024	Residential-Conversions-Less than 5
025	Residential-Conversion-5 units
026	Residential-Cooperative-Horizontal
027	Residential-Cooperative-Vertical
028	Residential-Cooperative-Mrth5
029	Residential-Mutlifamily, Misc
117	Condo-Vertical-Combined

126	Coop-Horizontal-Mixed Use
127	Coop-Vertical-Mixed Use
216	Condo-Investment-Horizontal
217	Condo-Investment-Vertical
316	Condo-Duplex

For the second parameter, block length, each street segment (excluding alleyways, driveways, and ramps) is assigned to a block group or number of block groups. In some cases, segments are assigned to as many as three different block groups. In Figure 1 a street segment is shown that is assigned to three separate block groups, due to a number of ‘intersections’ actually being over/under-passes, meaning that this segment runs uninterrupted through multiple block groups. Street segments are assigned to block groups that they are either fully contained by, intersected, or for which they formed a portion of the boundary. However, segments that only share one vertex with the block group are not included. Due to slight misalignment between street and block group data, each of the 433 block groups in this case study was manually examined to confirm the appropriate streets were assigned to it. While it is possible to achieve this assignment through a standardized programming approach, the precise nature of the algorithm may differ slightly from dataset to dataset given the unique relationships that block group and street segments may have to one another. Following this assignment the length of each street segment, in feet, is then calculated. The total number of street segments and their total lengths for each block group is then calculated and a mean street segment length for each block group is calculated from these totals. Finally, the mean street segment length for each block group is rescaled from 0 to 1 utilizing the same format as Equation 1, where V_i equals the value to be rescaled, V_{min} equals the lowest mean street segment length, and the V_{max} equals the highest mean street segment length. This results in all values being scaled from 0 to 1, with values closer to 0 having a lower mean street segment length than values closer to 1. For this parameter, the lower values are preferred to the higher values.

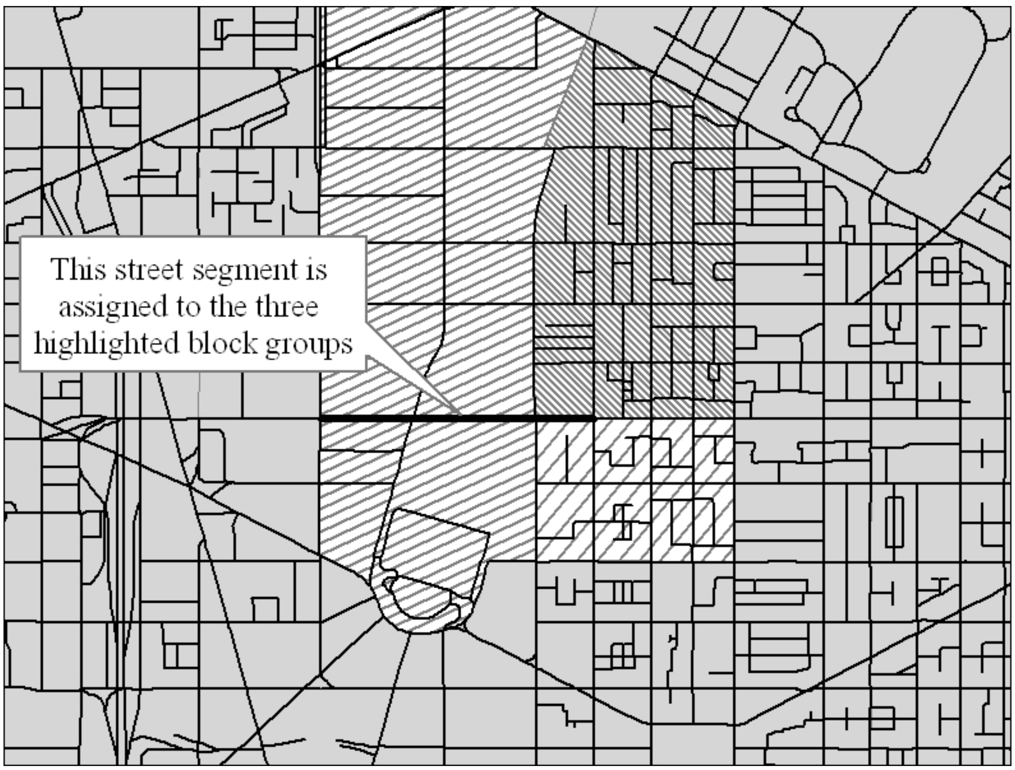

Figure 1 - Street Segment Assigned to Multiple Block Groups

While there are a number of methods that measure street connectivity, such as alpha and beta indexes (Rodrigue, Comtois, and Slack 2009, 29-31), the connectedness of the streets within a block group is not Jacobs' primary concern. A large block group with six long street segments and six intersections would have the same level of connectedness as a small block group with six short street segments and six intersections. However, Jacobs would find the small block group with shorter street segments to be a better generator of diversity than the larger block group with longer street segments. For this reason, the block length parameter examines the mean street segment length, rather than the connectivity within a block group.

For the third parameter, mix of building age, each ownership point and its associated dates are examined. Of the three available dates (construction, renovation, and addition), the newest date is extracted and used for the following calculations. This is based on Jacobs' statement that "a successful city district becomes a kind of ever-normal granary so far as construction is concerned. Some of the old buildings, year by year, are replaced by new ones – or rehabilitated to a degree equivalent to replacement. Over the years there is, therefore, constantly a mixture of building ages and types" (1992, 189). First the standard deviation of the dates of the points within a block group is calculated. Then once these the standard deviations have been calculated for each block group, they are rescaled from 0 to 1 utilizing the same format from Equation 1, where V_i equals the value to be rescaled, $V_{\min}$ equals the lowest standard deviation, and the $V_{\max}$ equals the highest standard deviation. This results in all values being scaled from 0 to 1, with values closer to 0 having a lower building age difference than values closer to 1. For this calculation, a higher value is preferred, since by Jacobs' estimation, areas with the greatest variance are better generators of diversity.

For the fourth parameter, mixed-uses, two slightly different methods are used and evaluated. While there are existing methods, such as binary assignments, where geographic units are determined to be mixed-use or non-mixed-use, based on different criteria (Krizek 2003), the methods employed here seek to create a scale of 'mixed-ness' within a block group. The first method evaluated consists of calculating the distance between each residential point and the nearest commercial point within the same block group. The mean of these distances is then calculated and rescaled from 0 to 1 utilizing the same format from Equation 1, where V_i equals the value to be rescaled, $V_{\min}$ equals the shortest mean distance, and the $V_{\max}$ equals the highest mean distance. This results in all values being scaled from 0 to 1, with values closer to 0 having a shorter mean distance between residential and commercial locations than values closer to 1. Block groups that either do not contain commercial points or do not contain residential points are assigned a value of 1, indicating that they are the least mixed-use.

The second method evaluated consists of calculating the mean center of all the residential points within a block group and the mean center of all the commercial points within a block group. The distance between the two mean centers is then calculated. This distance is then rescaled from 0 to 1 utilizing the same format from Equation 1, where V_i equals the value to be rescaled, $V_{\min}$ equals the shortest distance between mean centers, and the $V_{\max}$ equals the greatest distance between mean centers. This results in all values being scaled from 0 to 1, with values closer to 0 having a shorter distance between residential and commercial mean centers than values closer to 1. As with the first method, block groups that either do not contain commercial points or do not contain residential points are assigned a value of 1, indicating that they are the least mixed-use. For both of these methods, ‘commercial’ includes uses described as ‘retail’. See Table 2 for a list of the uses included as ‘commercial’ in these calculations.

Table 2 - List of Commercial Uses for Mixed-Use Calculation

Use Code	**Description**
001	Residential-Single Family (Commercial Use)
031	Hotel-Small
032	Hotel-Large
033	Motel
034	Club-Private
035	Tourist Homes
036	Dormitory
037	Inn
038	Fraternity/Sorority House
039	Residential-Transient, Misc
041	Store-Small 1-Story
042	Store-Misc
043	Store-Department
044	Store-Shopping Center/Mall
045	Store-Restaurant
046	Store-Barber/Beauty Shop
047	Store-Super Market
048	Commercial-Retail-Condo
049	Commercial-Retail-Misc
051	Commercial-Office-Small
052	Commercial-Office-Large
053	Commercial-Planned Development
056	Office-Condo-Horizontal
057	Office-Condo-Vertical
058	Commercial-Office-Condo
059	Commercial-Office-Misc.
061	Commercial-Banks, Financial
066	Theaters, Entertainment
067	Commercial-Restaurant
068	Commercial-Restaurant-Fast Food
069	Commercial-Specific Purpose, Misc.

165	Vehicle Service Station -Kiosk
365	Vehicle Service Station-Market
465	Vehicle Service Station-Market

The idea behind both of these methods is that in each instance the calculations reflect the level of inter-mixing of residential and commercial uses. The closer the shortest distance between a residential location and a commercial location within the same block group, the more inter-mixed these uses are; the closer the mean centers of these two use types, the more mixed these uses are. For both methods, the Euclidean distance is used for the calculations, as opposed to the manhattan or network distance. This done as an effort to separate the measure of this particular parameter as much as possible from the actual structure of the street network, which has its own measure in the form of street lengths. This will help to identify areas that may have an adequate street network, but a poor mix of uses, or vice versa. Both methods are evaluated since they may provide slightly different results, though one, the mean center calculation, is far less computationally intensive than the other, making it more repeatable for other cities. As with the block length parameter, lower values (closer to 0) are preferred to higher values (closer to 1), since lower values are indicative of a more fine-grained mix of uses.

It should be noted that in the interest of easing the computational complexity of these calculations they have both been limited to commercial and residential points within the same block group. This creates the possibility, particularly for the mean shortest distance method, that some residential points may be assigned a distance that is higher than if all commercial points (including those outside of the block group) were used. For example, if a residential point were located close to the edge of a block group, and the nearest commercial point within that block group was on the opposite side of the block group, but there is another commercial point only a few dozen feet away but outside of the block group, the residential point in question will be assigned the longer distance to the point that is within the block group. Similarly, for block groups that either contain no residential points or contain no commercial points, those block groups will have mean distances of 0 and will be assigned the value for least-mixed, rather than reflecting the true distances to the nearest commercial points (which may be just outside of the block group). While a more inclusive computation is more robust, it has been sacrificed with the intention of reducing the computational burden and with the understanding that the final calculation is derived from the mean which aids in mitigating the impact of these types of occurrences.

The final part of the methodology consists of a composite index, the Urban Livability (UL) index, which combines all four parameters into a single number. For this composite index, the final score for each of the four parameters is combined. In the case of the block length and mixed-use parameters, the negative of the values is taken, since for these particular indices, negative scores are considered better than positive scores. The final index is as follows:

Equation 2:

$$UL_i = d_i + (-a_i) + b_i + (-m_i)$$

Where UL_i equals the final composite index for the selected block group, d_i equals the rescaled value of the selected block group for the density parameter, b_i equals the rescaled value for the selected block group for the block length parameter, a_i equals the rescaled value of the selected block group for the building age difference parameter, and m_i equals the rescaled value for the selected block group of the mixed-use parameter. While this un-weighted additive approach to the composite index may appear somewhat simplistic, it corresponds most closely to the work of Jacobs, who did not view one of the parameters to be any more important than the other three. For the final calculation, these composite scores are rescaled from 0 to 1 utilizing the same format from Equation 1, where V_i equals the value to be rescaled, $V_{\min}$ equals the lowest composite value, and the $V_{\max}$ equals the highest composite value. This results in all values being scaled from 0 to 1, with values closer to 0 having a less 'livable' environment across the four parameters than values closer to 1.

For this research, all of the parameters have been examined at the Census block group level of aggregation. Jacobs carefully notes that her four generators of diversity operate on a fine-grained level (Jacobs 1992, 150-151). While it would be ideal to examine each of these parameters on a block-by-block basis, there is difficulty in doing so. The most challenging of the parameters to examine at such a small geographic level is that of mixed-use. Simple observation in most cities will show us that having a wide variety of uses on a single block is highly uncommon. Figure 2 shows an example from Northwest DC where uses are clearly delineated by street block. Commercial uses are clearly aligned along U Street, while T Street along with 15th and 16th Streets are all residential in nature.

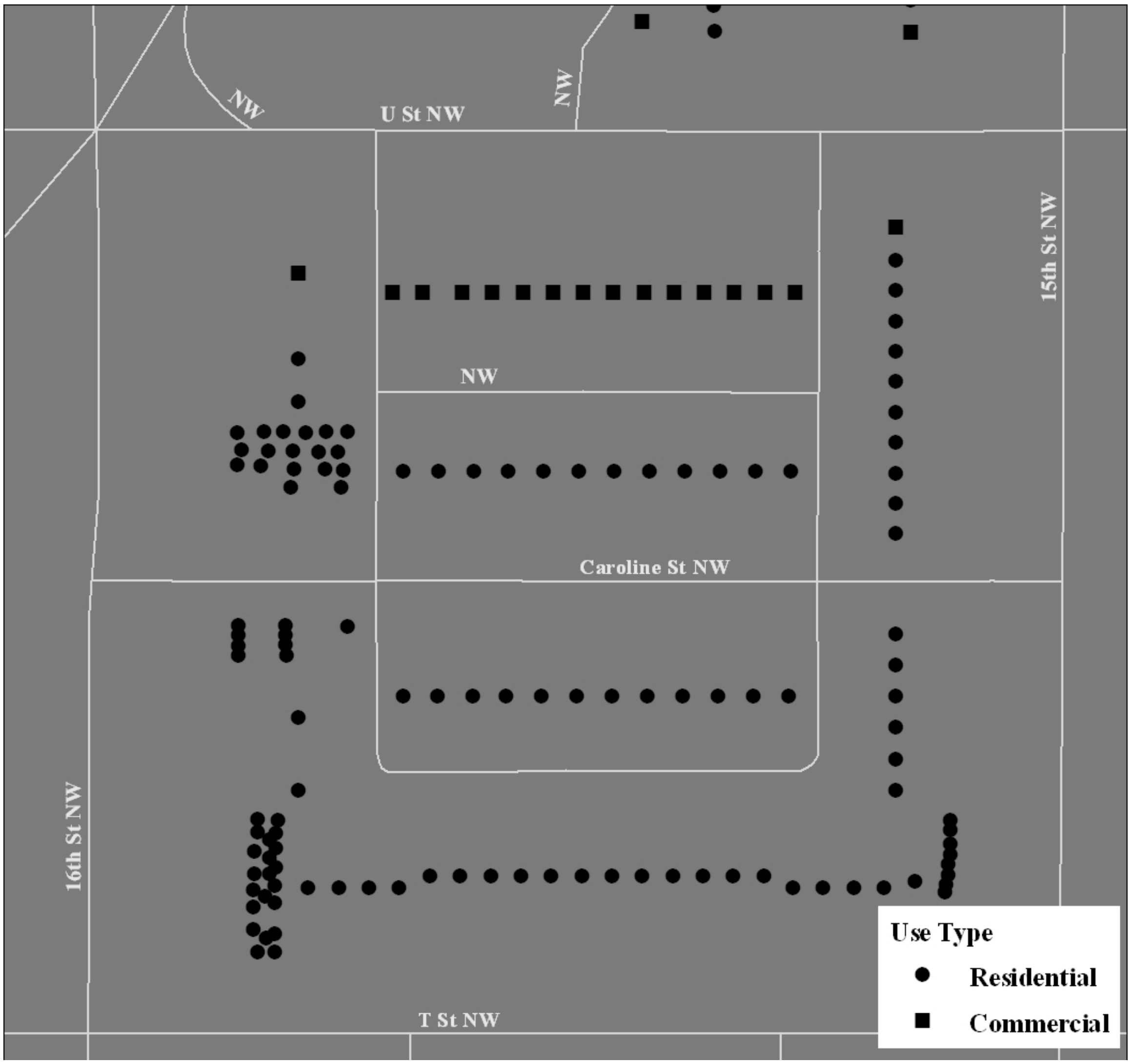

Figure 2 - Mix of Uses by Street Block

It is far more common for uses to be mixed by adjacent blocks, such as a residential block adjacent to an office block and a retail block. Thus, it becomes necessary to have a minimum level of aggregation to capture this mixture of uses. Census block groups provide a convenient, yet sufficiently fine-grained level of aggregation for this study, as shown by the number, 433, needed to cover the entire city. The most apparent downside to utilizing block groups is their irregular size. This creates a challenging situation for comparing certain parameters across block groups – again, mixed-uses present a challenge. For areas with particularly high population counts, block groups are smaller. For especially dense populations, the block group may only contain a single residential complex. This creates problems when calculating the percentage units within a block group that are residential as opposed to commercial. Block groups that are geographically larger inherently have the potential to capture more non-residential uses. Some authors have addressed this by utilizing a regularly spaced grid overlaid on the study area, and aggregating by each of the grid squares (Krizek 2003). However, by utilizing a grid that is unique to that particular study, it becomes very difficult, if not impossible, to verify the study using additional data. Here, by using block groups, there is the possibility of examining the results of the research against certain types of Census data (such as poverty rates), used as proxies for livability. The utilization of readily available block groups also facilitates the reproduction of this research within other cities and by other authors. Other researches have utilized larger areas of aggregation, such as Traffic Analysis Zones (TAZs) or Census tracts. By way of comparison, there are 320 TAZs within Washington, DC (which are not necessarily contiguous, thus leaving some areas of the city unstudied), and there are 188 census tracts – far fewer than the 433 contiguous block groups used in this study

RESULTS

After processing the data according to the methodology outlined above, a number of interesting patterns emerged. Beginning with the first parameter, dwelling density, the number of dwellings per acre ranged from zero to 65.97, with a mean of 11.22 and a standard deviation of 10.02. Figure 3 shows the distribution of the densities, as a histogram. Figure 4 illustrates the rescaled values as an unclassed choropleth map. The spatial distribution is as expected, with high densities especially evident in the Foggy Bottom, DuPont Circle, and Columbia Heights/Mount Pleasant neighborhoods, and a wide mix of densities in the Southeast quadrant of the city, east of the Anacostia River. Low densities are clearly present in upper Northwest, as well as the Northeast quadrant and along parts of Rock Creek Park and the National Mall.

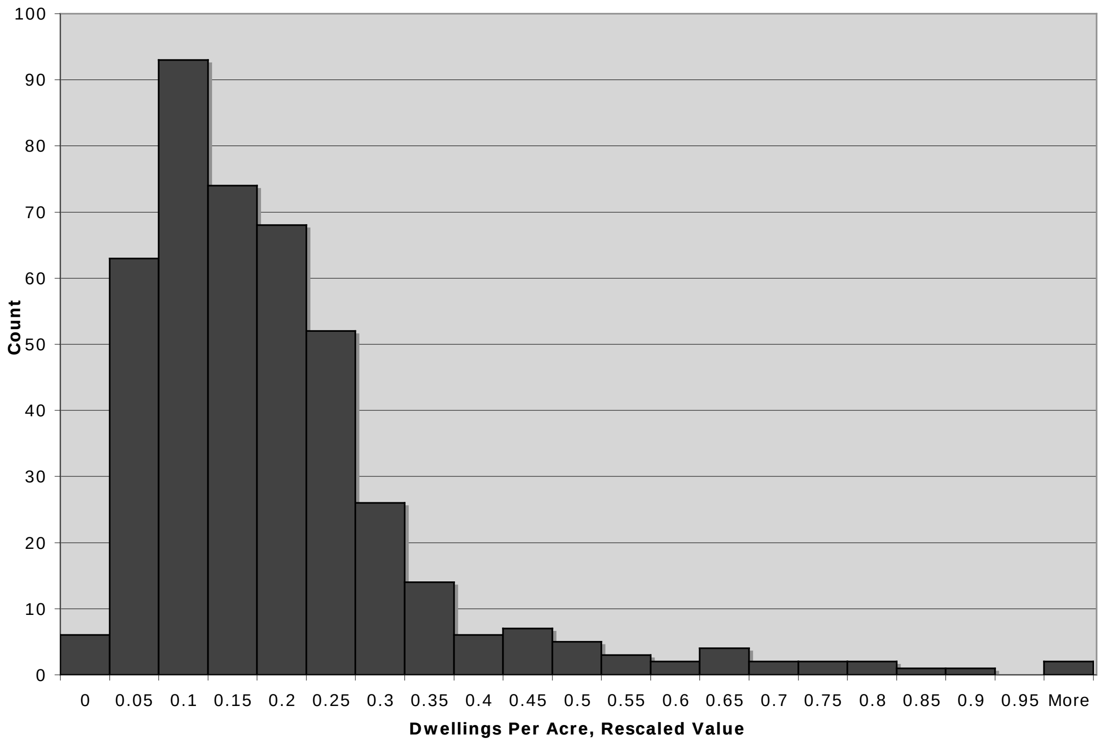

Figure 3 - Dwellings Per Acre Frequency

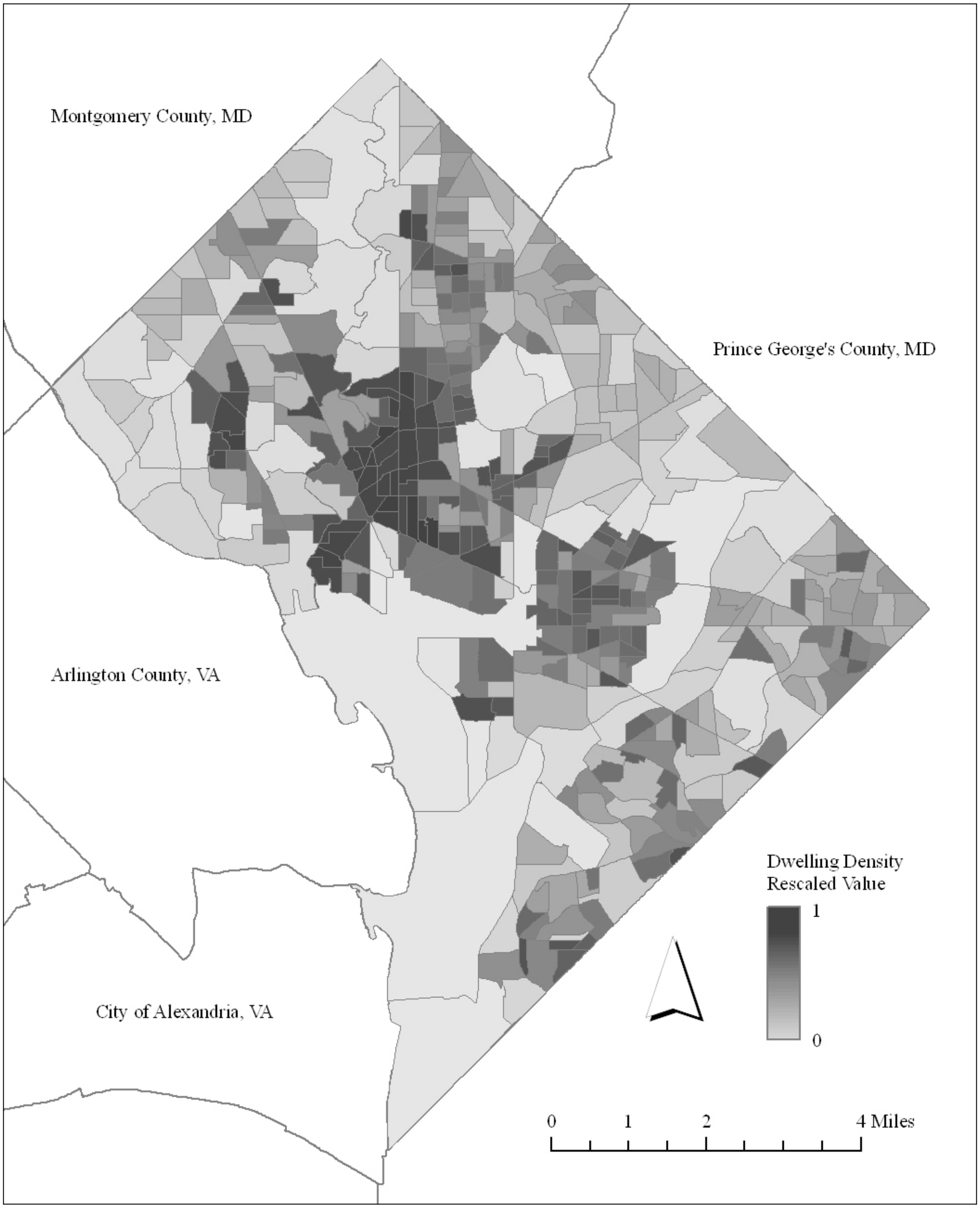

Figure 4 - Dwelling Density Rescaled Values

For the second parameter, block length, the mean block length for each block group ranges from 154.15 feet to 737.04 feet, with a mean of 276.17 and a standard deviation of 93.08. Figure 5 shows the distribution of the mean block lengths as a histogram. Figure 6 shows the rescaled values as an unclassed choropleth map. With a few exceptions, the spatial distribution is not particularly surprising. Many of the areas with high mean block length contain freeways or other large, disruptive roads. With the exception of the block group containing the National Mall (which is to be expected, given the street layout of this area), many of the areas that have a higher mean block length are outside of the parts of the city that utilize a regular street grid. Notable exceptions are the block groups within Georgetown. This is one of the oldest parts of the city and has many short, gridded streets, however this area also contains the elevated Whitehurst Freeway, which skews the values for this area higher, though they are certainly not the highest.

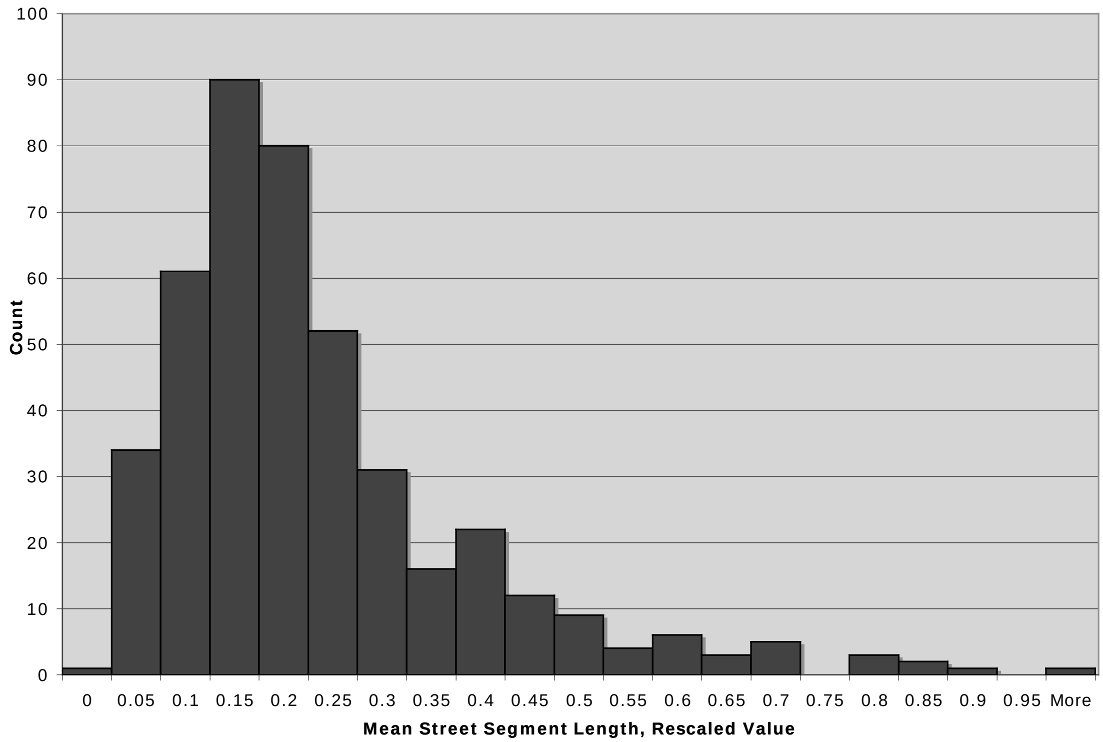

Figure 5 - Mean Street Segment Length Frequency

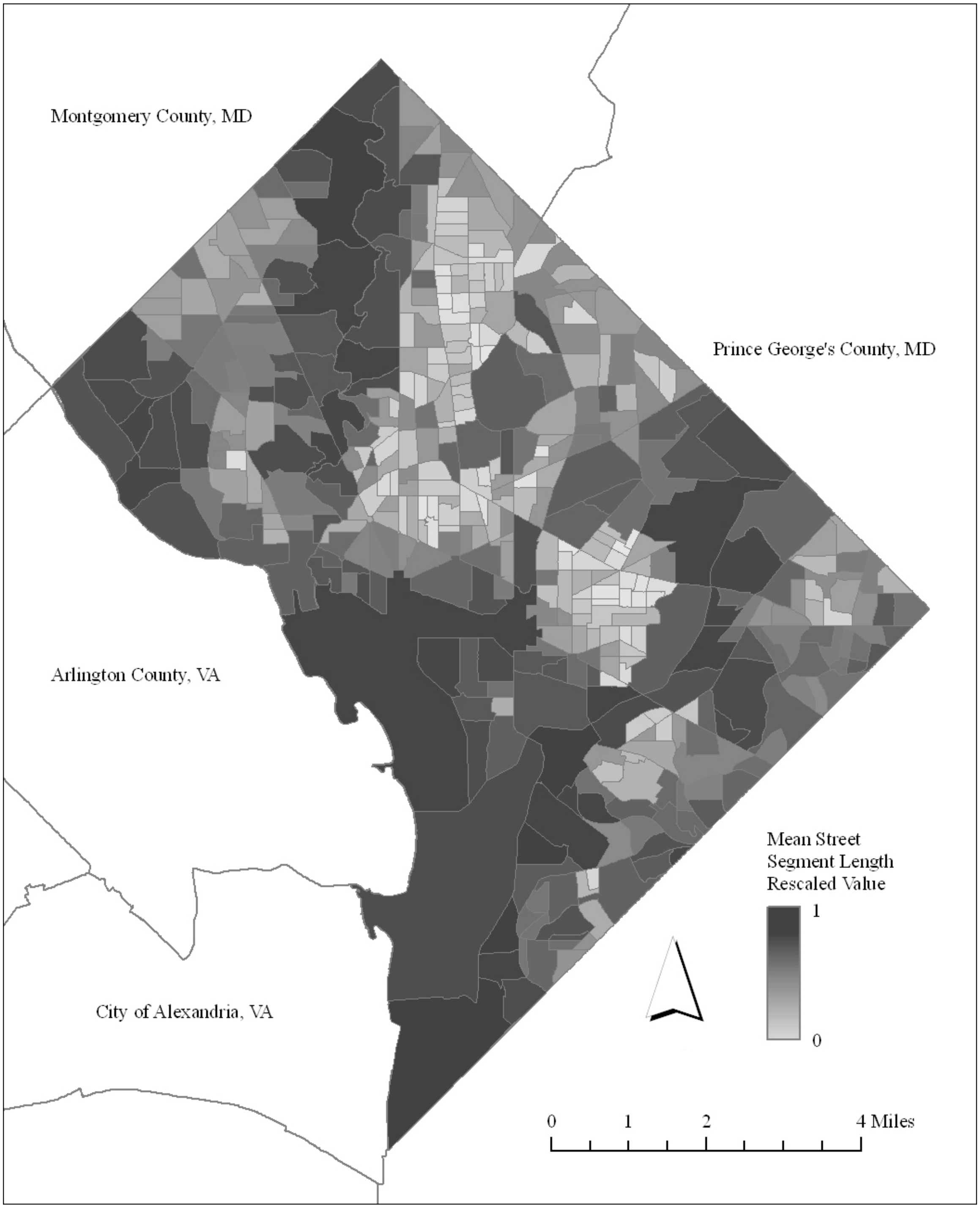

Figure 6 - Mean Street Segment Length Rescaled Values

For the third parameter, building age, the results reflect the standard deviation within each block group. Of the 180,836 ownership points, 14,339 (7.9% of the dataset) did not have any valid year information available. These were excluded from the analysis, resulting in the use of only the remaining 166,497 points. The invalid points were fairly evenly distributed throughout the city. This was verified by calculating the mean distance to the nearest neighbor for the points with and the points without valid year information. Points with valid year information had a mean nearest neighbor ratio (observed over expected) of 0.48, while points without valid year information had a ratio of 0.46. Thus, the exclusion of points without a valid year was not considered to have a detrimental effect on the analysis. Using the valid points, standard deviation for each block group ranged from 0 to 53. These standard deviations had a mean of 21.78 and a standard deviation of 5.67. Figure 7 shows the distribution of the standard deviations as a histogram. Figure 8 shows the rescaled values as an unclassed choropleth map. As with the other parameters, this map is generally as expected. Some of the greatest variability is located in the areas around Shaw/Mt. Vernon Square, as well as Historic Anacostia and Columbia Heights. These are all areas where are currently undergoing significant new development and seeing noteworthy demographic changes. The area of the National Mall again stands out as something of an anomaly. This is largely explained by the small number of address points within this block group, thus having even one very new structure can easily alter the standard deviation for this area.

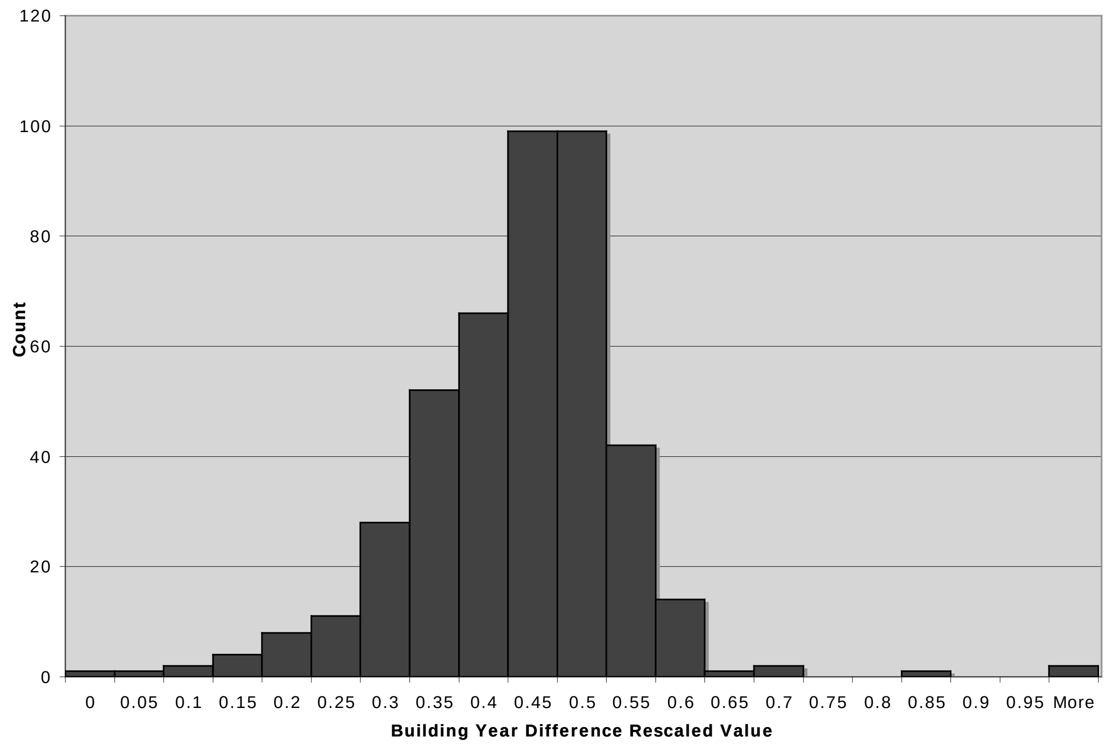

Figure 7 - Building Year Difference Frequency

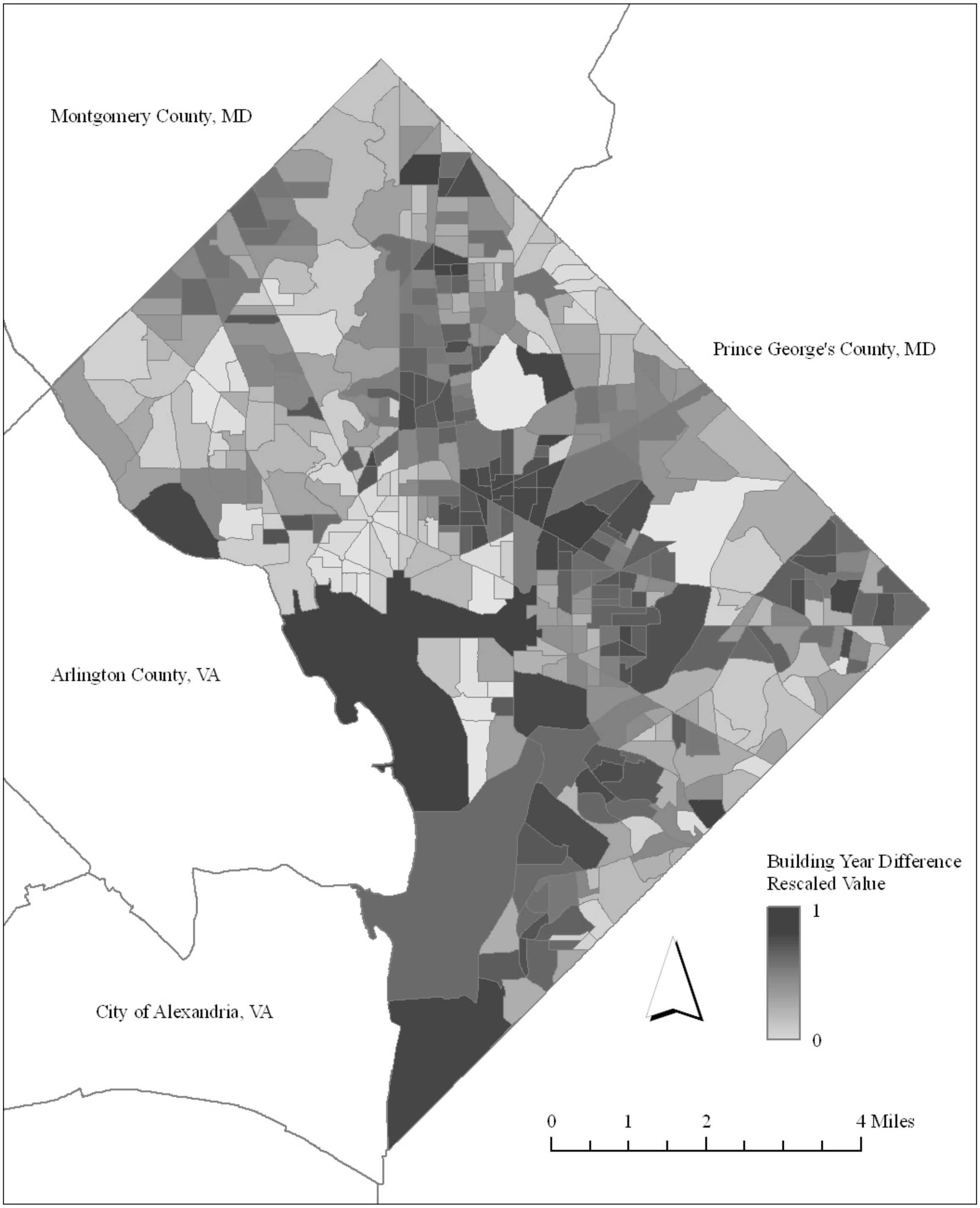

Figure 8 - Building Year Difference Rescaled Values

For the fourth parameter, mixed primary uses, the results have been calculated for the two different methodologies; mean shortest distance between residential and commercial locations, and the distance between the mean center for residential locations and the mean center for commercial locations. For the first method, mean shortest distance, the values calculated range between 18.16 feet and 3,047.05 feet with a mean of 499.21 feet and a standard deviation of 482.12 feet. A total of 94 block groups contained either no residential locations or no commercial locations, and thus were automatically assigned the highest rescaled value of 1. Figure 9 shows the rescaled values as a histogram. Figure 10 shows the distribution of the rescaled values as an unclassed choropleth map.

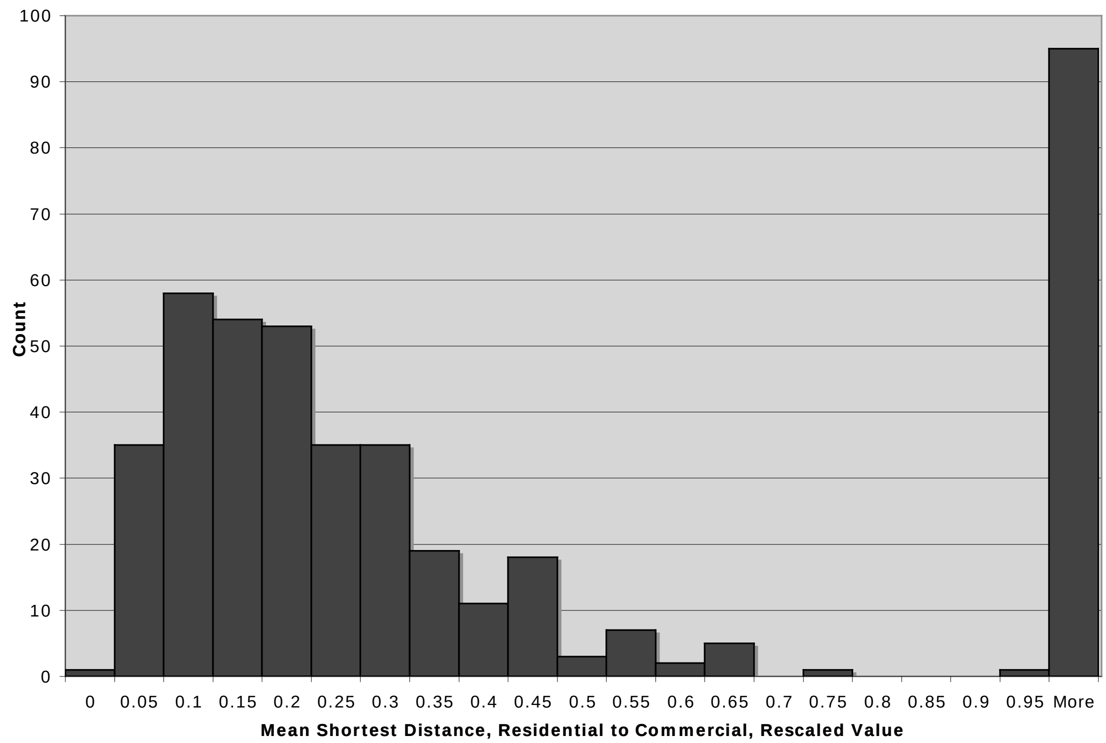

Figure 9 - Mixed-Use Mean Shortest Distance Frequency

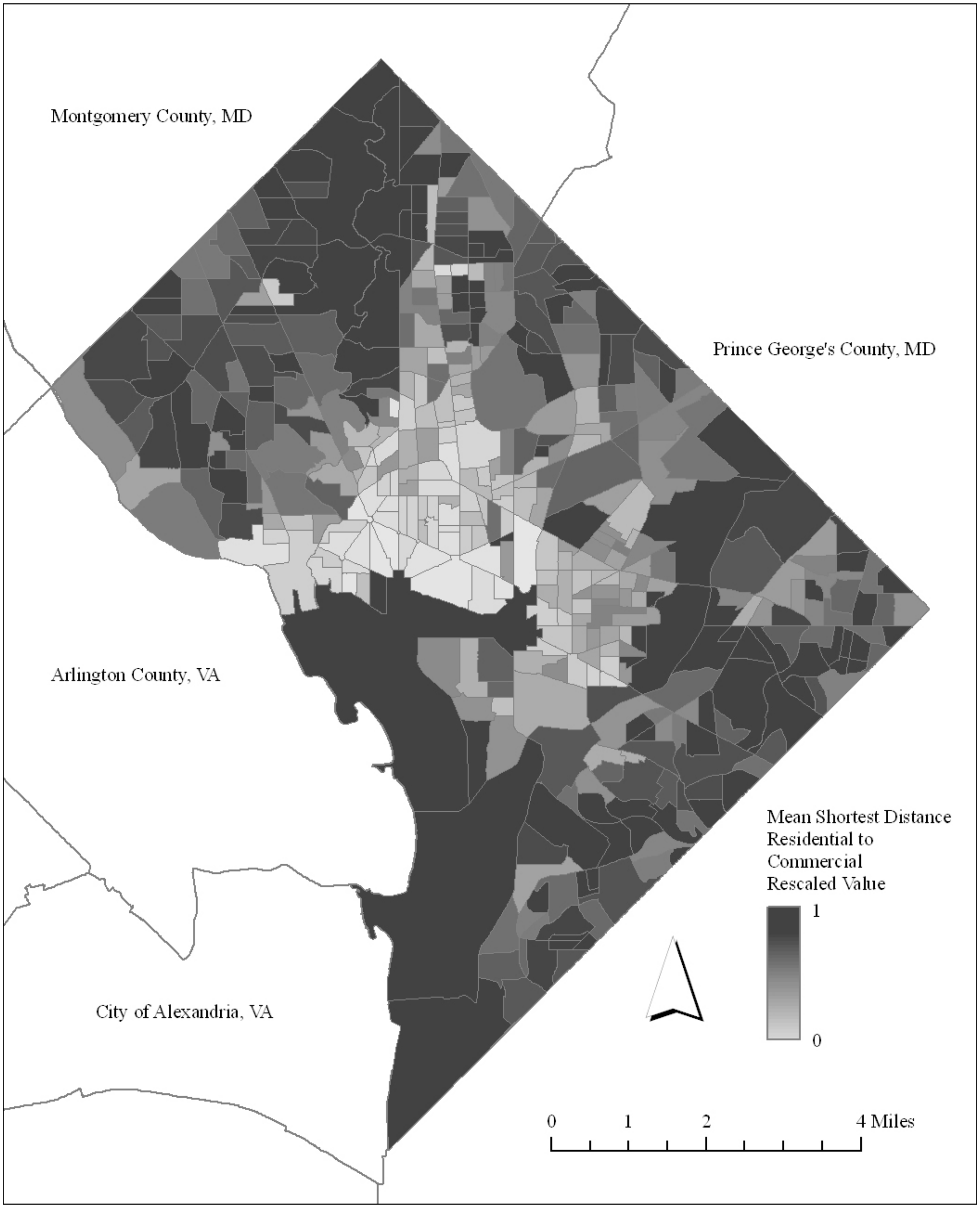

Figure 10 - Mixed-Use Mean Shortest Distance Rescaled Values

For the second method, distance between residential mean center and commercial mean center within a block group, the values ranged from 14.37 feet to 3,397.49 feet with a mean of 555.51 and a standard deviation of 506.44. Again, a total of 94 block groups contained either no residential locations or no commercial locations, and thus were automatically assigned the highest rescaled value of 1. Figure 11 shows the rescaled values as a histogram. Figure 12 shows the distribution of the rescaled values as an unclassed choropleth map.

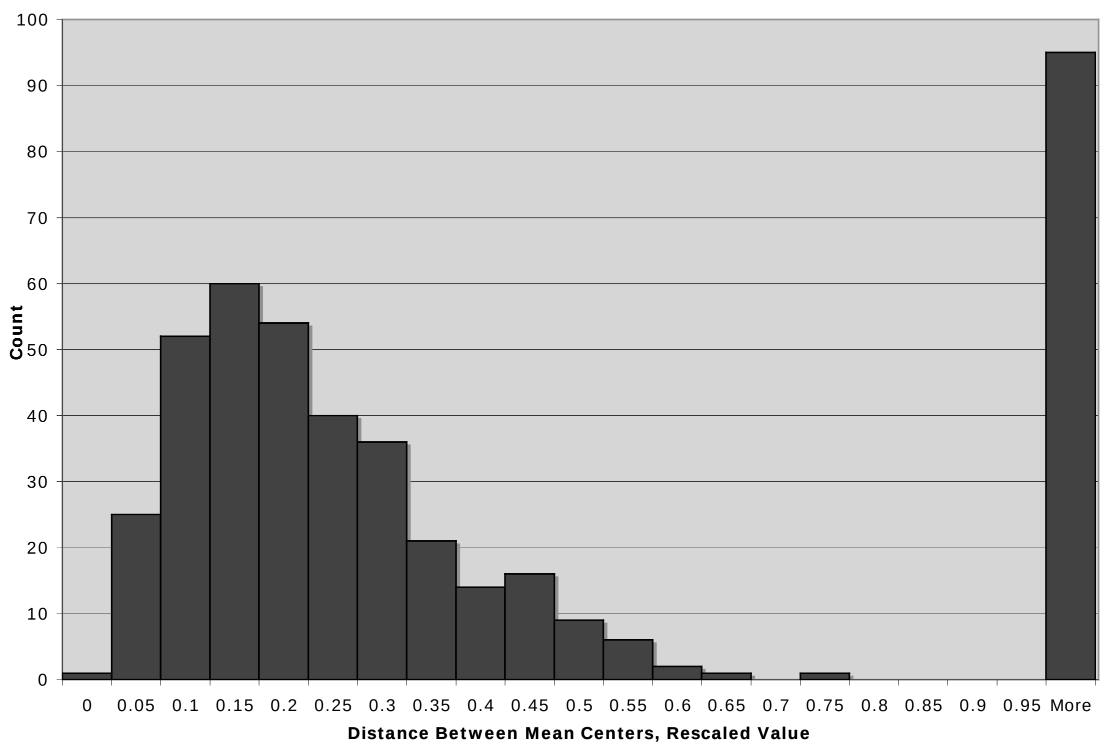

Figure 11 - Mixed-Use Mean Center Difference Frequency

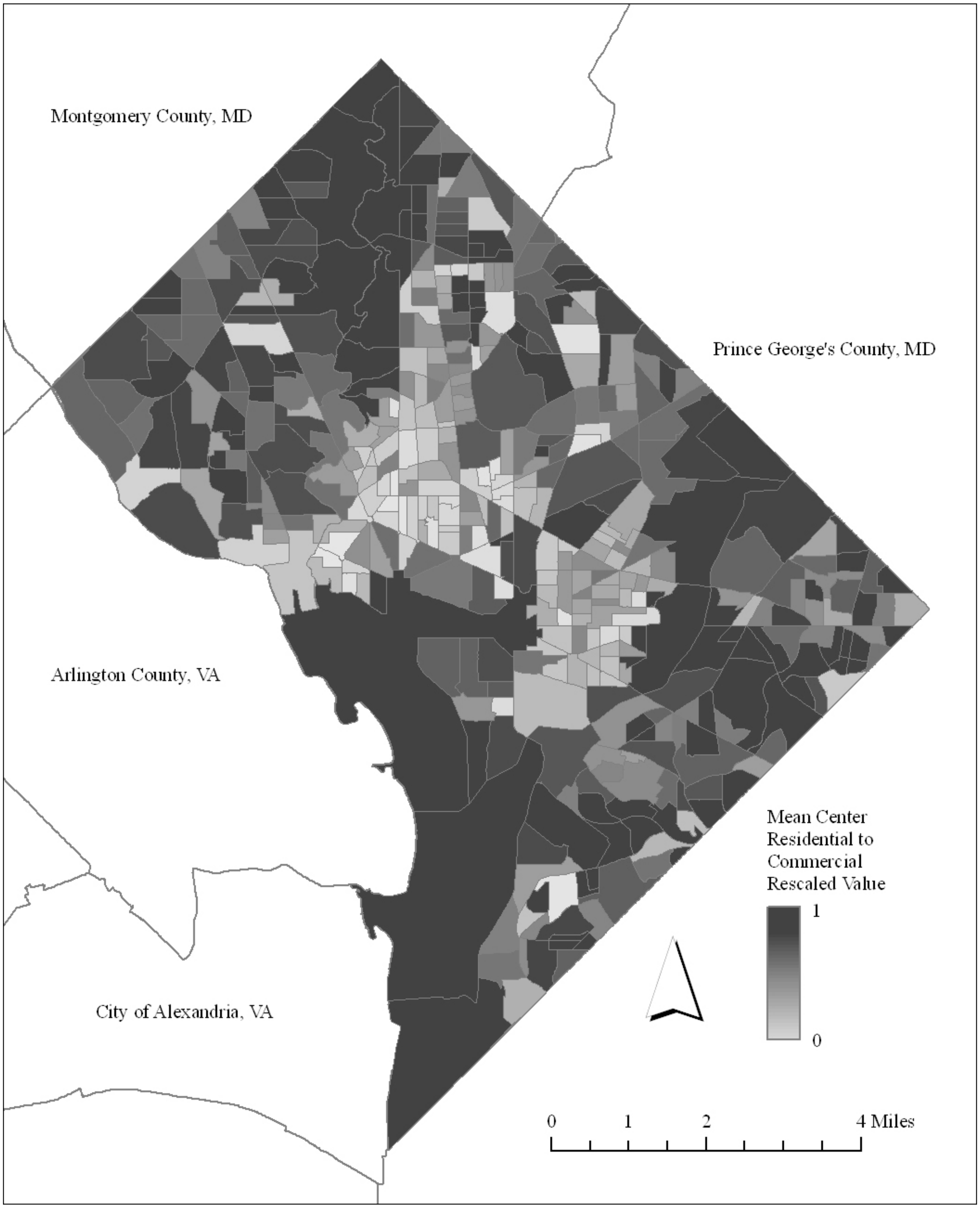

Figure 12 - Mixed-Use Mean Center Difference Rescaled Values

While both methods produce similarly shaped distributions, it is clear that the results are dispersed differently. The nature of the mean center method means that it is less sensitive to localized conditions, making it a less suitable method for measuring uses at a fine-grained level. Suppose, for example, that a block group contained a cluster of residential units in the center and contained commercial uses along its boundary; the mean center method would place mean centers for both residential and commercial very close to one another, even though they are not highly interspersed. The same method would produce similar results for a block group that contained evenly distributed commercial and residential locations, even though, by Jacobs' estimation, this second block group contains a preferential configuration. For this reason, the first method, the mean shortest distance between residential and commercial locations is preferred. This first method is more sensitive to clustering and dispersion within the block group. The difference in the results of these two methods is clearly illustrated in Figure 10 and Figure 12.

As noted in the methodology section, it was thought that both of these measures might be sensitive to the size of the block group for which they are calculated, however, this proves not to be the case. Figure 13 is a scatter plot of the size of each block group against its rescaled value for the mean shortest distance calculation. Figure 14 is a scatter plot of the size of each block group against its rescaled value for the mean center difference calculation. In both instances, there is only a very weak correlation between the two parameters, primarily that extremely large block groups have a higher likelihood of not having a sufficient mix of uses – the opposite of what was expected.

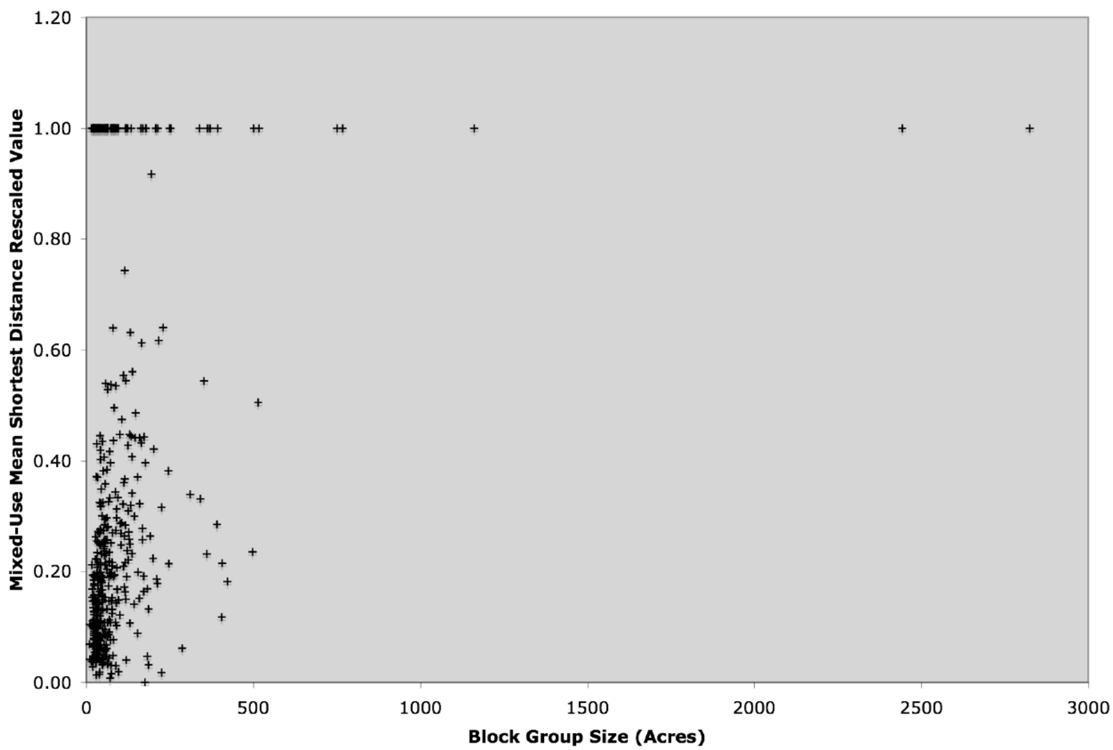

Figure 13 - Mixed-Use Mean Shortest Distance Vs. Block Group Size

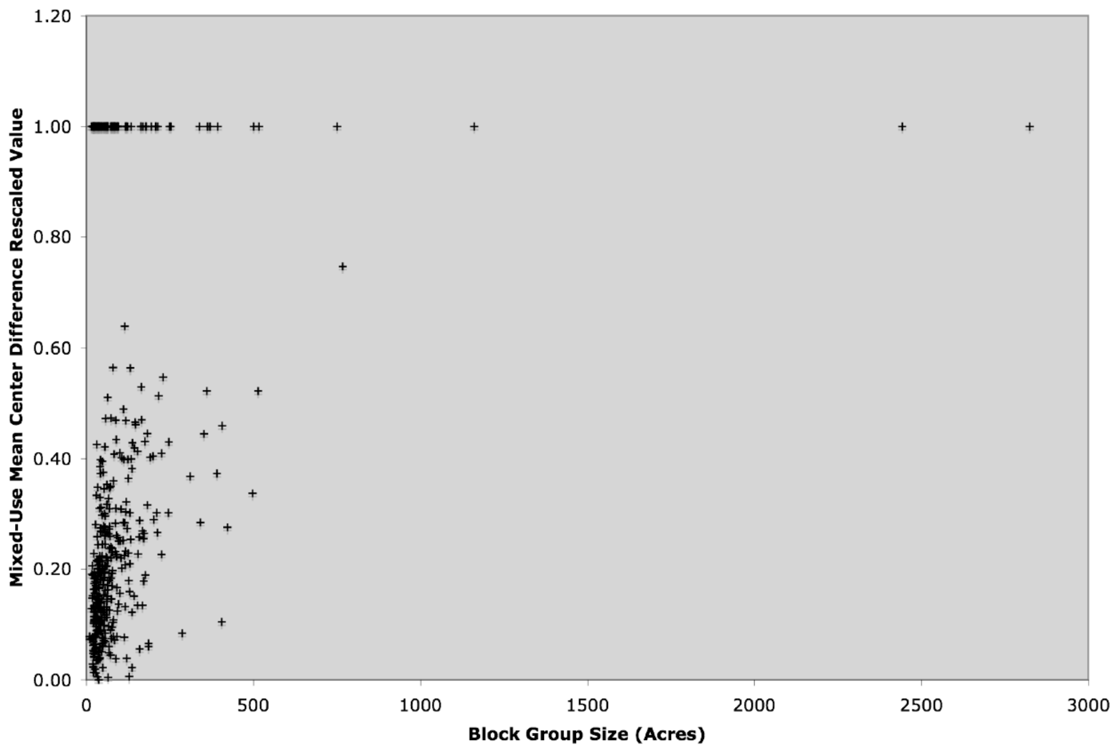

Figure 14 - Mixed-Use Mean Center Difference Vs. Block Group Size

In order to examine possible spatial relationships between the two methods for calculating mixed-use, a map was created that depicts the difference between the two calculations for each block group. Figure 15 shows the difference when the rescaled values for the mean center method are subtracted from the rescaled values for the mean shortest distance calculation. Higher numbers indicate that the mean shortest distance method provided a higher value than the mean center method. A visual inspection of this map does not reveal any clear correlations relating to the location of block groups and under which method they perform better. A detailed examination of possible correlations may be warranted as an area of future research, as the possibilities are too numerous to explore within the context of this particular study.

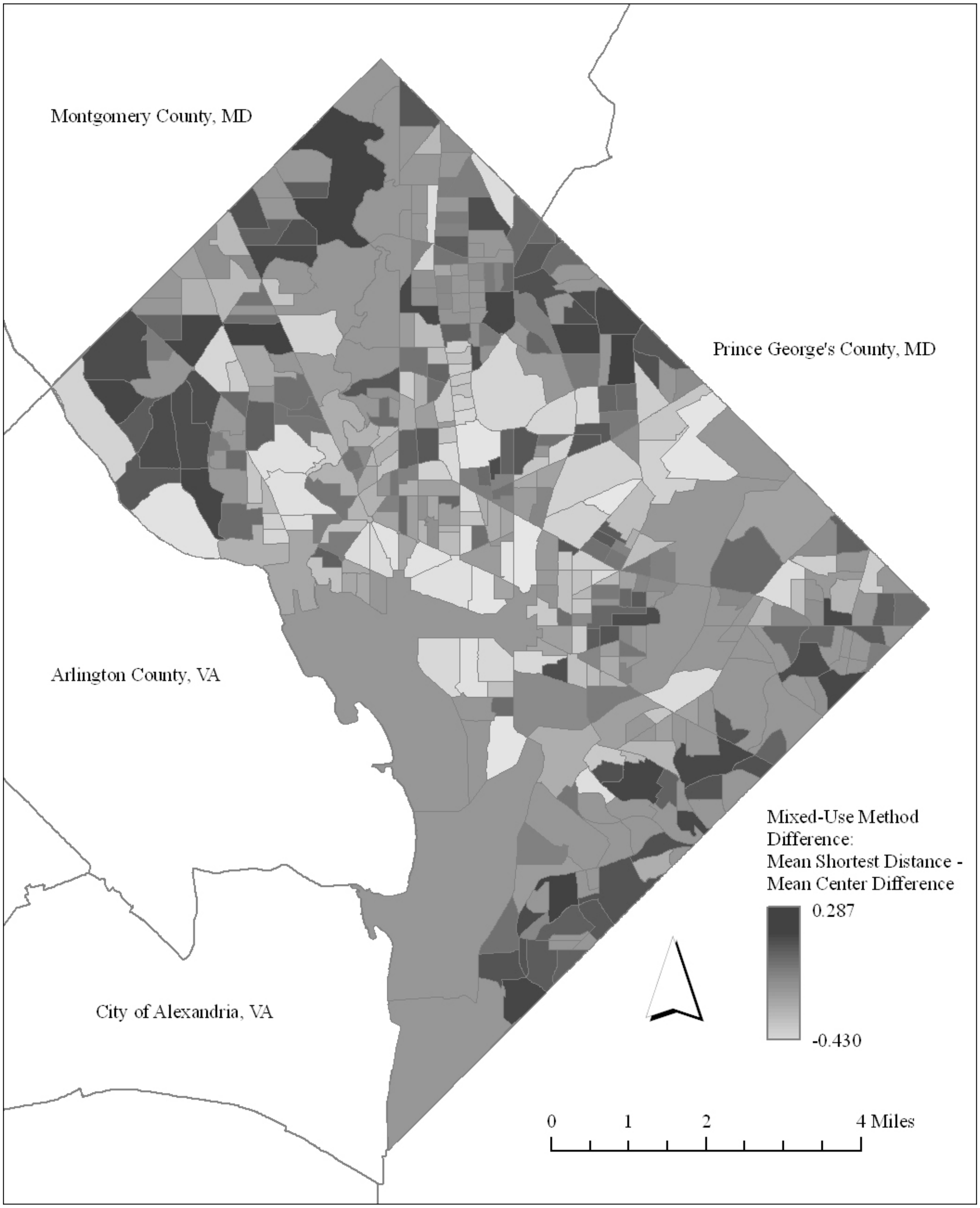

Figure 15 - Difference Map for Mixed-Use Methods

Created using the preferred method, Figure 10 is as expected. Many of the areas containing the highest-quality use-mixes are contained in the central city along with the area just north of the central business district (especially the Columbia Heights area) as well as parts of Georgetown and Capitol Hill, including the H Street NE Corridor. There are other high-quality pockets, such as the area of Historic Anacostia, and the northern section of Connecticut Ave., NW, near Tenleytown/American University. The poorest performing areas include the National Mall as well as Upper Northwest, which consist primarily of single-family homes.

For the final, composite (*UL*) index, the more sensitive mean shortest distance mixed-use parameter was used. The composite scores range from -1.75 to 1.16, with a mean of -0.005 and a standard deviation of 0.51. Figure 16 shows the distribution of the rescaled composite scores as a histogram. Figure 17 shows the rescaled composite scores as an unclassed choropleth map.

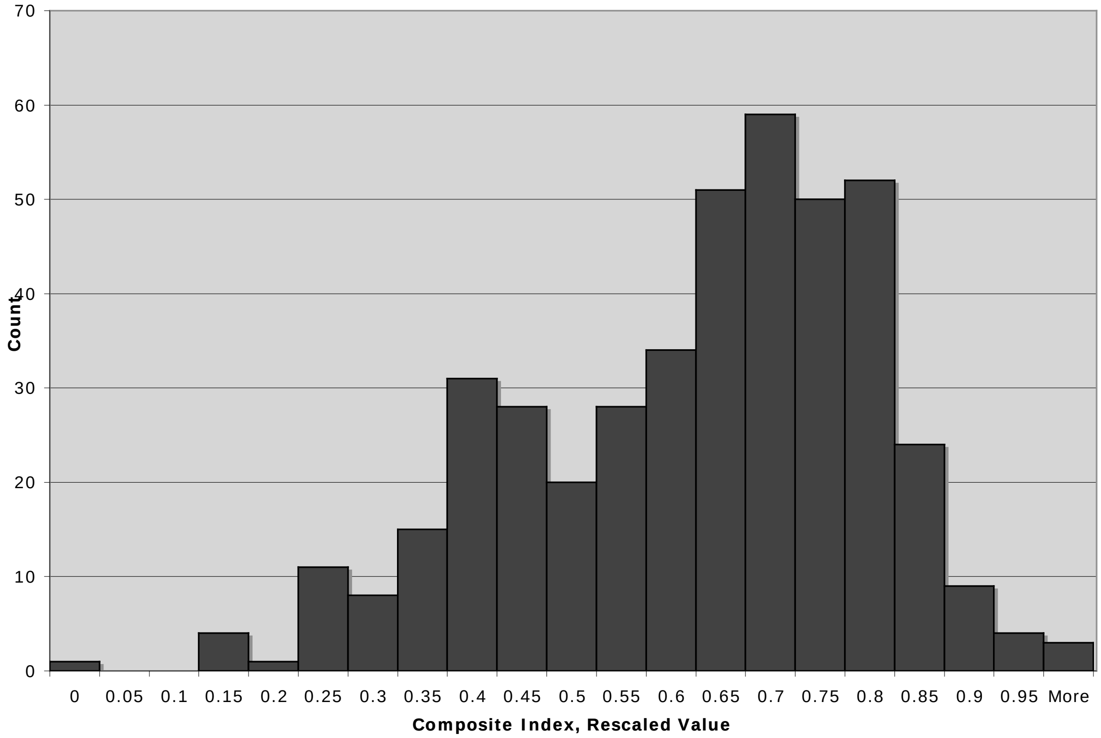

Figure 16 - Composite Index Frequency

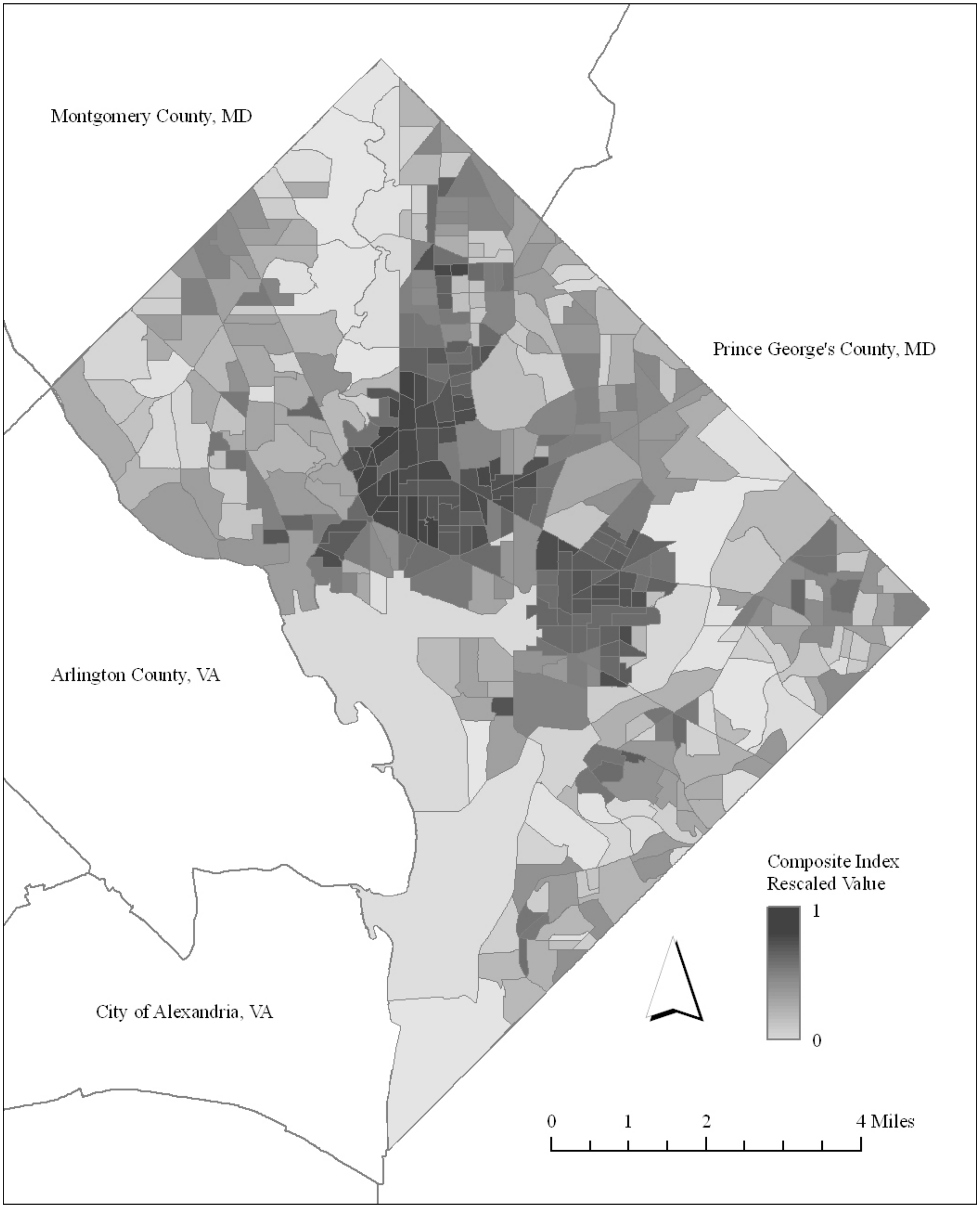

Figure 17 - Composite Index Rescaled Values

An examination of Figure 17 shows that there are some well-defined areas of maximum livability within Washington, DC. The area between Dupont Circle and Shaw/Mt. Vernon, extending north to Columbia Heights, as well as the general area of Capitol Hill clearly appear to be the most livable areas within the city across all four parameters. While the *UL* index is not particularly useful in terms of indicating exactly what parameter(s) certain areas are lacking or excelling in, it does well to show where all four parameters are performing well. When compared to the results of each of the individual parameters, the two high-performing areas in the composite index consistently perform well. In other areas of the city, such as Georgetown and Historic Anacostia, the *UL* index shows them performing at a some-what mixed level. This also corresponds well to each of the individual parameters, where these areas performed well under some parameters, but not as well for other parameters.

In order to better understand locational relationships of each of the parameters and the *UL* index, a cluster analysis was performed. First, in order to confirm the presence of clustering, a general Moran's *I* statistic was calculated for each of the parameters and the *UL* index, using a threshold of just over one mile. This distance can be considered a reasonable distance to approximate the area that might be considered a neighborhood for a resident of the subject block group, whether walking, bicycling, driving, or taking transit for the mode of travel. Table 3 presents the Moran's *I* statistic and associated *z*-score from each of the parameters and the *UL* index.

Table 3 - Moran's I and Z-Scores for All Parameters and UL Index

	Dwelling Density	Mean Street Segment Length	Building Year Difference	Mixed-Use	*UL* index
Moran's *I*	0.44	0.25	0.18	0.28	0.4
Z-Score	36.55	20.45	15.38	23.2	33.18

From the Moran's *I* statistic it is confirmed that each of the parameters and the *UL* index exhibit significant spatial clustering, as Table 3 shows both *I* and the associated *z*-score for all parameters is greater than 0. However, this fails to inform as to whether high or low values are clustering together. For this final step in the cluster analysis, the Getis-Ord Gi* statistic was examined for each parameter and the *UL* index, again, using a threshold of just over a mile. Figure 18 presents an unclassed choropleth map of the results of the Getis-Ord Gi* calculation for the dwelling density parameter. From this map, it becomes clear that dwelling density exhibits strong clustering of both high and low values, with high values indicating higher densities, and low values indicating lower densities.

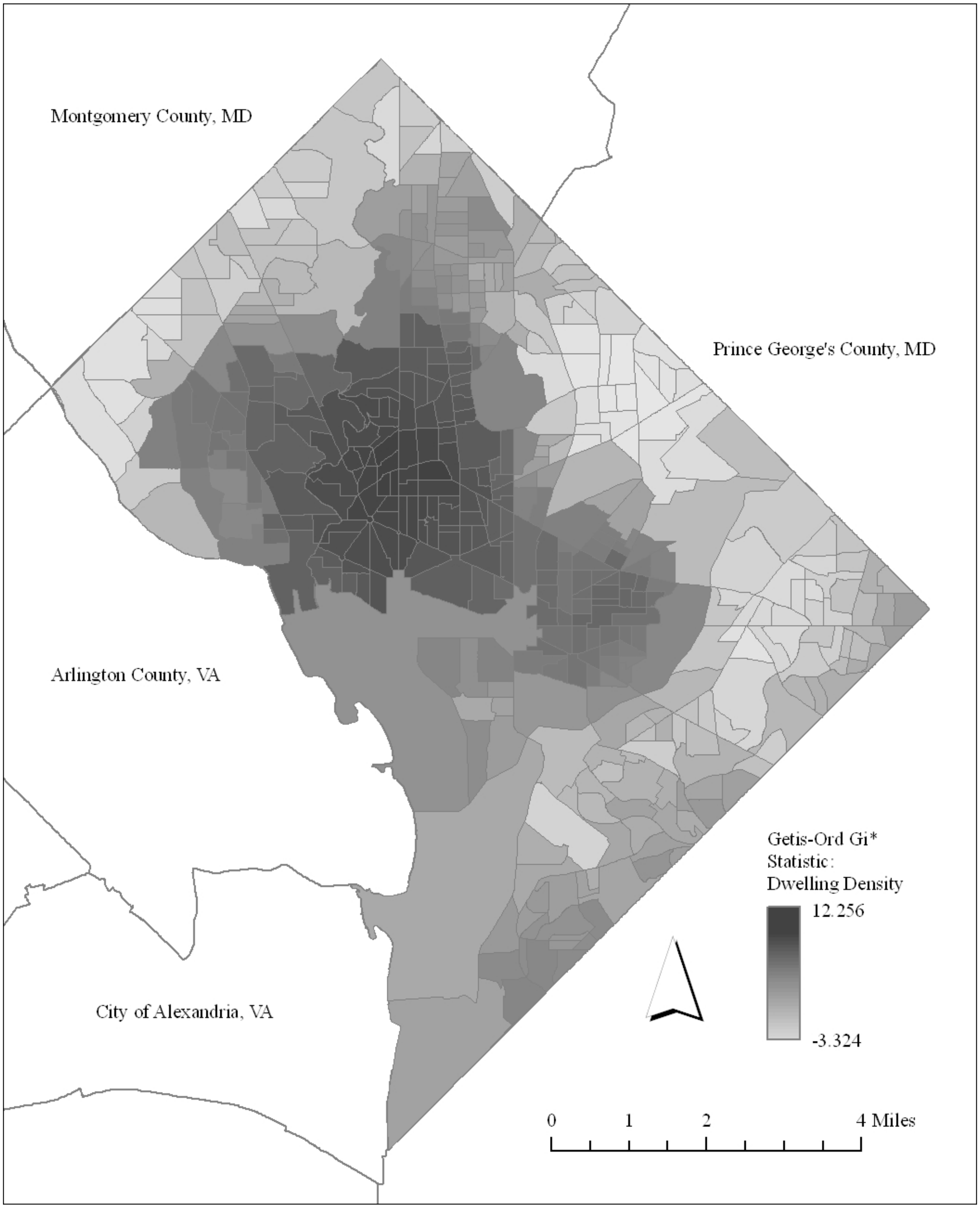

Figure 18 - Getis-Ord Gi for Dwelling Density*

Figure 19 is an unclassed choropleth map of the Getis-Ord Gi* calculations for the mean street segment length parameter. This map depicts a strong clustering of low values, and a slightly weaker clustering of high values. Here, low values indicate shorter mean street segment length, while higher values indicate longer mean street segment lengths.

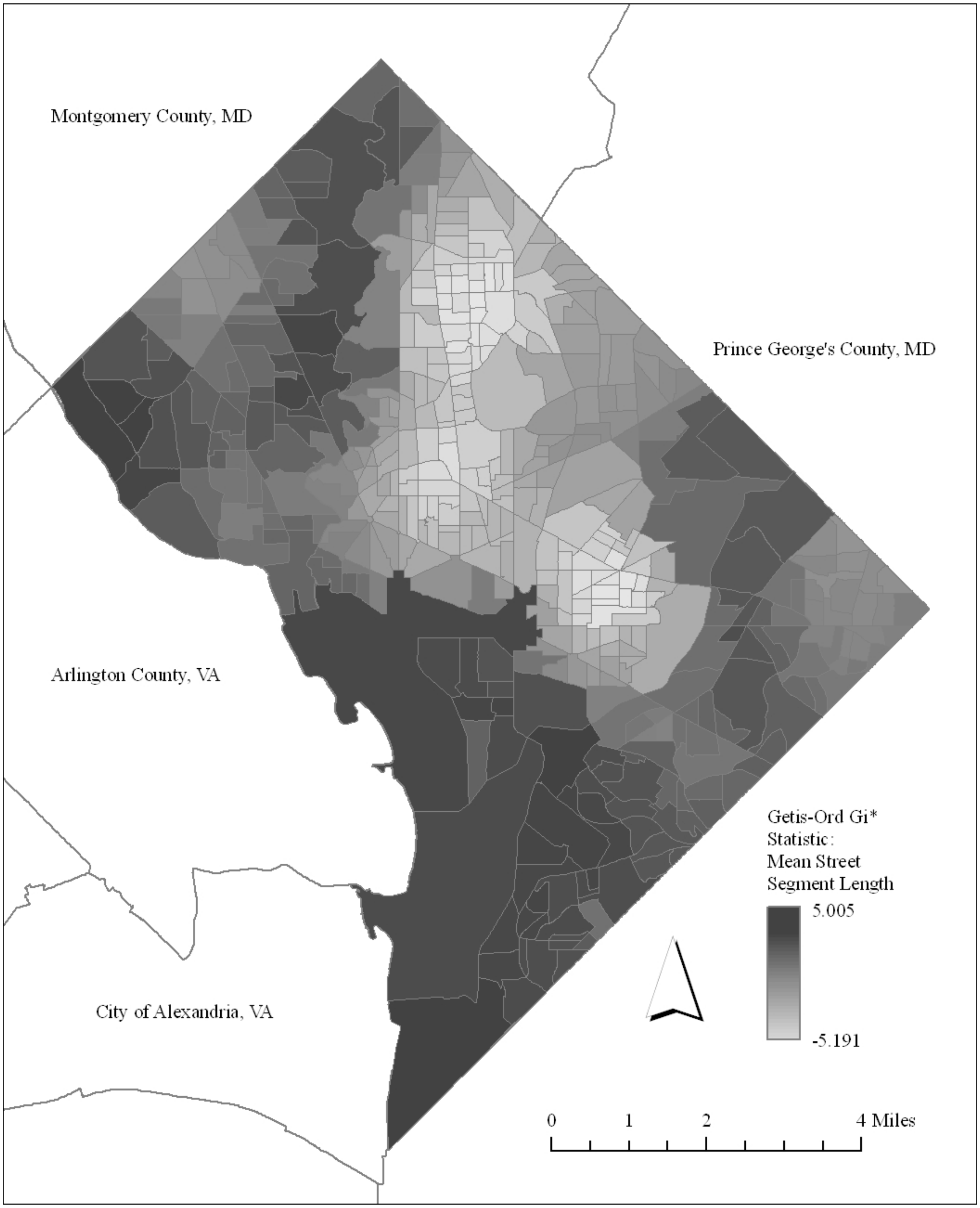

Figure 19 - Getis-Ord Gi for Mean Street Segment Length*

Figure 20 is an unclassed choropleth map of the Getis-Ord Gi* calculation for the building year difference parameter. This map, again, shows clear clustering of high and low values. Here, high values indicate a greater range of building ages while lower values indicate a narrower range of building ages.

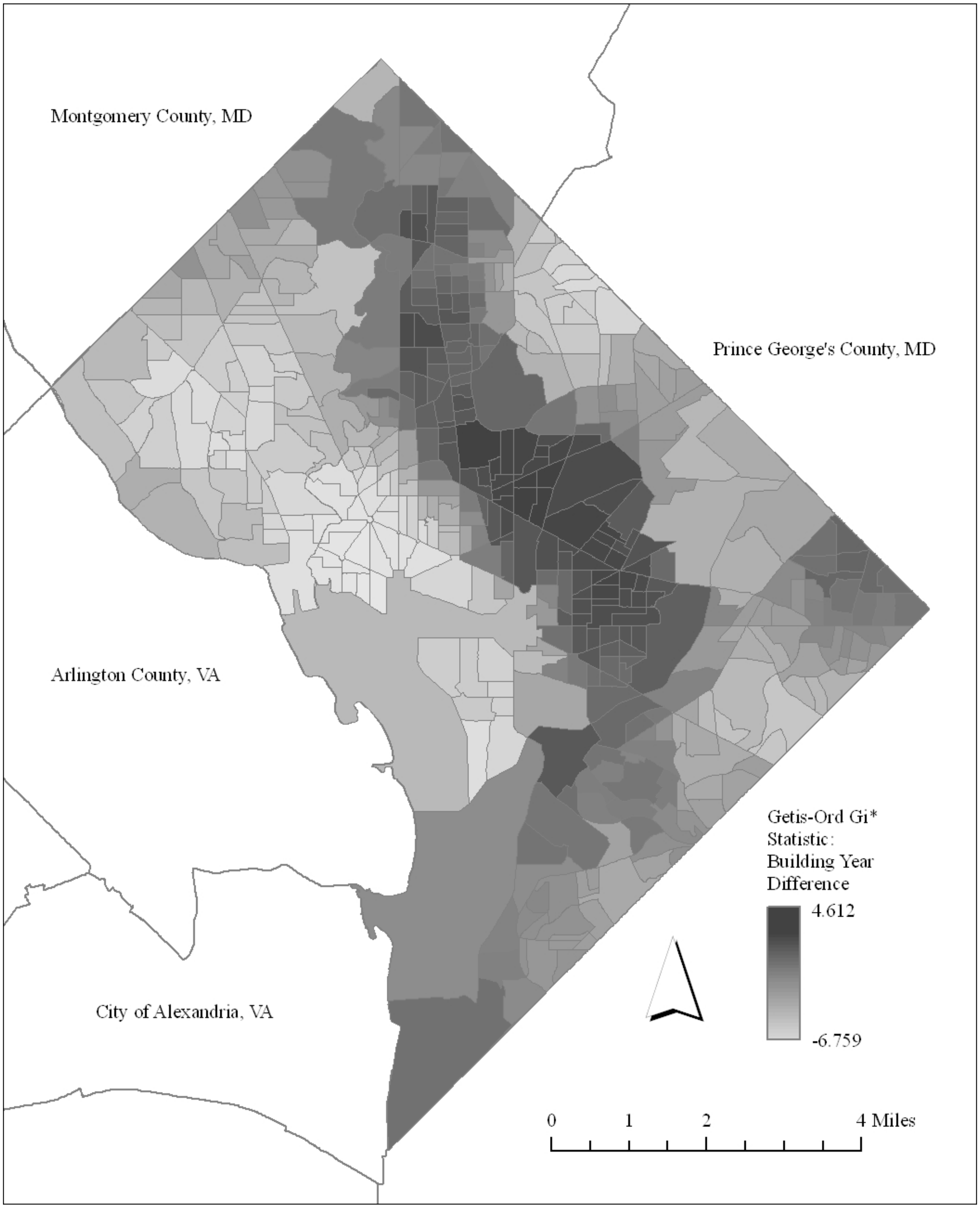

Figure 20 - Getis-Ord Gi for Building Year Difference*

Figure 21 is an unclassed choropleth map of the Getis-Ord Gi* calculations for the mixed-use parameter (again, using the preferred mean shortest distance method). This map shows a very strong clustering of low values and a weak clustering of high values. Here, low values indicate a more mixed-use environment, while high values indicate a less mixed-use environment.

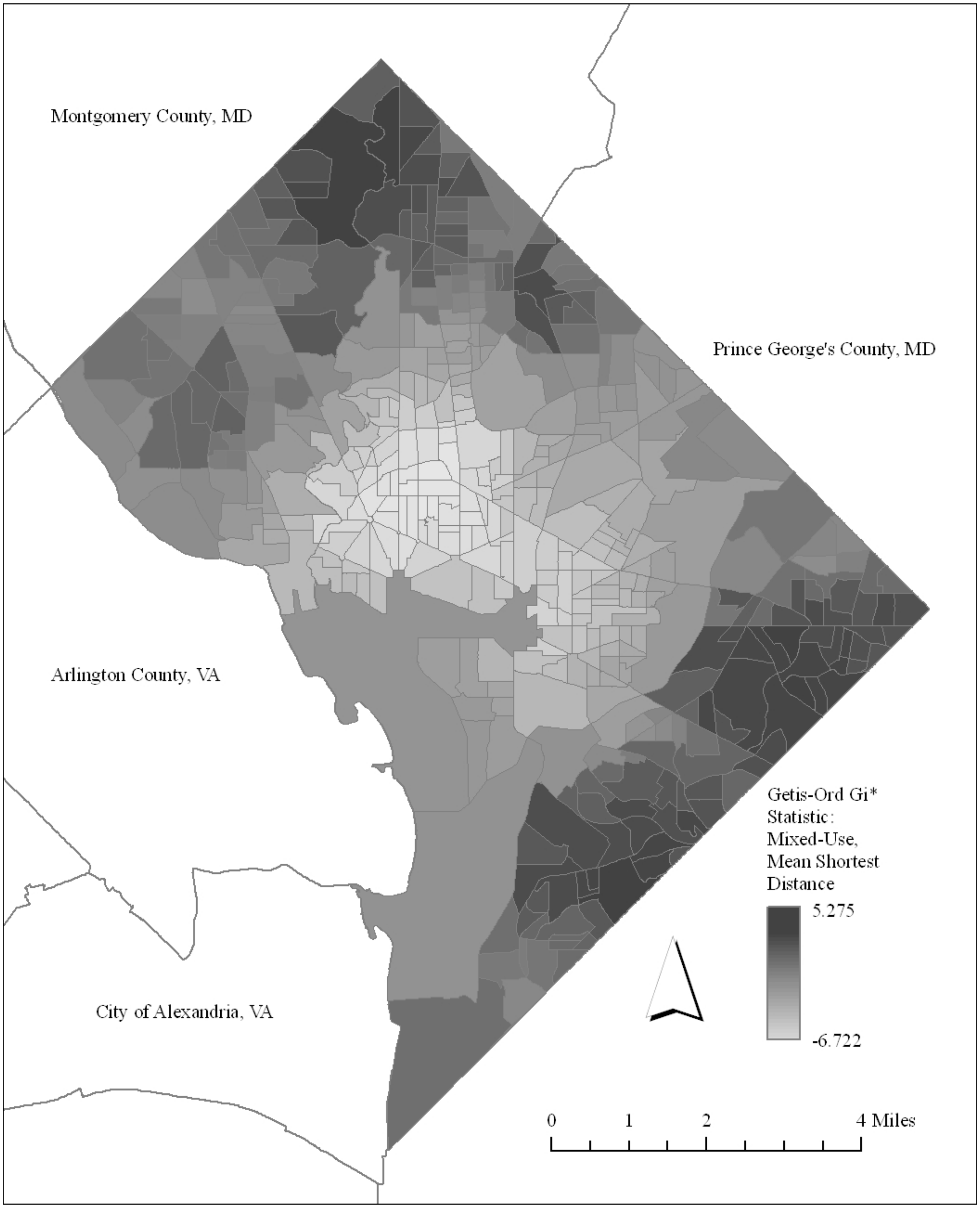

Figure 21 - Getis-Ord Gi for Mixed-Use, Mean Shortest Distance*

Finally, figure 22 shows an unclassed choropleth map of the Getis-Ord Gi* calculation for the *UL* index. This map shows a very strong clustering of high values as well as a strong clustering of low values. Here, high values indicate a higher composite 'livability', while low values indicate a lower 'livability' index.

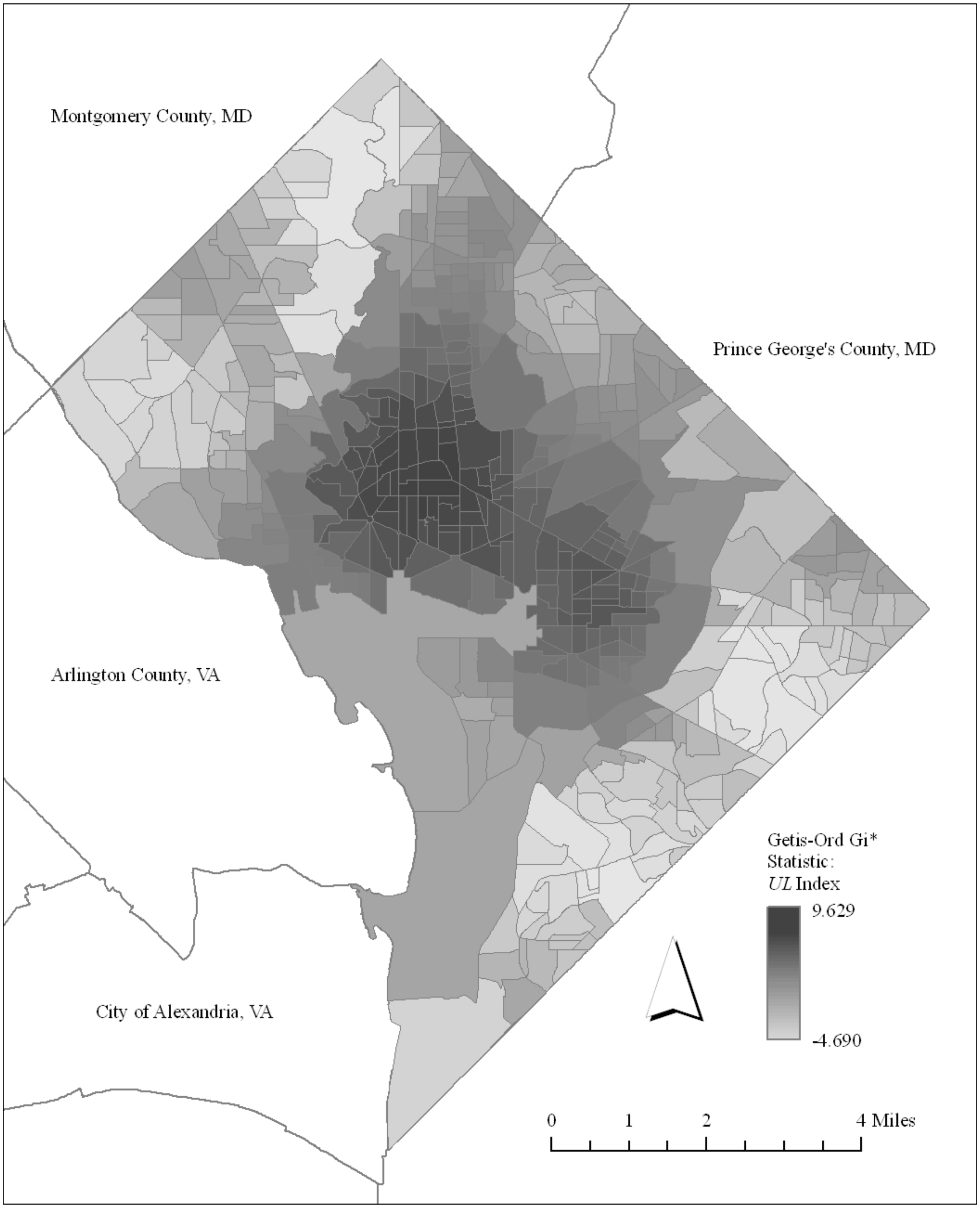

Figure 22 - Getis-Ord Gi for UL Index*

Each of the maps presented in figures 18-22 confirm the analysis of high and low-value areas noted earlier in the results, but they also serve to highlight the degree to which the parameters do tend to cluster both at the high and low ends of the spectrum.

To further examine the relationships between the *UL* index and the component parameters, correlation coefficients were calculated between the rescaled values for each of the parameters and the *UL* index, as presented in Table 4.

Table 4 - Correlation Coefficients Between Parameters and UL Index

	Dwelling Density	Mean Street Segment Length	Building Year Difference	Mixed-Use
Correlation Coefficient	0.568	-0.627	0.223	-0.863

Clearly the mixed-use parameter shows the strongest correlation, followed by the mean street segment length parameter and the dwelling density parameter. The building year difference parameter shows the weakest correlation of the four. For both the mean street segment length parameter and the mixed-use parameter, lower values are preferable, so a negative correlation coefficient is to be expected. Based on these coefficients, it is expected that the mixed-use parameter, mean street segment length parameter and the dwelling density parameter have the greatest influence over the final outcome of the *UL* index. While the building year difference parameter does display a correlation, it is weak in comparison to the other parameters. This is a parameter that has generally been overlooked in the much of the previous research, but is also a parameter that may be important from the perspective of preserving affordable housing and creating a wider socio-economic demographic within a neighborhood, so this may warrant more detailed analysis in the future.

CONCLUSION

The research presented here set out to place Jane Jacobs' four generators of diversity into a quantitative and repeatable methodology for use in the public discourse of city planning. The methodology that was used provides a fine-grained look at each of Jacobs' generators as well as constructing a new Urban Livability (*UL*) index comprised of all four parameters in concert. Overall, the *UL* index provides a good snapshot view of high and low performing areas within the city, while each of the individual parameters can be used to further investigate the level of performance within each of the four components. These five indices, when taken together, can provide useful information to public agencies and policy-makers as they make planning decisions both at the citywide and neighborhood levels.

Looking first at the results of the dwelling density parameter, the methodology presented here does an acceptable job of accurately presenting this parameter. While there are some slight shortcomings, such as the possibility that a portion of a block group contains land area that cannot reasonably be expected to contain dwellings, such as parkland or large water features, this is more a limitation of the data than the methodology. This type of over-calculation of area can be adjusted for by an astute investigator, provided the appropriate data is available.

The next parameter, block length, is also well represented using the method applied here. It is noteworthy that the method used here is sensitive to the inclusion of limited-access roadways, such as interstates. This is, from Jacobs' perspective, a benefit of the methodology, as expressways and the like are viewed by Jacobs as detrimental to the city, particularly when they form a barrier that negatively impacts neighboring communities (Jacobs 1992, 258-259). Thus, having a methodology that is sensitive to these types of intrusions can be powerful. This is illustrated in the case study presented here, by the lower ranking that is given to the Georgetown area, due to the presence of the Whitehurst Freeway. The presence of the Southeast-Southwest Freeway in the Southern quadrants of the city also plays a significant role in the outcomes in those locations with regard to the block length parameter.

The third parameter, mix of building age, is also well quantified using the methodology presented here. Perhaps the most challenging aspect of this parameter is that, given few enough structures, it can become excessively sensitive to the range of building ages. Thus, in the case study, the area of the National Mall performed very well, due to the low number of structures within this area. However, the causal observer may disagree with this assessment, particularly given the large geographic area that this particular block group includes. Thus, in terms of the spatial mixing of building ages, the National Mall performs poorly, since buildings of differing ages are not necessarily in close proximity to one another. This is perhaps the parameter of Jacobs that is most open to interpretation, since Jacobs provides little guidance for what range of ages (twenty years? fifty? one hundred?) is most beneficial to the district in question.

The fourth parameter, mixed-primary uses, is the most complex of the four parameters to calculate. However, the method presented here is certainly an improvement over the other methods that have been utilized in the past. This method provides the level of 'mixedness', rather than simply presenting a binary or strictly counting the number of different uses within an area and ignoring their actual proximity to one another within that area. The results of the calculation appear to provide a result that is close to what the casual observer who is familiar with the city might expect. Future research should explore ways to build on this methodology by effectively incorporated a richer mix of uses. The greatest challenge with this method is the computational complexity that quickly becomes problematic as the number of uses and point locations increases.

In addition to the correlations presented in Table 4, it is important to examine the correlations between each of individual parameters. Table 5 shows the correlation coefficients between each of the individual parameters, as well as the *UL* index.

Table 5 - Correlation Coefficients Between All Parameters

	Dwelling Density	Mean Street Segment Length	Building Year Difference	Mixed-Use	*UL* Index
Dwelling Density	-	-0.320	-0.114	-0.388	0.568
Mean Street Segment Length	-0.320	-	-0.139	0.285	-0.627
Building Year Difference	-0.114	-0.139	-	-0.009	0.223
Mixed-Use	-0.388	0.285	-0.009	-	-0.863
UL Index	0.568	-0.627	0.223	-0.863	-

Looking at each of the coefficients, it is clear that some parameters exhibit stronger correlations across the board than others. The mixed-use parameter and dwelling density parameters appear to exhibit the strongest correlations between each of the other parameters, while the building year difference parameter displays the weakest correlations. Although this analysis is not sufficient to draw strong conclusions, when paired with the strong correlations to the *UL* index for these two parameters, it suggests that mixed-use and dwelling density are perhaps the most important of the four individual parameters in terms of their contribution to the overall livability of the built environment. Jacobs, as noted earlier, would dispute the finding that any of the four parameters is more influential than the others.

In order to explore this further, some basic scenario testing was conducted. From the perspective of a city official it is important to know that if a targeted investment can be made in only one parameter, which of the parameters may show the greatest improvement for that investment. The basic scenario tested is one where the 43 (10% of the total) bottom performing block groups in a particular parameter are targeted such that their raw parameter input is increased (or decreased) to match the raw value of the best performing block group for that parameter. The sub-index is then scaled with these new values and the change in the raw *UL* is observed. This was repeated independently for each parameter. For all block groups outside of the bottom 43 in each parameter, a reduction in the *UL* value is observed. This is due to the fact that this test is in effect shifting the distribution such that the bottom 10% becomes top performers, making all other values (aside from the one previous top performing block group) lower, because the values are scaled relative to one another. Thus, only the effect of this change on the 43 block groups tested is noted below. This testing does provide some challenges for the mixed-use parameter. This is due to the 94 block groups that contained either no residential or no commercial. Originally, these block groups were automatically given the worst value, thus, all of the bottom 10% fall into this category. When these block groups are given the best value, they all show a change of plus 1 in the *UL* index. Given the uniform nature of this response for the mixed-use parameter, these 94 block groups were not examined, and the bottom 10% was chosen selected from the block groups for which a valid distance had been calculated (i.e. they contained both residential and commercial points). Table 6 presents the results of this scenario testing.

Table 6 - Results of Scenario Test for Bottom 10% of Block Groups

	Dwelling Density	Street Length	Building Year	Mixed-Use (Exclusive)
Mean Change in Raw *UL*	+0.983	+0.580	+0.795	+0.507
Median Change in Raw *UL*	+0.980	+0.539	+0.777	+0.447
Minimum Change in Raw *UL*	+0.969	+0.408	+0.714	+0.382

For all parameters, when the bottom 10% of block groups are targeted in such a manner that they become equal to the highest performing block group, an investment in dwelling density produces the greatest effect on the *UL* index. This is followed by the building year parameter, the street length parameter, and finally, the mixed-use parameter. However, as noted earlier, given the high number of block groups that contained no mix of uses, this parameter would hold the greatest influence if those block groups were targeted. This suggests that while adding a mix of uses to areas that currently have none can have a dramatic effect (an increase of 1 in the *UL* index), adding a greater mix to areas that already contain some mixing does not result in a similar improvement. Given the results of this testing, it suggests that while all of the parameters have a significant influence on the *UL*, it may make sense for city planners to target density and (only for areas where no mixing is present) the mixed-use parameters. To a lesser extent, a focus on maintaining a diverse mix of building ages may also be beneficial. This parameter can be difficult to influence since buildings cannot be artificially aged, leaving the options of new construction and preservation of older structures. It is important to note that these conclusions may only be applied to the case study city, Washington, D.C., and not necessarily to other cities. A wider study that includes the same methodology applied to other cities would be needed to draw wider conclusions. This testing highlights the importance of utilizing the *UL* index in conjunction with the four sub-index calculations. A skilled planner may locate areas in need of improvement using the *UL* index and then consult the sub-indexes to evaluate which parameter will have the greatest impact for this particular location.

Ideally, city planners (perhaps to Jacobs' chagrin) and policy-makers can utilize the individual parameters, along with the *UL* index to focus revitalization efforts on specific locations within a city. For example, if a particular section of a city is expected to undergo massive redevelopment, and it has also been identified as having excessively long street lengths, the city may choose to make the inclusion of shorter street lengths a prerequisite for any redevelopment or rezoning efforts. An effort along these exact lines is currently being undertaken in the Crystal City section of Arlington County, just outside of Washington, DC. This area consists of numerous super-blocks and the county has included the addition of new cross-streets to break up these blocks as a part of its transportation plans for this highly urbanized area as it undergoes redevelopment. In a similar vein, using a combination of the mixed-use parameter and *UL* index, city planners may identify large areas with a poor mix of uses. This may lead to a re-evaluation of zoning policies within the city, in order to encourage a healthier mix of uses at a fine-grained level. However, as noted by Hirt (2007), even the current efforts to modify U.S. zoning laws fall short of what European communities have achieved with their zoning laws. The use of the methods presented here may open up new ideas on ways to create zoning laws that encourage a more effective mix of uses under all conditions.

Based on the cluster analysis presented in the results section, it is clear that all of the parameters as well as the *UL* index exhibit clustering at both ends of the spectrum. While cause and effect is difficult to determine, it is possible that this clustering is an effect of spillover from successful neighborhoods. As a particular location becomes more desirable, those individuals and families who wish to live there, but may not have the resources, may be attracted to the edges of that neighborhood and over time, begin to emulate the successes of the desired neighborhood within their own. If this is true, it may be possible for city planners to ‘seed’ a neighborhood by focusing on creating a highly livable location that may then influence the surrounding areas over time. Obviously, this is a process that can take decades, so it is difficult to gage the effectiveness of this strategy in the short-term. It is also important to note, however, that Jacobs' ideas about livability do not necessarily mirror that of the entire population. Thus, it becomes important to retain areas that are well suited to all segments of a city's population. There are some individuals that are willing to sacrifice the convenience of nearby commerce and entertainment for the urban retreat offered by a single-family home.

While the methods presented here are structured in a manner that allows them to be applied across a number of cities, it is important to remember the unique nature of individual cities. As these methods are applied to other cities, researchers may choose to strengthen the methodology by taking into consideration the unique nature of the subject city and the data that may be available. For example, the Washington, DC case study could be strengthened by dealing more effectively with the unique presence of the Federal government within the city. The city contains an inordinately high percentage of federally owned land that is not subject to the ordinances of the local government; indeed Congress may overrule decisions made by the city council. In order to account for this it may be more useful to exclude all federal properties and land area from the analysis, or place a negative value on these particular locations. Similarly, in a city with a significant number of waterways or parkland, these areas may be excluded or treated in a different manner in order to strengthen the results of the analysis. However, it was not the purpose of this research to provide a study strictly of one city, but to provide a framework that can be extended to other cities.

Ideally, this research also lays the groundwork for future research into livability at a detailed intra-city level. This includes the examination of possible correlation between the indices presented in this research and the outcomes that Jacobs' sought, such as low crime rates, socio-economic diversity, and '24-hour' neighborhoods. Also, there is more research that may be conducted into the precise locational nature of the parameters; do some parameters, such as dwelling density and street segment length have a tendency to co-locate (as the correlation coefficients presented here suggest)? Furthermore, it would be useful to have this methodology applied to other major U.S. cities and have corresponding subjective methods (such as collecting resident's perceptions of their neighborhoods) applied to these cities in order to begin building a broad-based assessment of Jacobs' theories.

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