ABSTRACT

Title: SUSTAINABLE DC
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Over the past three decades, sustainability has earned a growing importance in city planning and policy decisions. Planners often champion sustainable development as the model framework for achieving social, economic and environmental objectives. However, sustainability in practice is less about striking the perfect balance between these three components than it is about building livable cities. In 2011, Washington DC launched the Sustainable DC initiative. This vision sought to identify focus areas and goals for making the District "the healthiest, greenest and most livable city in the United States" by 2030. The purpose of this thesis is to understand ways in which the city can ensure a high quality of life for residents as it works to implement the Sustainable DC initiative. This research examined relationships between the physical environment and socioeconomic characteristics of residents across DC neighborhoods to make recommendations for implementing Sustainable DC.

SUSTAINABLE DC

by Frances E. Doherty

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of the requirements for the degree of
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Advisory Committee:
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Dedication

This thesis is dedicated to my husband for giving me his full support even while I spent most weekends during our first year of marriage immersed in this research.

Acknowledgements

I'd like to acknowledge the follow people who provided information, support and guidance through my journey researching and writing.

First, I'd like to thank the Sustainable DC planning team at the District Department of the Environment and the Office of Planning. Specifically, Dan Guilbeault, John Heermans and Laine Brendan who took the time to meet, offer suggestions and critique my ideas as I was developing my study.

Second, I want to thank my thesis chair, Casey Dawkins, for taking on an ambitious yet unfocused student and giving me your time and a nudge in a more substantive direction. I was lucky to also have a encouraging committee, including James Cohen, Matthew Bell and William Hanna.

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I. Introduction

Washington DC is in the process of finalizing its Sustainable DC initiative. This initiative sets an ambitious goal – to make DC the most sustainable city in the country.

> "In just one generation - 20 years - the District of Columbia will be the healthiest, greenest, and most livable city in the United States. An international destination for people and investment, the District will be a model of innovative policies and practices that improve quality of life and economic opportunity. We will demonstrate how enhancing our natural and built environments, investing in a diverse clean economy, and reducing disparities among residents can create an educated, equitable and prosperous society."

Sustainability is often understood as a relationship between social equity, economic opportunity and environmental protection (Campbell). Planners aim to balance the three in order to achieve a high quality of life. Using this definition as a framework, the purpose of this thesis is to understand ways in which the District can ensure a high quality of life for residents as it works to implement the Sustainable DC initiative. To reach their sustainability goals, city leaders need to understand what the quality of life is like for residents in different neighborhoods across the city, identify locations that would benefit most from future investment and clarify what types of investment that would be most useful.

I will examine the following three questions for this research:

- In what ways does the physical environment of different neighborhoods provide residents access to positive environmental features or cause them exposure to negative environmental features?
- Is there a correlation between the physical characteristics of a neighborhood and the social and economic characteristics of the people who live there?
- What can the city learn from its neighborhoods as it crafts targeted strategies to reach its sustainability goals?

My goal with this research is twofold. First, to provide a sustainability benchmark for the City as it undertakes this high-reaching program. Second, I aim to identify neighborhoods that can serve as useful models for what sustainable urbanism looks like on the ground.

II. Background

Sustainability

Since its inception into the global lexicon by the Bruntland Report in 1987 (WCED), sustainability and sustainable development have become a guiding force for managing resources and growth. Sustainable development can trace its roots to the progressive era where actors such as Frederick Law Olmstead, Daniel Burnham, John Muir and Gifford Pinchot introduced ideas about conservation, balancing nature with the built environment and creating a sense of place (Daniels). In the mid-twentieth century, environmental science gained a foothold in development practice as concerns over regional planning and resource protection emerged against a backdrop of rapid post-war expansion. At the same time, urban activists and advocates began to criticize federal policies that were destroying the quality of life in central cities. Jane Jacobs penned her classic Death and Life of Great American Cities during a time of great upheaval and change in the United States. Across the country, public housing projects wreaked havoc on city residents by destroying vibrant yet vulnerable neighborhoods while the interstate highway system leveled predominantly poor urban areas and, via freeways, granted developers access to cheap land for suburban development (Teaford, Kunstler).

Jane Jacobs was in good company as she critiqued the trajectory of the country's existing development paradigm. In 1961, Rachel Carson published Silent Spring and sparked an environmental awakening that fundamentally changed the way humans interact with the planet. Betty Friedman added the Feminine Mystique in 1963 and brought to light the isolated and stultifying lives of suburban housewives. This troika of visionaries sparked an ongoing debate about how human and natural ecosystems operate, interact and influence one another (Campbell, Klemek). Their revolutionary works provided fodder for people who were dissatisfied with the path of American development to argue for a different future. Contemporary sustainable development trends emerged from this milieu in the 1970's when practitioners across disparate fields, such as planning, ecology and health, began to identify and explore their overlapping concerns (Rowan). Sustainability in its modern incarnation arrived in the 1980s and early 1990s as architects and planners began to employ traditional urban forms to promote walkable, transit friendly environments that were scaled to the pedestrian and not the car (Hayden).

After decades of steady advocacy, sustainable development is at the forefront of city planning. New urbanism, smart growth, transit oriented development and most recently eco-cities are common planning movements that exemplify these principles. Form based codes, which guide building form and size but not use, have been adopted by cities and towns across the country, from Florida to Texas to California, as a means to encourage –

and often to legalize – mixed-use, compact development (Benfield, FBCI). Public leaders have also embraced LEED for Neighborhood Development, a joint program from the U.S. Green Buildings Council, National Resource Defense Council and the Congress for the New Urbanism that promotes sustainability through environmentally conscious site design, infrastructure improvements and individual building performance (Benfield). Regional and statewide policies, such as Portland Oregon's statewide urban growth management system and Maryland's Smart Growth legislation, are examples of sustainable development initiatives adopted at a large scale. Though there is debate around the impact that demographic shifts and rising energy costs will have on urban environments, cities are nonetheless turning to sustainable development strategies as they invest in infrastructure and amenities that aim to rejuvenate long-neglected downtowns (Kemp, Rybsczynski).

Today, planners champion sustainable development as a framework for achieving social, economic and environmental goals (Birch and Silver, Jepson and Edwards). Even with such constant and growing attention, sustainability remains a difficult term to define (Holden, Jepson 2001). While differences remain, the various definitions formulated over the previous two decades share a common theme: interrelatedness between environmental resources, socioeconomic activities and quality of life on both a local and global scale (MacFarlane and Ogazon). The challenge of sustainability is that it is an abstract and all-encompassing idea. Due to this, it is far most useful to think of a sustainable environment as one that creates a high quality of life, socially, economically and physically, for people who live there without decreasing the potential for future generations to enjoy the same high quality of life.

Like sustainability, quality of life is difficult to define since it means different things to different people. In a world of normal goods, people will generally chose to increase access to elements that make them better off and restrict their exposure to features that make them worse off. Relating this to residency choices, a person would prefer to live in a location near useful amenities (convenient shopping, good schools and well-maintained parks), with easy mobility (uncongested, transit options) and healthy surrounding (clean air and water) than in an environment that was harmful to their well-being. Planning a city to nurture these amenities, and enable equal access particularly to public goods like schools, air and water, is a primary goal for planners. However, the patterns of development are often far from equitable and can make the quality of life for city residents vary greatly from one neighborhood to the next. As the city embarks on its Sustainable DC initiative, they will do well to understand the quality of environments across the city and use that information as a guide when implementing strategies to make the District a healthy and opportunity filled place for all residents.

Sustainable DC

Throughout the past two decades, sustainability has taken a prominent place among city planners and policy makers. The Sustainable DC initiative is one of many such plans taking shape across the country. Announced by Mayor Vincent Gray in July, 2011, it builds on the efforts of former administrations and individual departments to address livability, inclusivity and access to resources during a time when the city and its region are experiencing rapid population growth and demographic change. Lead by the District Department of the Environment (DDOE) and the Office of Planning (OP), the city published A Vision for a Sustainable DC in early 2012 that brought together recommendations from the community and advisory committees to set a vision for the city. The vision defined sustainability as "balancing the demands of economic development, environmental protection and community equity across our city" and identified cores areas on which to focus their work. Subsequent community and internal discussions narrowed the scope from eleven to seven goals with a twenty-year horizon for achievement:

Table 1: Sustainable DC Goals

Focus Area	Goal
Green Economy	3x more DC based businesses; Cut unemployment by 50%
Energy	Cut energy consumption 50%; Increase renewable energy use by 50%
Food	Local food within 1/4 mile for 75% of population
Nature	40% covered by tree canopy; All residents within 10-minute walk to nature
Transportation	75% all trips by walk, bike or transit
Waste	Zero waste
Water	All waterways swim-able; 75% landscape filters rainwater

The city is currently engaged in developing a detailed strategy to achieve these objectives. The final public working group meeting was held on November 7, 2012, where the Sustainable DC team presented their recommendations for implementing the more than 1,000 suggestions collected during the past year (Canter). DDOE and OP will review comments from the meeting as they complete the final plan, which is set for release before the end of the year.

Background

The seeds for Sustainable DC were sown during the previous decade through legislation, plans and departmental leadership. Examples of this work include:

- Anacostia Waterfront Initiative: a 30-year, $10 billion plan, started in 2000 as a partnership between 19 regional and federal agencies, to revitalize the areas adjacent to the Anacostia River with new parks, residences, multimodal transportation and commercial centers.
- 2006 Comprehensive Plan: outlined goals and actions that encouraged future development to occur in an inclusive manner that is sensitive to the city's unique character and history.
- Green Building Act of 2006: established high-performance building standards and incentives that required new construction of 50,000 square feet or more to be either Energy Star or LEED rated.
- Climate Action Plan: Shortly before Mayor Fenty left office in 2010, his administration released a draft action plan entitled Climate of Opportunity. The draft plan set aggressive targets for reducing greenhouse gas emissions through a focus on green buildings, sourcing renewable energy and targeting development near mass transit.
- Energy Efficiency Financing Act of 2010: established the PACE program which offers city financing for energy-efficiency improvements to commercial buildings that property owners repay through a long term special tax assessment.

Throughout the fall and winter after Mayor Gray's announcement, the city organized a planning team to gather input from community members about issues that they believed DC's sustainability plan should address. The planning team was tasked with engaging residents, particularly those whom are typically underrepresented in city governance, and solicit their ideas about the sustainability initiative. The Mayor then created two advisory groups, the Green Ribbon Committee, which consisted of community leaders from public, private and nonprofit sectors, and the Green Cabinet, an intergovernmental team of agency directors. From these advisory committees and input from the planning team, working groups were formed to evaluate the community's ideas against national best practices and departmental plans.

Implementing the Initiative

Fueling the Sustainable DC initiative was a drive to identify ambitious yet achievable goals that could be implemented immediately and result in widespread benefits for the community at large. While the process used to establish the seven goals sought transparency and inclusivity, the planning team nonetheless faced a number of challenges from the onset. The following challenges were identified in an interview held with the Sustainable DC planning team in the fall of 2012 (Guilbeault and Heermans).

- Setting the scope: Sustainability is a wicked problem in that it is nearly impossible to define definitively and therefore invites an ever-expanding reach into issues that are not directly related (Blanco).
- Establishing realistic goals: Budgets constrain what an agency can prioritize and implement. Proclaiming an ambitious long-term goal is one thing; committing to and executing small and mid-range actions that work in a measurable way to achieve that goal is quite another thing entirely.
- Finding common ground: Sustainability can be divisive because many people approach the topic with an "us versus them" mentality. A common narrative describes sustainable development as only for rich, new residents and doesn't take into account the needs of long time Washingtonians. This mindset undercuts the potential for widespread impact because it frames change as something that is mandated from afar instead of promoted from within.
- Managing competing interests: Controversial tones are often hit when projects require regional collaboration. Because of our metro's unique position between three major jurisdictions, many long-term strategies involve sophisticated negotiations and advanced levels of cooperation.

The solution to many of these challenges was to aim for achievable yet practical objectives first. The planning team identified a number of sustainability-oriented activities that departments across the city were preparing to execute, but had not yet fully launched. By bringing these innovative departmental plans together under one initiative, Sustainable DC validated existing departmental priorities with an administrative commitment for financial and political support. A majority of focus areas in the plan involve the physical environment. Crosscutting issues such as health, climate and the built environment, particularly the changes that rapid population increase will demand, all impact the seven focus areas and deserve consideration for any strategy developed. Such topics were important to the residents and community partners who engaged in preliminary brainstorming. They also provide a platform for communicating the initiative to the broader population and generating buy-in for implementation.

The initiative is seen by its planning team to be the first in an iterative process. Future versions would build off the work of this plan to focus on more controversial issues once there was a history of successful implementation and increased buy-in from skeptical groups. Accomplishing the goals set out in this initiative depends heavily on community buy-in. This first plan mostly ignores equity issues that cause conflict and create controversy among residents. Instead, by aiming at physical improvements with demonstrable positive impacts for all, the planning team hopes to create an inclusive policy that all residents believe in and support. Going forward, the city hopes to leverage its initial successes to tackle more contentious problems and expand the reach of goals to include multijurisdictional activity.

Next Phase: Action

After two years of planning, the Sustainable DC initiative is nearing launch. Already, a number of smaller components that in the future will be covered by the plan are delivering results. The Green Building Act and Green Building Code are progressive approaches that codify sustainable strategies. An example of these policies' influence is the expanding number of LEED certified buildings that are under constructed or recently delivered throughout the city. Revised stormwater requirements revamp policies to require water filtration onsite and energy benchmarking protocols and under development for all public and private building above 50,000 square feet. These new standards have the potential to dramatically changing the way buildings and their sites are designed.

These activities provide valuable lessons learned as the city moves to implement the core components of Sustainable DC. To expand on these programs, the planning team will need to keep in mind a number of best practices going forward. First, they should establish benchmarks for each of the focus areas using appropriate metrics that will allow them to compared existing conditions with future results. Such benchmarks only work if there is ongoing measurement and assessment to refine strategies that aren't performing as expected. This has been a self-identified weak point for the planning team in the past. Data has often been collected at the ward or city level, which doesn't allow for analysis of direct impacts in specific neighborhoods or target areas. Also, useful data is often times unavailable or nonexistent. The waste processing system is an example of this. Because the city contracts its waste disposal needs to private companies, who then aggregate and dump the material at central locations, there is no information recorded about the quantity, type or originating location of the waste these contractors process. Other data, such as energy use for individual buildings, requires sensitive agreements with private partners, such as Pepco.

Once the strategies are operating, there is a need for continual engagement with residents. Generating ground level support is a necessary tactic to hedge against plan derailment due to political flux. Changing political administrations bring changing priorities, and could derail the plan if the current level of support dwindles. Although the initiative has enjoyed wide political support to this point, this is a point of uncertainty that affects even the best-laid plans. Garnering popular support from residents serves a two-fold purpose of making it easier to execute shovel-ready projects while ensuring that there will be support in the future for planned activities.

III. Methodology

Six of the final seven goals in the Sustainable DC initiative focus directly on the physical environment: energy, food, nature, transportation, waste and water. For this reason, my study will look at the city's physical environment to determine how neighborhoods differ in the quality of life they are able to offer their residents. The three questions my analysis seeks to answer are:

- In what ways does the physical environment of different neighborhoods provide residents access to positive environmental features or cause them exposure to negative environmental features?
- Is there a correlation between the physical characteristics of neighborhoods and the social and economic characteristics of the people who live there?
- What can the city learn from its neighborhoods as it crafts targeted strategies to reach its sustainability goals?

Variables

I examined eight variables for this study, four associated with the physical environment and four that are commonly used to assess social and economic characteristics. The four physical environment variables relate to specific goals of the Sustainable DC initiative: food, nature, transportation and water. The energy and waste goals posed excessive challenges to acquiring usable data and for this reason were excluded from this preliminary analysis. As noted earlier, information on waste processing is not collected for the city while energy use data is maintained by Pepco and is not currently available in an analysis-ready format.

The four physical environment variables pertain to the built and natural environment. These variables were chosen for their association with the Sustainable DC goals, their recognition by academics and professionals as useful quality of life indicators and my ability to obtain and analyze the data on a census tract level. The four physical environment variables analyzed were: transit, walkability, tree canopy and Permeability.

Built and Natural Environment Variables

<u>Transit – Sustainability Goals: Transportation and Energy</u>

Transit accessibility was derived from TransitScore, a subsidiary product of WalkScore. TransitScore is a GIS-based tool for measuring transit accessibility. It uses an algorithm to score addresses based on their proximity to various public transportation systems and the frequency of these systems. The scores are normalized on a 0-100 scale with 100

indicating "world-class public transportation" (TransitScore) and 0 meaning minimal transit is available.

TransitScore provides GIS shapefiles for researchers who are interested in examining transit in cities across the country. The DC shapefile contained point data laid out in a grid pattern that I aggregated into polygon data by census tract. Depending on the census tract, there were on average 15-20 points within its boundaries. The aggregated data included averaged TransitScores for each census tract that were used in later analysis. The scores were already fully calculated with the TransitScore algorithm.

TransitScore measures how well or poorly different parts of the city have access to reliable public transit options. This relates directly to the transportation goal of having 75% of all trips complete by foot, bike or transit because it shows where the city is not well served currently. When combined with information from other variables, particularly social and economic characteristics, TransitScore can help guide decisions about where best to increase and promote additional transportation options. A drawback of aggregating and averaging scores by census tract is that it removes the gradual changes that are reflected in the original raster map.

Despite the loss, this method still maintains the overall intent of TransitScore even if some of the nuance was lost when creating the manipulated dataset. For example, census tract A may have one portion of its geography that is within a five-minute walk to transit that is in census tract B while the remainder of census tract A does not contain any transit. Upon averaging the point data into an overall score, the low scores for most of census tract A would dilute the high transit accessibility of the portion near census tract B. However, if census tract B did not have transit, census tract A would have an even lower overall score because no part of the census tract would be transit accessible. Using this method, census tracts that are near but do not have transit within their borders still reap the benefits of having a higher average score than census tract that are not proximate to others with transit. This logic also applies to WalkScore and the proximity to amenities.

Walkability – Sustainability Goals: Food, Nature and Transportation

Walkability was calculated from the WalkScore algorithm. WalkScore is a GIS-based tool for measuring pedestrian walkability. The algorithm measures proximity from an address to various residential destinations such as grocery stores, banks, schools or parks and produces a rasterized heat map to display the resulting walkability patterns. The resulting score is normalized on a 0 to 100 scale based on distance to these destinations and road connectivity metrics. Scores near 100 indicate a "Walker's Paradise" while those less than 50 are considered car-dependent.

WalkScore provides GIS shapefiles for researchers who are interested in examining walkability in cities across the country. The DC shapefile contained point data that I aggregated into polygon data by census tract. The aggregated data included averaged WalkScores for each census tract that were used in later analysis. The scores were already fully calculated with the WalkScore algorithm.

The destinations used to determine the WalkScore are widely regarded as essential neighborhood serving amenities. A number of these destinations, specifically parks and grocery stores, are identified in the Sustainable DC goals. Also, to achieve the city's ambitious transportation goal, destinations must exist to which residents can walk. Analyzing WalkScore shows the ability for residents to fulfill common daily needs without requiring travel far outside their neighborhood.

Tree Canopy – Sustainability Goals: Nature, Water, Energy

The Wooded Areas (2012) and Street Trees (2012) GIS layers from DC clearinghouse were used to compute tree canopy coverage in the city. The USDA Forest Service defines an urban tree canopy (UTC) as the layer of tree leaves, branches and stems that cover the ground when viewed from an aerial perspective. UTC is typically measured as a percentage of land area in a given geography that is covered by trees systems.

The Street Trees file contained point data that catalogued all publicly owned trees in the city. The point data was converted to polygon data by defining each point as having a 24-foot crown diameter and was combined with the Wooded Areas file to create a new polygon shapefile that contained an approximation of tree coverage citywide. From there, the tree coverage polygon was intersected with the census tract polygons and a coverage percent was calculated based on the square feet of tree covered land divided by total square feet in each census tract.

Trees provide indispensible services to human and natural ecosystems. Casey Trees, a leading advocacy organization in the District, describes trees as "green infrastructure essential to creating and maintaining healthy, sustainable and economically viable communities" (Casey Trees). They maintain healthy air quality, mitigate and filter pollutants in water, provide habitats for wildlife, reduced energy use and heat island effects through shading and contribute to a pleasing outdoor aesthetic. These benefits are all things that the Sustainable DC initiative aims to achieve.

Permeability – Sustainability Goals: Water, Nature and Energy

The DC GIS clearinghouse offers an impervious surface layer. This shapefile combines features from the 2008 Planimetrics Dataset including airport taxiways, helipads, outdoor building stairs, buildings, sidewalks, roads, alleys, driveways and swimming pools to derive impervious surface area across the city. The impervious surface shapefile was

intersected with the census tract shapefile. A surface area coverage percent was calculated based on the square feet of impervious surfaces divided by total square feet in each census tract. This percentage was subtracted from "1" to calculate the permeability coverage percentage.

DC Water defines an impervious surface as "a man-made surface that cannot be easily penetrated by water" (DC Water). Impenetrable surfaces affect the environment in three key ways. First, they restrict rainwater infiltration and groundwater recharge, enabling pollutants to enter the local watershed or cause overflows in combined sewer systems. Excessive impervious coverage also raises air temperatures and causes heat islands, which lead property owner to use more energy to cool their buildings. Finally, impervious paving interferes with vegetation by depriving root systems of aeration interrupting fragile ecosystems that rely on contiguous coverage. Measuring this data will emphasize areas where innovative strategies, such as green roofs, would be most beneficial to tackle the negative consequence of too much pavement.

Social and Economic Variables

Four variables were also used to express social and economic characteristics. The chosen variables are resident-oriented, meaning that the data is driven by traits expressed by the people who live within a census tract or activity that directly involves people. This approach was taken in attempt to assess the relationship between people who chose to reside in various parts of the city and not the indirect effects of environmental conditions. For example, economic viability is measured by the percentage of employed persons who live in an area and not by the number of jobs that exist in that same location since environmental decisions such as zoning impacts the type of land uses allowed and therefore the number of jobs possible. The four social and economic variables analyzed were: racial diversity, violent crime, median household income and unemployment. Each of these variables is referenced in Sustainable DC as outcomes that are inextricably linked to the primary environmental goals of the plan and are therefore important to understanding quality of life for city residents.

Racial Diversity

Data on race was derived from the 2010 Census. The race categories analyzed in this research were white, black, Asian and other. I performed the following calculation to derive a Gini-Simpson index of racial diversity for each census tract:

$$D_v = 1 - \Sigma\ (n/N)^2$$

In this equation, n is the number of people of one race, N is the total population and D_v is the diversity score. This diversity score is the probability that two people chosen at

random from a population will be from a different racial group. The index returns scores between 0 and 1 with scores closer to 1 indicating greater diversity.

Violent Crime

The DC Metropolitan Police Department publishes crime information in both GIS and database format on an ongoing basis. Information pulled for this analysis comes from the 2011 Crime Incidents data set. The data was filtered for violent crimes, defined as crime perpetrated against a person directly versus against his or her property. These crimes include assault with a deadly weapon, homicide, robbery and sexual abuse. The filtered data was geocoded in GIS to determine crime locations. The point data was aggregated by census tract and summed to combine all violent crimes into a single count. In each census tract, the violent crimes count was divided by population to arrive at total crimes per 1,000 residents.

Median Household Income

Median household income is reported annually in the American Community Survey. The most recent household income data available for DC was from the 2006-2010 ACS 5-year estimate. These data used without manipulation to see median income levels by census tract.

Unemployment

The unemployment rate for adults aged 25 or older whom are in the workforce is reported annually in the American Community Survey. The most recent unemployment data available for DC was from the 2006-2010 ACS 5-year estimate. These data used without manipulation to see unemployment rates by census tract.

Data Limitations

This study offers a preliminary assessment of the state of the environment, both built and natural, across the District. What I aim to do with this research is to look at quality of life issues in a more granular fashion. Washington, DC is known to be a city where conditions change drastically from one block to the next. Even though the differences between proximate blocks can be extreme, previous research often times only looked at data disaggregated at the ward level. Moreover, the variables used in this study are by no means the only variables salient to a study on sustainability or quality of life. My intention is to offer one of many possible angles for examining the quality of life offered by different neighborhoods. Because the number of variables used is limited, this is not a comprehensive analysis and the results should not be unreasonably extrapolated. What's more, this research did not account for the interrelated nature of environmental features or attempt to explain causation. It is meant to provide a descriptive overview of what

exists where and if there is any correlation between different features. Attempts to understand and explain causation would be interesting topics of future research.

Process

To gain an understanding of quality of life across the District and answer my three main questions, I performed a number of analyses of the eight environmental and socioeconomic variables.

Description

First, I examined how the eight variables were expressed across the city's census tracts, with particular focus on the data's frequency distribution and spatial dispersal. The data was mapped by quartile and descriptive statistics were calculated and analyzed.

Neighborhood Types

For the four physical environment variables, each census tract was labeled either "low" or "high" depending on whether or not a variable's value exceeded the citywide median. The low/high scores for each variable were combined to create a neighborhood type (for example LHLL would mean lower than median value for three variables and a higher than median value for one variable). The position of each variable remained constant i.e. transit was always first, walkability second, tree canopy third and permeability fourth. In total, there were sixteen possible neighborhood types from combining the low/high scores in this manner. The neighborhood types were mapped in GIS to determine where the different types were located and if they appeared to be clustered or randomly distributed.

One disadvantage of this technique is that it disregards the point at which a variable score is considered sustainable or not. Using TransitScore as an example, consider DC, which has a median score near 70, and Baltimore, with a score of 57. Overall, DC is a more transit-accessible than Baltimore, but that difference is not apparent if the scores are displayed solely through a quartile map. On the other hand, classifying a variable as low or high by comparing it to the citywide median allowed for a consistent ranking method that could be equally applied to all variables, regardless of what they measured. Since this study only analyzed one city, discrepancies from multi-city comparisons did not induce misrepresentation. The process also set an objective standard that judged census tract scores against existing city performance, proving that achieving a certain score is possible since part of the city are at that level.

Correlation

I examined what, if any, correlation exists between the environmental qualities of the city's census tracts and the characteristics of people who live in those locations. I performed a regression analysis the assessed the correlation and fit of the four environmental variables against the four socioeconomic variables. I also examined changes in median values of socioeconomic variables against different quartile ranges of the environmental variables. Lastly, I looked at spatial correlation between socioeconomic and environmental values through a blend analysis in GIS. This displayed geographic relationships between high and low value areas and offers a guide for identifying disadvantaged locations.

IV. Analysis

Existing Environment

The physical environment of different census tracts within Washington DC varies greatly across the city. As Table 1 illustrates, the four variables studied here all display a wide range of values, notably walkability and permeability coverage.

Table 2: Environmental Variables Descriptive Statistics

Variable	Median	Mean	Min	Max	St. Dev
Transit	67.3	69.3	33.6	100.0	14.3
Walkability	68.9	67.3	9.9	98.3	21.2
Tree Canopy	12.4%	15.8%	0.4%	59.2%	10.4%
Permeability	49.2%	50.5%	16.4%	94.0%	16.9%

Overall, the correlation between the four variables follows a predictable pattern. Variables that correspond to either the built environment (transit and walkability) or the natural environment (tree canopy and permeability) are strongly correlated in a positive direction to each other and negatively correlated to the other set of variables. Also as expected, there is a strong negative correlation between permeability coverage and transit and walkability. The relationship between tree canopy coverage, however, is much weaker relatively speaking.

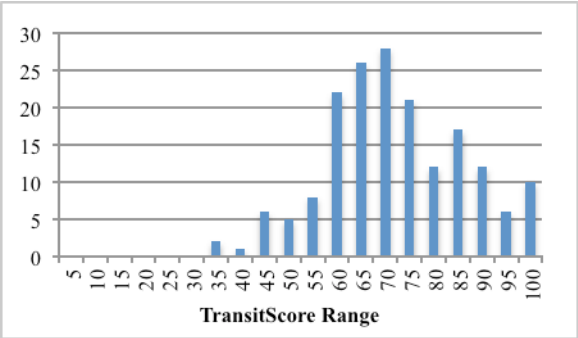
Table 3: Environmental Variable Correlation

	Transit	Walkability	Tree Canopy	Permeability
Transit		0.804	-0.378	-0.827
Walkability	0.804		-0.447	-0.895
Tree Canopy	-0.378	-0.447		0.591
Permeability	-0.827	-0.895	0.591	

These correlations point to the interrelatedness of these variables, but the lower correlation to tree canopy also hints that the presence of built and natural features is not always mutually exclusive.

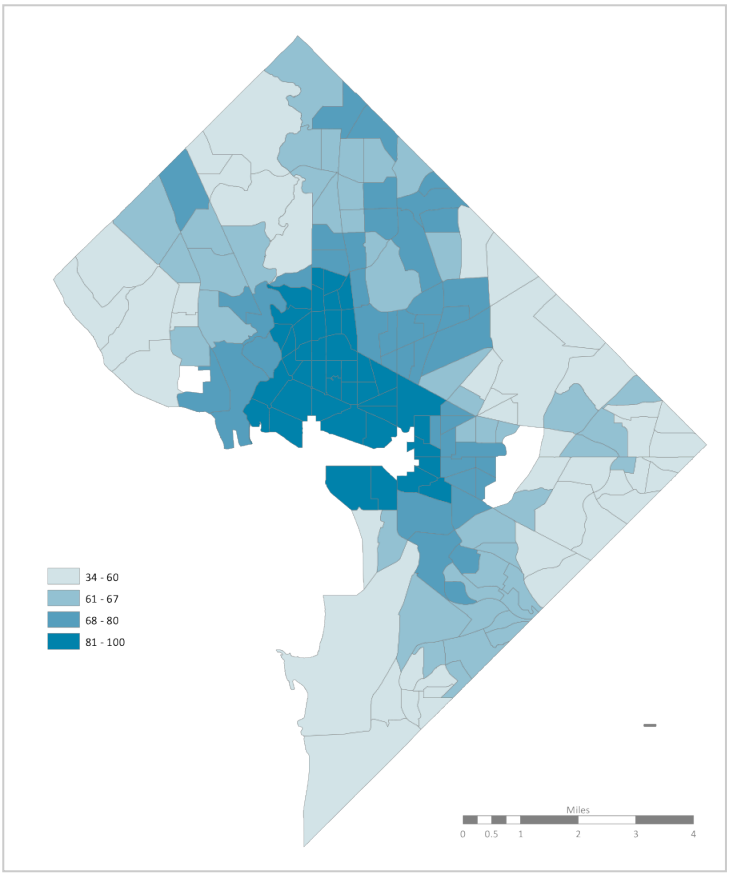
Transit

Chart 1: TransitScore Frequency



Many areas of DC are well served by transit. This analysis showed that the city has a median score of 68.9, which is near the 70-score threshold that the creators of TransitScore and WalkScore describe as the point at which it is possible to live a car-free lifestyle. When ranked against other cities on the TransitScore website, Washington DC, with a score of 69, comes in fourth behind New York (81), San Francisco (80) and Boston (74). Transit scores across the city display a normal distribution, albeit slightly skewed towards more census tracts that have higher scores than those that have lower scores. The lowest scoring census tracts in the District contain a transit profile that is similar to Kansas City, Austin and Sacramento, cities that have overall TransitScores in the low 30s.

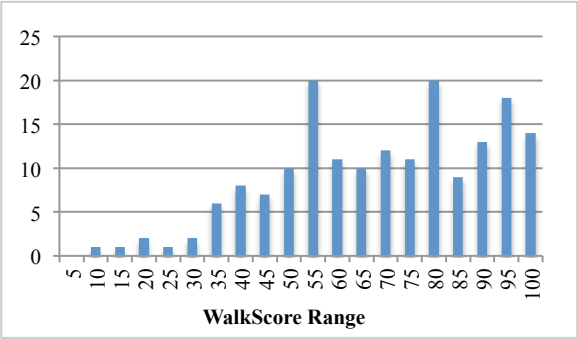
Map 1: Transit Environment



Geographically, the transit accessibility pattern across the city is highly monocentric. The central CBD and the adjacent neighborhoods have the highest scores among all census tracts. All census tracts with scores in the top 25% are in this area. The middle 50% of scores follow the metro lines, notably the red and green lines, in a hub and spoke fashion. The distribution of high value of scores indicates that the city is generally well served by transit, but there are pockets of acute need for improved access. These areas have opportunity for creative solutions, such as targeting metro accessible locations for mixed-use development.

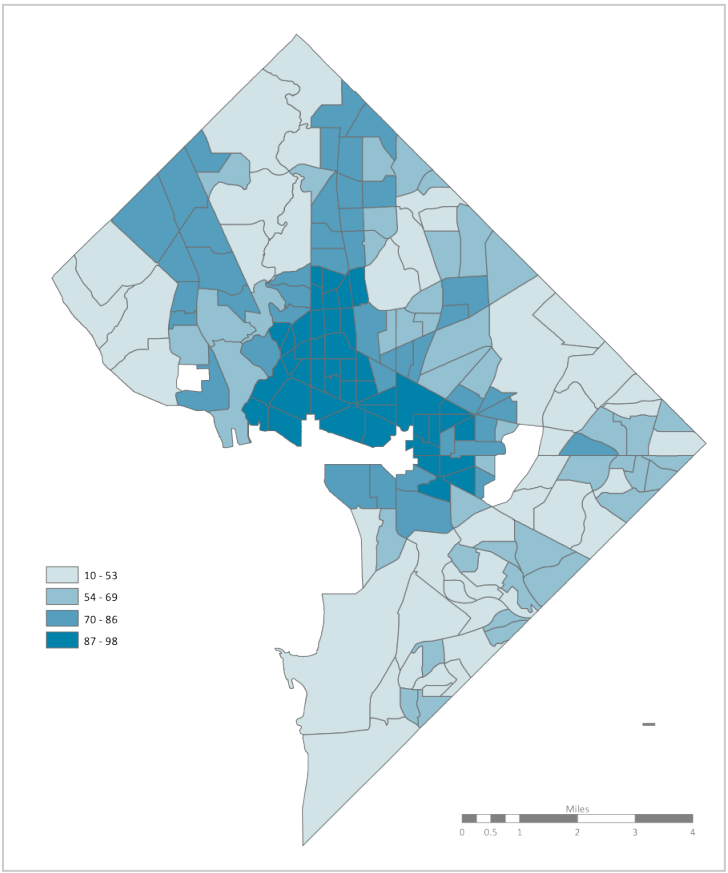
Walkability

Chart 2: WalkScore Frequency



The score distribution for walkability within census tracts is similar to transit; 81.8% of census tracts in the top quarter of scores for transit also are in the top quarter of scores for walkability. The difference between transit and walkability is the wide range of scores that exists throughout the city. The bottom quartile has scores between 9.9 and 52.7. Scores less than 50 are described by WalkScore creators as car dependent and display low density, wide streets and excessive parking. These census tracts lie along the city perimeter. In contrast, high scoring census tracts are concentrated in the center with the middle 50% of census tracts generally following metro lines.

Map 2: Walkability Environment

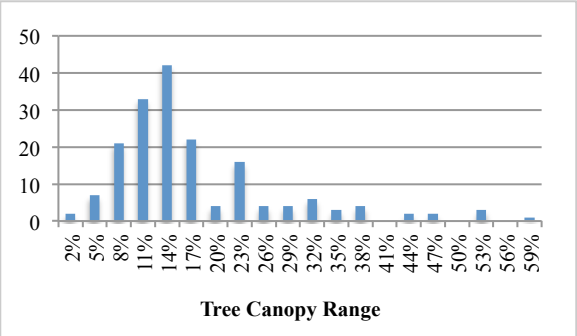


One caveat when analyzing WalkScore is that it does not measure the quality of nearby amenities, only that they exist. Moreover, in comparing existing walkability with DC's Comprehensive Plan Future Land Use Map (2012), areas of low walkability disproportionately affect residents on the east side of the Anacostia. The areas in Northwest and Northeast that contain low walkability scores are explained by land uses that do not require high levels of walkability. Rock Creek Park covers much of the northern most low-scoring census tracts while production zones and institutional grounds exist along the eastern stretch of the city. In contrast, much of Southeast is moderate to medium density residential. While this land use type is highly compatible with walkability, in its current state the census tracts in this neighborhood are not well served by amenities that are accessible by foot.

Tree Canopy

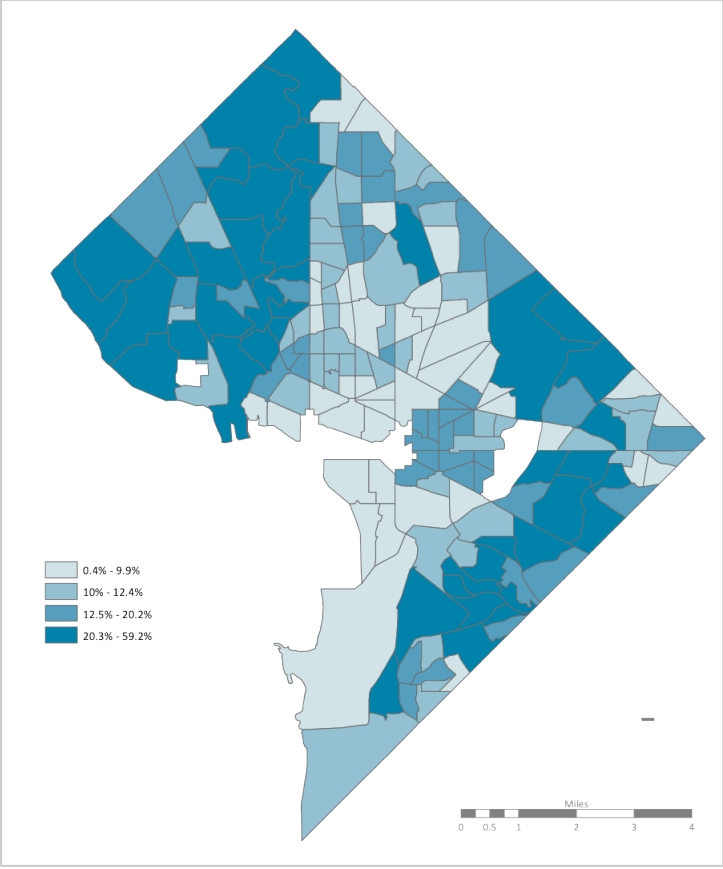
Tree canopy coverage varies greatly across the city. The median coverage percent is 12.4%, however there are census tracts with less than 2% coverage and others that boast 50% or more. The coverage frequency displays a fairly normal distribution but is slightly skewed left, showing that most census tracts contain less than 15% coverage.

Chart 3: Tree Canopy Frequency



Geographically, there are very distinct concentrations of areas with low or high tree coverage. Neighborhoods in upper Northwest, Southeast and near the National Arboretum have the largest coverage percentages. While there is an evident distinction between the central North-South axis that contains lower tree coverage and the outer east and west sections of the city, there are also locations within the low coverage axis that bunk the low coverage trend. Capitol Hill has a concentration of mid-to-high coverage, with its census tracts in the 50-75% group of scores. This is of note due to the fact that the census tracts surrounding this area are all below the citywide median. The presence of this cluster raises questions about why it is different and what caused it to develop differently than neighboring areas.

Map 3: Tree Canopy Environment



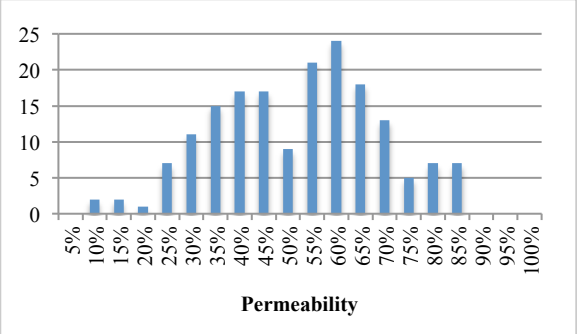
The census tracts with the highest scores relate to parts of the city that are national or regional parks or low density residential. Rock Creek Park, the National Arboretum and the Anacostia River parkland comprise the top twelve census tract scores. However, this data does not take into account trees planted on privately owned land. Including information about private trees

could substantially change the coverage percentages, especially in residential areas that currently display moderate scores.

Permeability

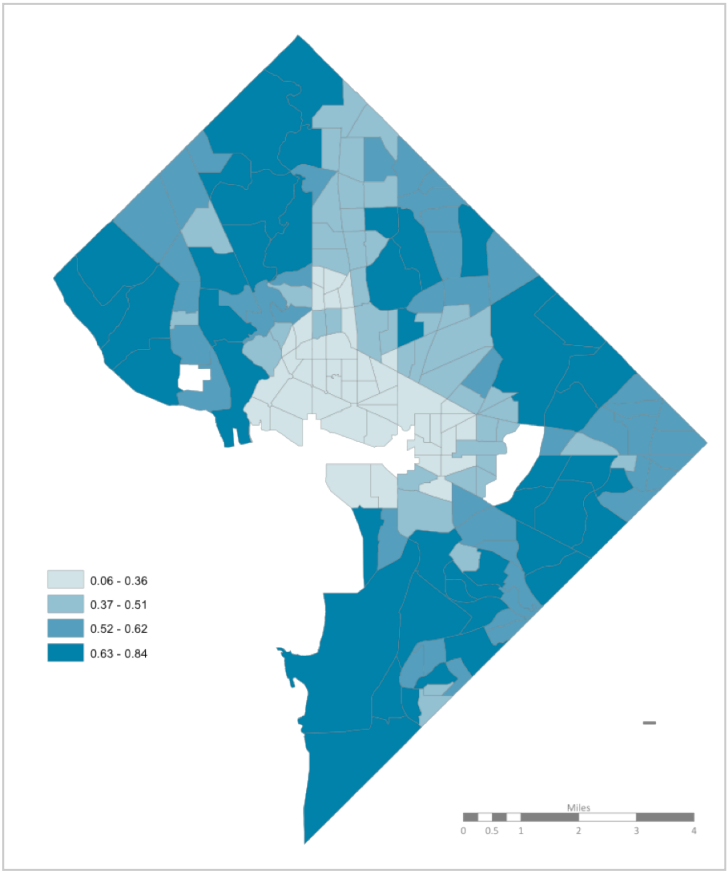
The percentage of permeability coverage varies greatly across the city's census tracts, ranging from as low as 6.0% in the CBD to 83.6% in areas near Rock Creek Park. The percentages follow a generally normal, non-skewed distribution, with half of all census tracts falling between 37% and 63% covered. Although he frequency distribution displays a mostly normal shape, there are a handful of outliers with permeability of 15% or less. These values indicate excessive pavement coverage and portend careful examination of the land uses in these areas.

Chart 4: Permeability Frequency



The spatial pattern for permeability inversely mirrors that of walkability and transit, with the center of the city containing the bottom 25% of scores (most impervious), the middle 50% corresponding to metro corridors and the top 25% filling in the least walkable and transit accessible census tracts. The correlation between permeability and walkability is the greatest of all variable relationships, with an R-value of 0.895. Transit comes in a close second. This correlation is not surprising; areas that have high transit and walkability are intensely developed and leave little area for bare land or landscaping.

Map 4: Permeability Environment



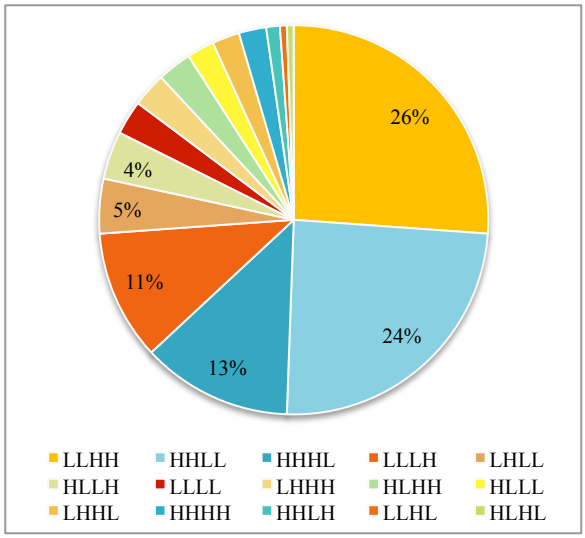
Data Limitations

One limitation of data is that the type of surface isn't considered. For example, a brick alley that allows some rainwater to percolate into the ground instead of forcing all water to run into the sewer system is better for the environment and can have many benefits for a city's stormwater management system. The impervious surface GIS layer does not account for different types of paving and considers a brick alleyway to be equivalent to a concrete sidewalk or paved street. Also, the presence of green roofs, particularly in dense areas, can reduce both the quantity of stormwater that enters the system and minimize the heat island effect of intense development. Although the city has published a green roof GIS layer, information included in the layer regarding coverage area and filtering capacity is still under development. The green roof GIS layer was excluded from this analysis for that reason.

Neighborhood Types

Though there is an inverse relationship between the natural and built environment variables, they are not mutually exclusive in all census tracts. There are areas throughout the city that contain high scores for all four variables (scores above that variable's median value), meaning that they provide greater access to high quality amenities as measured by the variables included in this study. Similarly, there are parts of the city that contain low scores for all four variables. The types of neighborhoods that exist in the city vary along this spectrum. For the neighborhood types, the high/low designation labels transit first, walkability second, tree canopy third and permeability fourth. Detail on all sixteen different neighborhood is included in Appendix A.

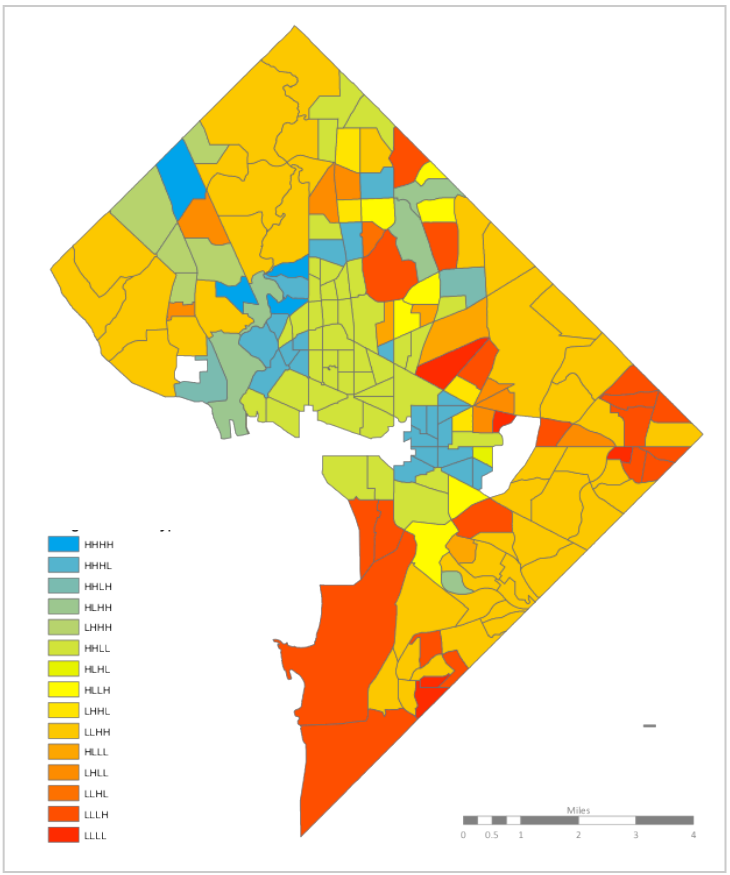
Chart 5: Neighborhood Type Percentages



While there are 16 possible different combinations, four neighborhood types comprise 74% of all census tracts in the city. The four most common neighborhood types were HHHL, HHLL, LLHH and LLLH. The two that are high in built amenities are concentrated in the center of the city while the two that are high in natural amenities are along the northwest and southeast edges. An interesting observation that becomes visible when the neighborhood types are mapped is that census tracts immediately adjacent to one of the four main neighborhood types are often more similar to the type that it abuts

than to the other three common groups. In this way, variation among census tracts follow a gradient pattern from center to periphery (or vice versa), appearing as though there were spillover effects from a common neighborhood type to the nearest adjacent area.

Map 5: Neighborhood Types



It is important to conceptualize neighborhoods in this way as a first step in determining sustainability actions that will have the widest impacts because they can be replicated at scale throughout many similar parts of the city. Conversely, understanding which areas of the city are unique will also inform the need for nuanced approaches to address issues specific to that neighborhood. The table below details how the median scores for each variable differ among the four most common neighborhood types. These differences are indicators of which sustainability goals ought to be prioritized for each neighborhood.

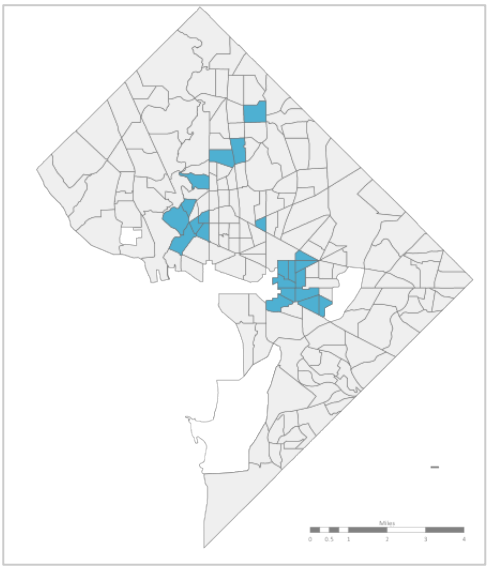
Table 4: Median Scores of Common Neighborhood Types

Type	Transit	Walkability	Tree Canopy	Permeability
DC All	67.3	68.9	12.4%	50.8%
HHHL	80.3	89.1	14.8%	32.9%
HHLL	85.6	90.4	9.4%	31.7%
LLHH	58.5	48.7	23.7%	66.2%
LLLH	58.9	53.6	9.1%	56.0%

HHHL: Urban Neighborhoods

Capitol Hill, Dupont Circle, West End, Petworth

Map 6: Urban Neighborhoods

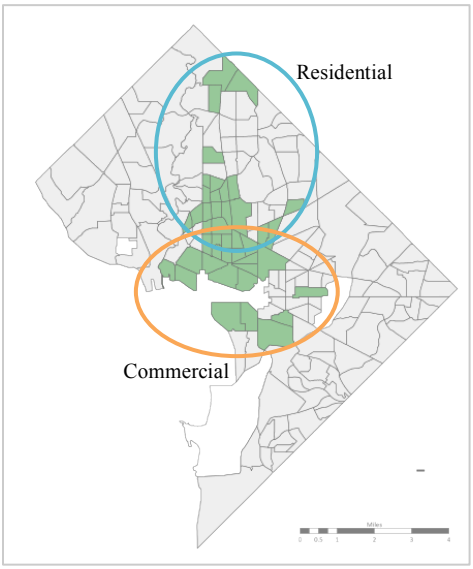


These census tracts have high scores for all variables except permeability. The neighborhoods lie just outside the central business district, but are still within easy walking distance to commercial concentrations. There is a high degree of mixed uses that are contained within these areas. While residential property is the majority land use type, there is still a large presence of neighborhood serving retail, small office space and public facilities such as parks. This combination of uses present at moderate densities creates neighborhoods where residents have easy access to built and natural amenities.

HHLL: Urban Core

Downtown CBD and immediately adjacent neighborhoods, Takoma Park

Map 7: Urban Core

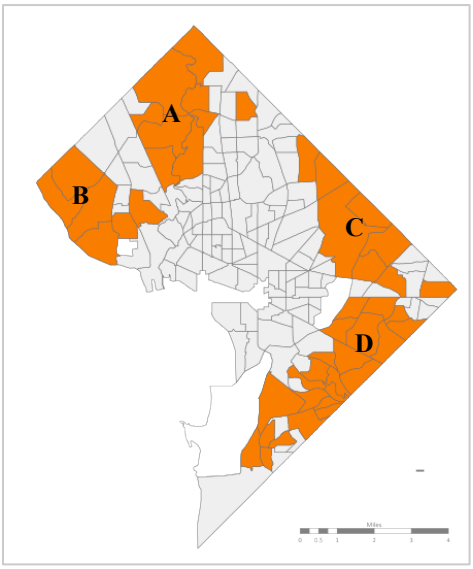


These census tracts have high scores for built environment variables and low scores for natural environment variables. There is a distinction between residential and commercial areas that both fit into this neighborhood type. The commercial and residential components are similar in that they are both highly dense and soon to be fully built out. The key difference, however, is the population that will be impacted by any sustainability actions. The commercial section is dominated by offices and institutional property owners while the residential section has a broader mix, including permanent and transient residents housed in a plethora of property types, retail storefronts as well as offices, institutional and cultural centers. These eclectic stakeholders require a nuanced approach to understand, coordinate and satisfy their varied interests.

LLHH: Suburban Neighborhoods

Upper NW, Palisades/Foxhall, Arboretum and Anacostia River, Southeast

Map 8: Suburban Neighborhoods

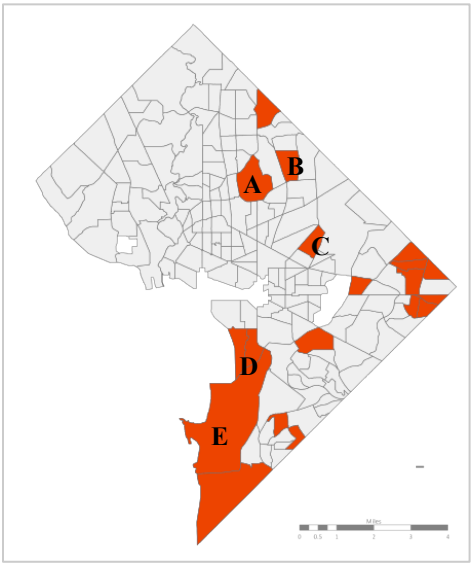


These census tracts typify areas of low-density development that is either residential- or park-oriented. Areas B and D are primarily single family residential neighborhoods. In addition to single-family development, area A contains Rock Creek Park while area C contains the National Arboretum and the Anacostia River Park. The description as a "suburban" refers to the qualities that these neighborhoods share with locations that are commonly thought of as the suburbs, such as single family detached homes and a heavy reliance of vehicle travel. Unlike some suburban tract development, the residences in this neighborhood have remained sensitive to the existing natural environment. There is still abundant tree cover and vegetation. The absence of suburban-style retail also means that big box stores and their expansive parking lots do not negatively affect the environment here.

LLLH: Special Purpose

Bowling AFB, St. Elizabeth's, U.S. Soldiers and Airmens Home, Lincoln Heights

Map 9: Special Purpose



The fourth most common neighborhood type is designated "special purpose" due to the unique characteristics of its census tracts. This category includes the U.S. Soldiers and Airmens Home (A), Providence Hospital (B), Mt. Olivet Cemetary (C), St. Elizabeth's (D) and Bowling Airforce Base (E). These locations contain unique destinations that visitors travel to for a specific reason, so their phsycial environment is relatively less important for attracting and retaining users. The census tracts not labeled with a letter are of concern. These parts of the city do not contain a special purpose use; they are residential areas that have low access to amenities.

Existing People

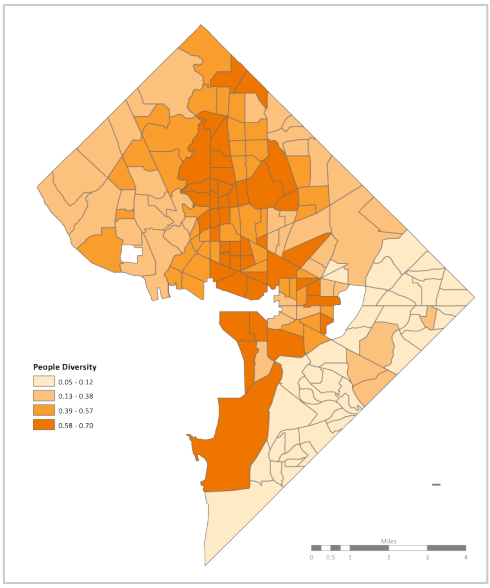
Like the existing environment, the social and economic characteristics of people in different census tracts cover a wide range of values. Table 5 shows the wide ranges that exist for each variable.

Table 5: Social and Economic Variable Descriptive Statistics

Variable	Median	Mean	Min	Max	St. Dev
Racial Diversity	0.382	0.365	0.045	0.696	0.209
Violent Crime	10.7	12.1	0.0	40.8	8.3
Median Income	$52,465	$63,130	$11,375	$213,889	$35,272
Unemployment	9.6%	11.0%	0.0%	36.8%	8.0%

Racial Diversity

Map 10: Racial Diversity



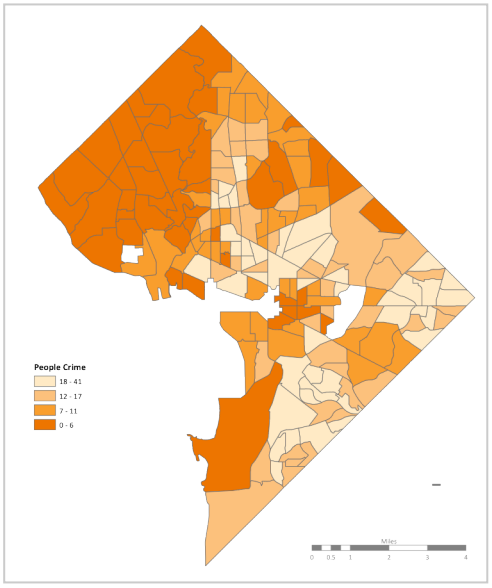
Washington DC has a median diversity score of .382, which means that there is a 38.2% probability of selected two people at random from the city's population who are not of the same race. The median reflects an abnormal distribution that is weighted at the bottom and top of the value spectrum. This distribution plays out spatially. Diverse census tracts are clustered along the central north-south axis. The bottom 25-50% of diverse census tracts lie immediately adjacent to this diverse core while the bottom quartile is restricted to Southeast. When you look racial percentages for these four quartiles, the bottom quartile is predominantly black, the eastern portion of the 25-50% quartile is mainly black with some Hispanic and white residents, the western portion of the 25-50% quartile is mainly white with some Hispanic and black residents while the central axis is highly mixed. The diversity pattern for above median census tracts is similar to the distribution of high transit and walkability scores, particularly through the central core.

Crime

The median violent crime rate in 2011 was 10.7 per 1,000 residents. As with racial diversity, there were evident patterns of low crime versus high crime concentrations.

Upper Northwest is an area of extremely low crime. Slightly more than 70% of census tracts in the bottom quartile for total crimes committed were in this part of the city. Generally, crime increased as you moved from northwest to southeast census tracts. However, this pattern is more like a patchwork than a smooth gradient. A number of census tracts identified as a "special purpose" neighborhood type, such as the U.S. Soldiers and Airmens Home, Bowling Airforce Base and St. Elizabeth's campus, are among the safest in the city. This is likely due to their unique nature. The quartile of highest crime rates is interesting due to the fact that these census tracts occupy a number of different environments. There are high crime areas within the urban core as well as throughout the suburban residential neighborhoods. It would be interesting to see how the census tracts in the bottom quarter compared to one another after delineating what types of violent crime were committed.

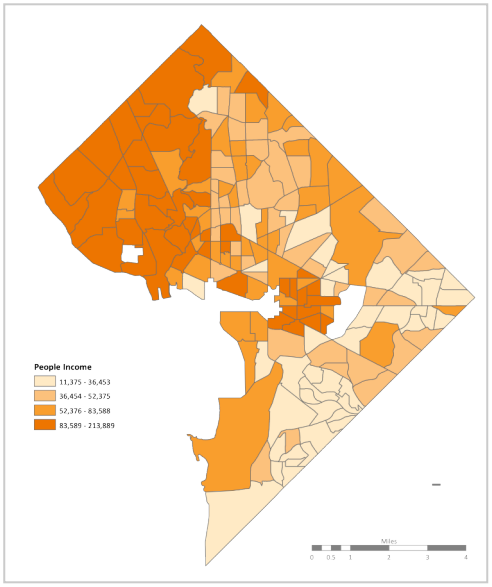
Map 11: Violent Crime



Median Household Income

Household median incomes across the city range from $11,375 to $213,889 with a median value at $52,465. In this skewed distribution, the bottom 75% of census tracts contains a median household income of $84,033. Household income shares a similar spatial pattern to crime and unemployment. Nearly all the top quartile scoring census tracts are in Upper Northwest and Capitol Hill. Moving from northwest to southeast, median household incomes display a familiar decreasing pattern, with the exception of a cluster of above median census tracts near the National Arboretum and points immediately north. Bowling Airforce Base and Fort Stanton Park again are outliers compared to other census tracts in Southeast in that they are above the citywide median for household income while the surrounding areas are in the bottom quartiles.

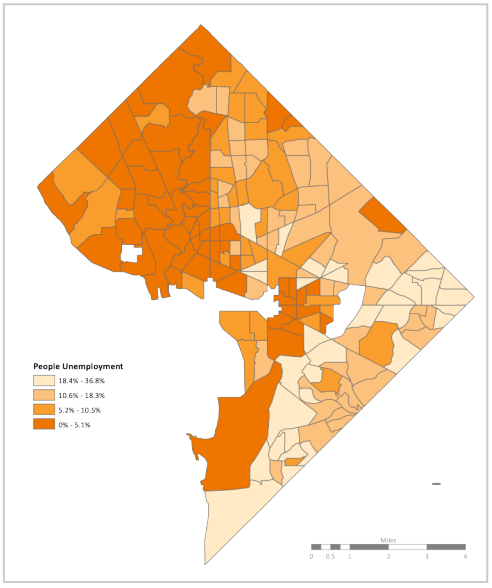
Map 12: Median Household Income



Unemployment

Overall, the city has a median unemployment rate of 9.6% across its census tracts with the bottom quartile at 4% or less. The top quartile, however, has an unemployment rate at or above 18%, with 36.8% unemployment being the maximum. The geographic unemployment distribution is similar to income and crime variables, with the best performing census tracts in the northwest section of the city and poorer performing areas towards the southeast. Areas with the lowest unemployment rate are predominantly in Upper Northwest and Capitol Hill. With the exception of Bowling Air Force Base and two other census tracts near Fort Dupont and Fort Stanton parks, unemployment rates in Southeast are above median throughout.

Map 13: Unemployment



Relationship between people and environment

Identifying locations that can serve as a model for what a sustainable neighborhood looks like is important for the city as it crafts future action. Neighborhoods that display high quality environmental characteristics as well as support social and economic objectives, such as inclusive and safe communities, can be valuable resource for understanding how these variables interact to achieve citywide goals. By looking at which physical, social and economic variables interact most greatly, as well as where that interaction occurs, we can begin to indentify neighborhood role models, areas in greatest need and opportunities for widespread impact.

Variable Correlation

The information presented thus far describes in great detail the physical environment and characteristics of people living across Washington DC. What this study has not yet discussed is how these worlds interact and relate to one another.

The built environment variables were positively correlated with diversity, crime and income and negatively correlated with unemployment. While these variables had a strong relationship to diversity and unemployment, the association with crime and income was relatively weak. The natural environment variables were both negatively associated with diversity and crime, however tree canopy coverage and income shared a positive

relationship while permeability and income were negative. Unemployment was also split, except in this instance tree canopy was negatively associated and permeability was positively associated.

Table 6: Correlation between Environment and People Variables

	Transit	Walkability	Tree Canopy	Permeability
Diversity	0.560	0.580	-0.248	-0.505
Crime	0.151	0.082	-0.250	-0.233
Income	0.075	0.207	0.231	-0.039
Unemployment	-0.294	-0.366	-0.099	0.214

With the exception of the permeability correlation to diversity, the natural environment R-values were less significantly correlated to the socioeconomic variables than the built environment R-values. Although the correlation magnitude was lower, a number of trends are visible in the data. A brief analysis of the median scores for the social and economic variable by the physical variable's quartile ranges offers intriguing evidence about the relationship. For tree canopy, the median values of diversity, crime and unemployment all decline as the coverage percentage moves from the first to the fourth quartile. Similar trends are evident across permeability quartiles. Median diversity and income values declined across the quartiles and unemployment increased. Due to the low overall correlation among natural environment and the socioeconomic variables, the remainder of this analysis does not discuss the impact of these elements for Sustainable DC. The trends expressed in the data are of interest for future study and a more detailed overview of the results for all four environmental variables is available in Appendix B.

The variables with the greatest correlation were between diversity, transit and walkability. Both built environment variables showed a strong positive correlation to diversity, with R-values of 0.56 and 0.58 respectively, and a less strong but still evident negative correlation with unemployment, with R-values of -.0294 and -0.366. Living in close proximity to transit and walkable amenities is something that people choose to do for various reasons. This relationship to diversity seems to indicate the ability of transit-oriented and walkable neighborhoods to offer an environment that attracts and supports a wide variety of people. Some cannot afford a vehicle and thus rely solely on transit or walking for daily mobility. Others choose to live a car free lifestyle for personal reasons. Regardless of the motivations that influence where a person lives, neighborhoods that provide access to transit and walkable amenities appear to support a greater level of diversity.

Neighborhoods that have increased access to transit and walkable amenities also show a negative correlation with unemployment. While this study does not attempt to explain

causation, this relationship is interesting because it could be used to argue for the positive indirect economic benefits of transit-oriented and dense development. In respect to diversity, what this research does not show is how an individual's race and personal income correlate to their choice to live near transit-oriented and walkable neighborhoods. It also does not distinguish between the quality of transit modes present or walkable amenities. Future research would do well to further examine the relationships hinted at in this study.

Permeability also has a strong negative correlation with diversity, with an R-value of -0.505. This is unsurprising considering that transit and walkability had a large negative correlation to permeability. Across the city, permeability and walkability were essentially inverted in terms of census tracts that were above or below the variables' median. What the diversity/permeability correlation speaks to most is density, which is also closely associated with transit and walkability. A control not employed in this study, with exception for crimes, was to adjust for density before correlation. The relationship of density to each of these variables is of great import for urban sustainability and development.

As shown above, neighborhoods with increased access to transit and walkable amenities correlate with greater diversity and reduced unemployment. These variables emphasize the four greatest points of correlation between the physical environment and socioeconomic characteristics and will be examined in greater detail below. Permeability also had a strong correlation to diversity, but since it is so closely related to walkability and transit, the results will mirror the other variables, albeit inversely.

Transit

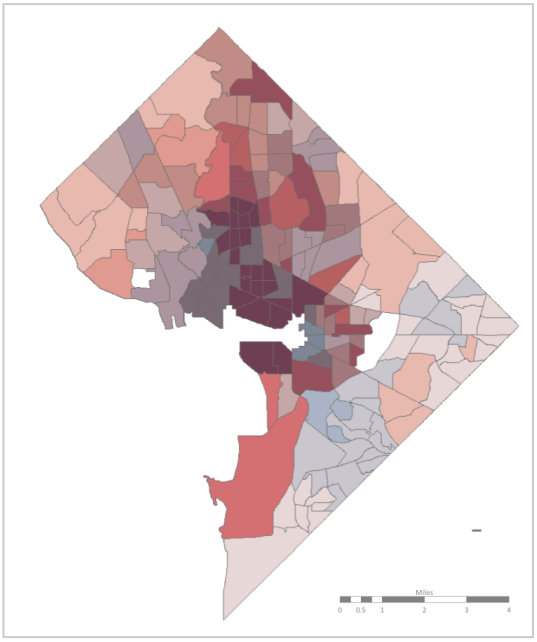
The relationship between transit, diversity and unemployment is evident along all points on the spectrum. The median diversity score of census tracts in each transit quartile doubles from the first to second quartile and again from the second to third. There is still an increase from the third to the fourth, although not as great as between the previous quartiles. For unemployment, the decline from the first to second quartile is small, however between the second, third and fourth the median rate drops by 4-5% each time. These results significantly show that as transit access increases, diversity and employment likewise grow.

Table 7: Transit Quartile Medians

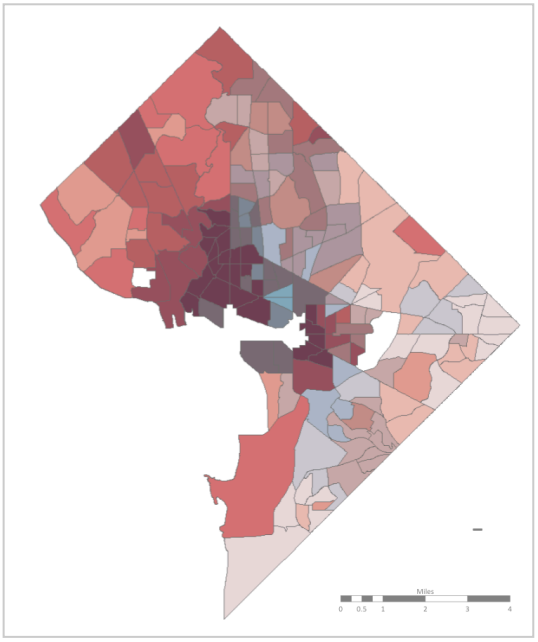
Median Values	Q1	Q2	Q3	Q4
Diversity	0.12	0.25	0.48	0.58
Unemployment	14.0%	13.5%	9.8%	4.9%

The maps below show an overlap of transit with diversity and transit with unemployment. Blue represents transit, red is for diversity or unemployment and purple indicates overlap of similar scores for both variables. Lighter hues are areas of below median value while deeper hues are above median value.

Map 14: Transit and Diversity



Map 15: Transit and Unemployment



For both diversity and unemployment, the high scoring census tracts are clustered near the center of the city. These clusters generally fall within the urban core and urban neighborhood types identified earlier. The location of the diversity clusters relate closely to well-recognized city neighborhoods, including Columbia Heights, Logan Circle/Shaw, Chinatown and NoMa. Unemployment is also matches existing neighborhoods such as Mount Vernon, Dupont Circle, Kalorama, West End and Capitol Hill.

There is a visible downward gradient that radiates outward from the high scoring clusters. Immediately adjacent census tracts are still dark in color, meaning they are better than median. The further away from the high scoring tracts that one moves, the lower the scores become for at least one if not both variables. While all perimeter census tracts are lower than the central clusters, Northwest fairs far better than Southeast. This reflection the general trend for all variables studied in this analysis.

Walkability

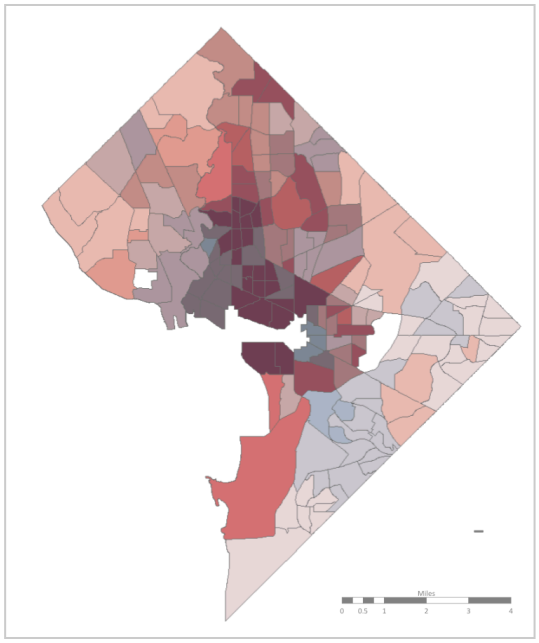
The relationship of walkability to diversity and unemployment is analogous to transit. The median diversity score increases substantially through each quartile. Unemployment likewise declines at a mostly linear rate, from 14.4% at its highest to 4.9% at its lowest.

Table 8: Walkability Quartile Medians

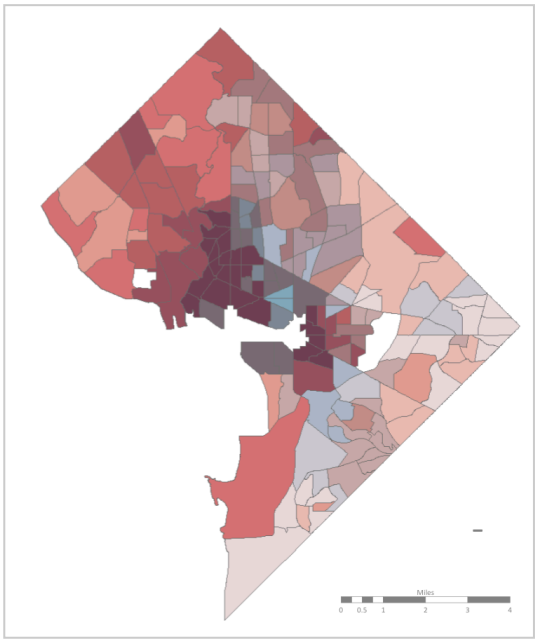
Median Values	Q1	Q2	Q3	Q4
Diversity	0.11	0.23	0.42	0.58
Unemployment	14.4%	13.8%	7.7%	4.9%

Spatially, the census tracts with better than median values are located almost exactly in the same clusters as for transit. A similar gradient pattern is evident as well. Of note in walkability/unemployment map is the prevalence of blue tinted census tract in close proximity to the clusters, indicating areas where unemployment is above median but the neighborhood is still walkable. This observation brings up intriguing questions about the quality of the walkable amenities and role walkability plays in stimulating job creation.

Map 16: Walkability and Diversity



Map 17: Walkability and Unemployment



Neighborhood Types and Socioeconomic Characteristics

In addition to the correlation patterns visible between people and environment variables across all census tracts in the city, distinct trends are also discernable within the

neighborhood types identified previously. Table six below details the median values for the four socioeconomic variables in the four most common neighborhood types and the city as a whole.The median scores for three of the four variables vary sharply depending on whether the physical environment of a neighborhood has primarily high or low scores. Median scores for all neighborhood types by socioeconomic variable is provided in Appendix C.

The most striking differences are between the HHHL and LLLH neighborhood types. The HHHL census tracts compared to the city median scores are slightly more diverse, experience less crime, have substantially higher household incomes and enjoy low unemployment rates. The LLLH census tracts, in contrast, display opposite characteristics for all variables; diversity and household income are low while crime and unemployment rates are high. The pattern is comparable between the HHLL and LLHH neighborhoods, with the exception of crime. Diversity shows a greater divergence but household income and unemployment are closer, with a $15,000 income advantage and 6% reduction in unemployment for HHLL over LLHH.

Table 9: Median Scores for People Variables by Neighborhood Types

Type	Diversity	Crime	Income	Unemployment
DC All	0.382	10.7	52,465	9.6%
HHHL	0.405	7.7	93,258	3.3%
HHLL	0.588	13.3	56,736	7.7%
LLHH	0.114	11.8	41,541	13.7%
LLLH	0.107	14.2	37,441	19.7%

This data eludes to the ways in which an amenity-rich or amenity-poor neighborhood supports and attracts different people and their attendant lifestyles. The social and economic scores of amenity-poor areas, depicted by the LLLH designation here, indicate a lower quality of life for residents, particularly in terms of reduced household incomes and elevated unemployment levels. On the other hand, amenity-rich neighborhoods appear to support a high quality of life. As with the rest of this research, correlation does not imply causation. But it does bring to light intriguing questions about why these distinctions occur and what should be done about them.

V. Recommendations

The challenges faced by the city as it moves to implement Sustainable DC are real, but the potential to improve the quality of life for city residents is also great. A striking result of the analysis was the correlation between neighborhood types that contained a majority of high or low scores and the median values for socioeconomic variables within those neighborhoods. The opposite scores indicate a relationship between environmental amenities and the quality of a resident's life. This is particularly interesting when looking at neighborhoods that scored high for three or more environmental variables. These neighborhoods include Dupont Circle, West End, Kalorama, Mount Pleasant, Petworth and Capitol Hill. With the exception of Petworth, these neighborhoods are commonly known to be concentrated with affluent, professional households and are expensive places to rent or own real estate.

While the study did not specifically address real estate, the results indicate an association between high quality environmental locations and higher real estate values. This connection should be addressed with caution. As the city implements sustainability initiatives that seek to improve the built and natural environments, it may succeed in making a neighborhood more livable but at the same time inadvertently stimulate price increases that displace current residents. The fact that the neighborhoods that contain high environmental values are nearly all populated by above-average wealth households is a potential harbinger of such unintended results. Taking into account these types of consequences will be essential so that sustainability initiative can act as a rising tide for all residents and not only benefit a select few.

Keeping this gentrification bias in mind, one of the most important factors the planning team must account for is that the city's neighborhoods are as unique and varied as the people who live there. For that reason, employing cookie-cutter solutions will fail to serve the diverse needs of city residents. As this study found, even when two disparate neighborhoods have a similar environment, the people living in those areas can differ substantially. Planners need to understand how to tailor their message to different audiences and understand that residents have different needs to address and resources to deploy for achieving similar sustainability goals. The city should take a flexible approach and partner with local residents and community groups that already have their finger on their neighborhood's pulse. This will invest local groups in the work and improve the likelihood of success. Community participation was a major component throughout the planning phase for Sustainable DC. Building on this collaborative effort will be paramount to fully achieving the initiative's ambitious goals.

Clustering patterns were visible for all variables (to differing degrees), indicating that, both for people and the environment, the characteristics of one census tract are most

similar to other adjacent census tracts. Following this logic, planners would do well to invest in areas where the surrounding neighborhoods have existing assets that can complement an improvement. This technique often leads to a synergistic relationship between existing and new assets and induces elements from the higher quality environment to spill over into the adjacent area. A targeted approach like this would build off the existing physical, social and/or human capital that exists nearby to induce positive results for the project. Similar to the spillover approach, targeting investment into a neighborhood that has existing amenities and is near, but not quite at, the city's median value can tip the neighborhood toward a higher quality environment. Both spillover and tipping point strategies offer a substantial "bang for your buck" in terms of implementation effort and potential to leverage private support that may be interested but were not yet ready to invest without the city showing its commitment first.

Of the four environment variables, walkability had the highest correlation to social and economic characteristics, particularly diversity and unemployment. Because of this, focusing on creating walkable environments is poised to have the greatest impact for improving the quality of the city's neighborhoods. Increasing access to high quality resident-serving amenities, such as public facilities and retail, is a strategy for tackling sustainability goals while simultaneously addressing equity issues for disadvantaged neighborhoods. A limitation of this study is that WalkScore does not account for amenity quality, only that a store or restaurant or park exists. Taking an inventory of the quality of the amenities in location with high WalkScores would be useful for understanding locations that have the existing market demand to support such activity but could benefit from improvements to urban design.

As stated earlier, this study was limited in scope and was not meant to provide definitive, scientific answers. What it sought to do was paint a picture of the quality of life that District's residents can access in their immediate neighborhoods. The city and other interested parties can use the trends and relationships identified here as a guide for future research. Even with this study's limitations, it highlights the importance of measuring results at ground level. As shown by the analysis, physical, social and economic conditions can vary drastically block by block. Without measuring the results at a fine level, it will be easy to miss important details about where and why actions succeed or fail. Also of import is the interrelated nature of city's seven remaining sustainability goals. For example, increasing public tree planting will help reach the 40% canopy goals while simultaneously reducing energy use since shaded areas require less artificially cooling. Understanding the indirect impact that a strategy will have on achieving the other goals is essential to optimize resources and maximize results.

Finally, although the goals in Sustainable DC are ambitious and set a high bar for success, the city can't let "the perfect" be the enemy of "the good". There are still many unknowns when it comes to best practices, not to mention new energy efficient

technology and design standards that seem to emerge daily. As long as the city puts forth a dedicated effort to reach its chosen objectives, any improvement that is achieved will be meaningful, regardless of the precise numbers hit. This is precisely the argument for assessing progress regularly, so the disappointment of not reaching a goal is replaced by the realization of how far you've actually come. That is the hallmark of a progressive society. Whatever outcomes emerge from Sustainable DC, the projects implemented in the coming years will supply invaluable new knowledge that will further our ability to deliver high quality environments to urban populations. That is one goal planners should be confident the initiative can achieve.

Appendices

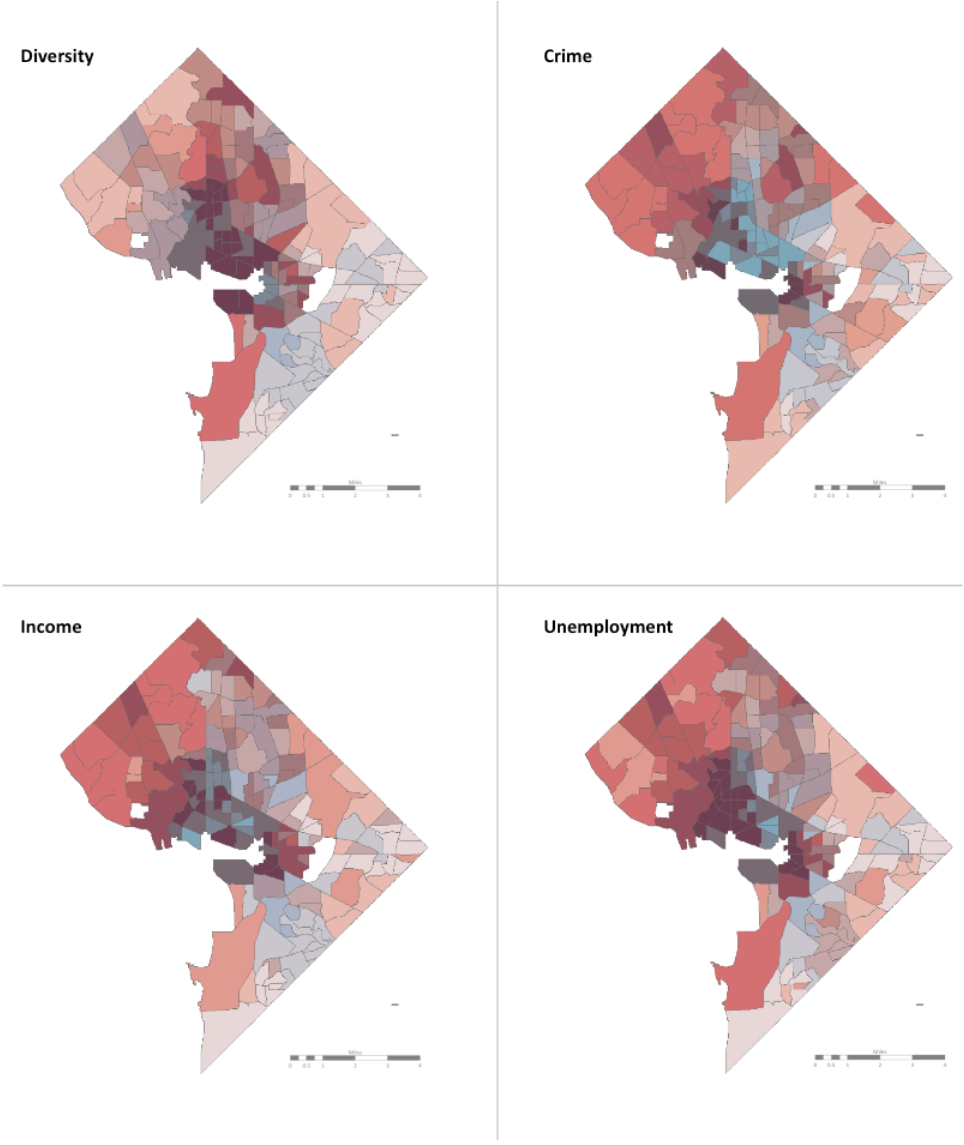
Appendix A: Neighborhood Types

Neighborhood Type	Census Tract Count	Census Tract Percent	Population Count	Population Percent
HHHH	4	2.3%	17,675	3.0%
HHHL	22	12.5%	72,316	12.2%
HHLH	2	1.1%	8,568	1.4%
HLHH	5	2.8%	20,416	3.4%
LHHH	5	2.8%	23,115	3.9%
HHLL	43	24.4%	149,030	25.1%
HLHL	1	0.6%	1,949	0.3%
HLLH	7	4.0%	17,399	2.9%
LHHL	4	2.3%	14,361	2.4%
LHLH	0	0.0%	0	0.0%
LLHH	46	26.1%	160,308	27.0%
LHLL	8	4.5%	30,631	5.2%
HLLL	4	2.3%	12,307	2.1%
LLHL	1	0.6%	2,974	0.5%
LLLH	19	10.8%	51,890	8.7%
LLLL	5	2.8%	11,165	1.9%

Appendix B: Environment and People Variable Correlations

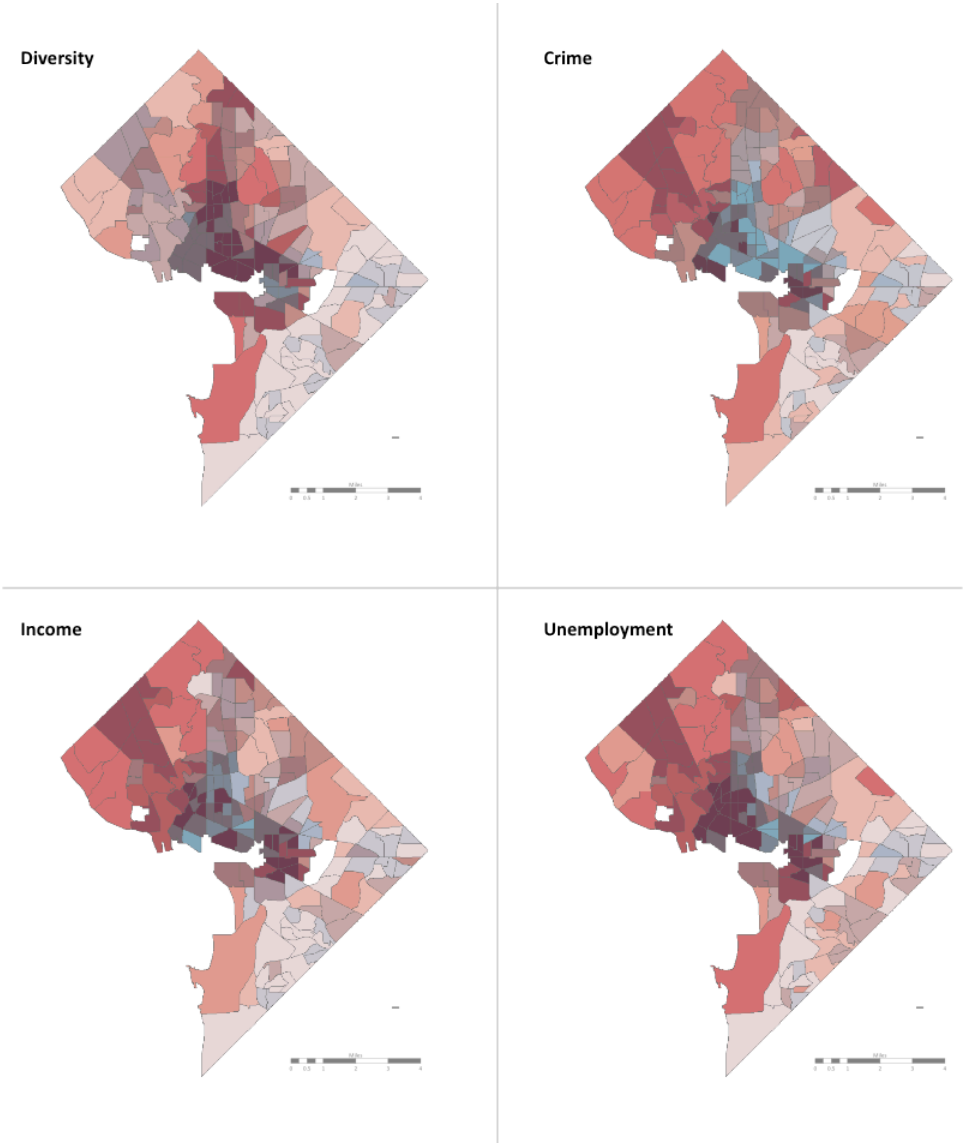
Transit Correlations

Median Value	Q1	Q2	Q3	Q4
Diversity	0.12	0.25	0.48	0.58
Crime	12.8	13.1	9.6	9.3
Income	41,675	42,019	58,952	72,820
Unemployment	14.0%	13.5%	9.8%	4.9%



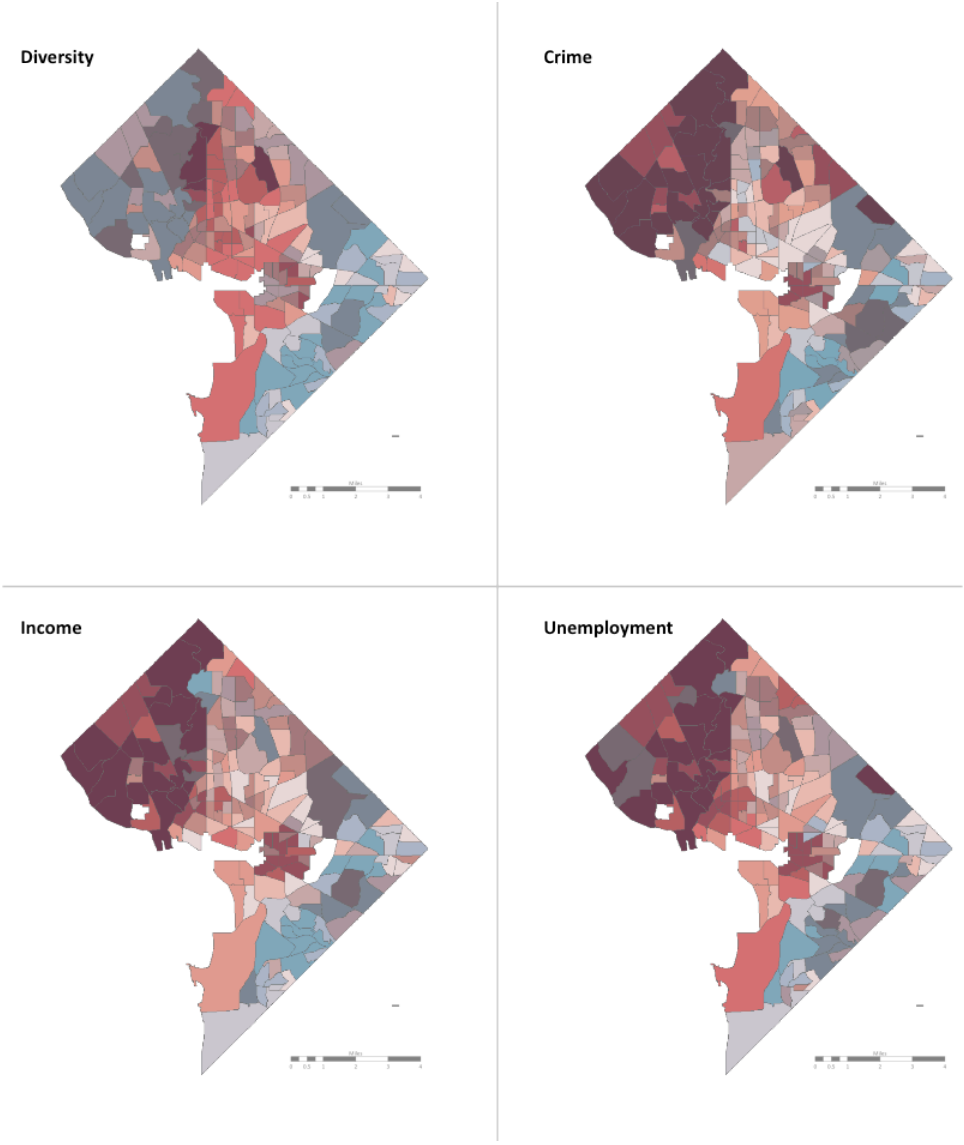
Walkability Correlations

Median Value	Q1	Q2	Q3	Q4
Diversity	0.11	0.23	0.42	0.58
Crime	11.6	14.5	8.2	10.5
Income	38,670	42,794	67,503	71,118
Unemployment	14.4%	13.8%	7.7%	4.9%



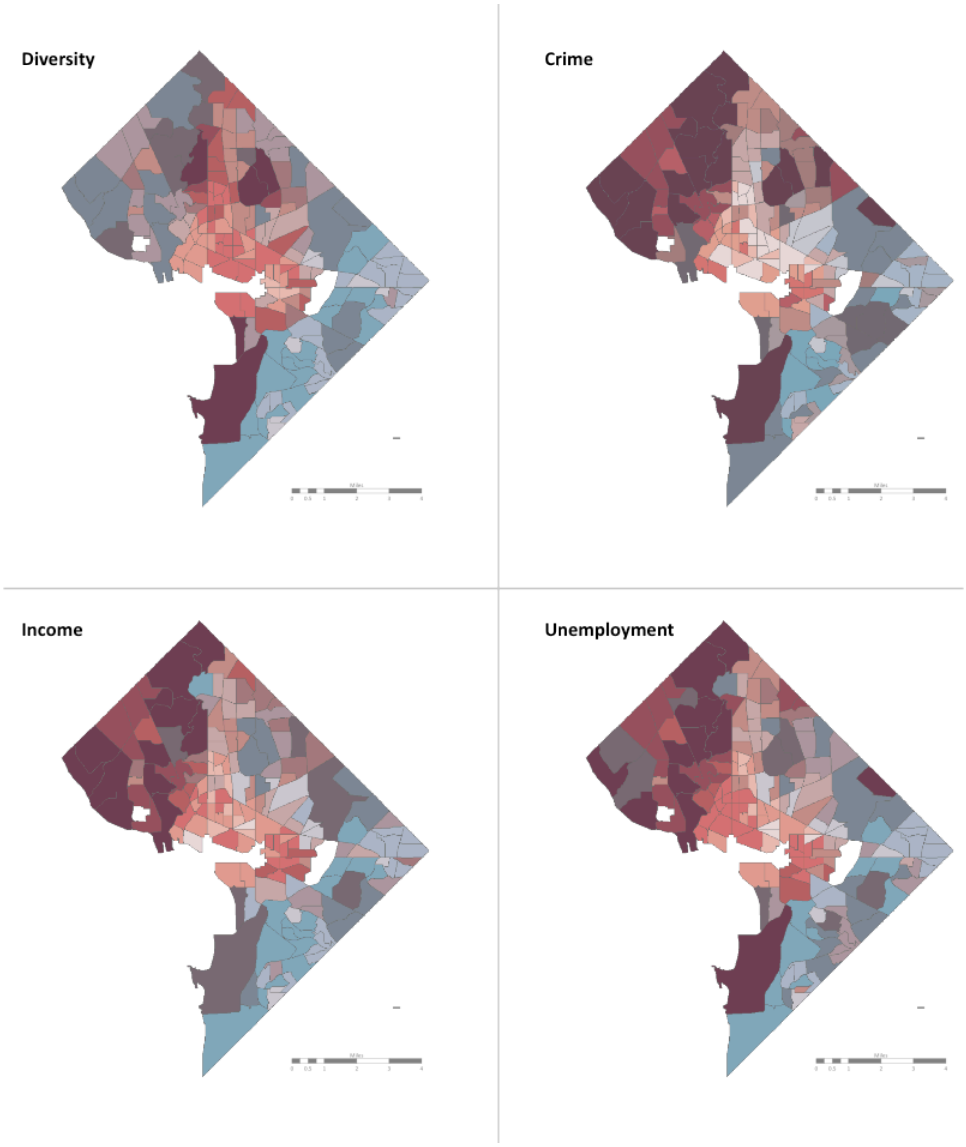
Tree Canopy Correlations

Median Value	Q1	Q2	Q3	Q4
Diversity	0.52	0.42	0.38	0.28
Crime	13.8	14.1	9.0	5.8
Income	42,880	52,964	78,802	56,985
Unemployment	11.3%	10.9%	8.7%	6.0%



Permeability Correlations

Median Value	Q1	Q2	Q3	Q4
Diversity	0.57	0.51	0.41	0.38
Crime	10.1	11.6	11.9	10.7
Income	75,433	61,653	55,634	52,465
Unemployment	4.9%	7.9%	8.9%	9.6%



Appendix C: Median Scores All Variables by Neighborhood Types

Type	Transit	Walk	Tree	Perm	Diversity	Crime	MedInc	Unempl
DC	67.3	68.9	12.4%	50.8%	0.382	10.7	52,465	9.6%
LLLL	60.2	65.0	11.4%	49.6%	0.101	19.2	34,269	11.4%
LLLH	58.9	53.6	9.1%	56.0%	0.107	14.2	37,441	19.7%
LLHL	66.3	68.5	13.6%	44.5%	0.457	9.4	61,500	13.8%
LHLL	63.5	78.0	11.3%	44.8%	0.333	16.0	40,145	15.2%
HLLL	71.5	65.8	8.4%	47.5%	0.243	14.4	32,179	13.6%
LLHH	58.5	48.7	23.7%	66.2%	0.114	11.8	41,541	13.7%
LHHL	65.8	81.1	13.6%	40.0%	0.457	11.2	59,307	9.9%
HHLL	85.6	90.4	9.4%	31.7%	0.588	13.3	56,736	7.7%
LHLH	NA	NA	NA	NA	NA	NA	NA	NA
HLHL	72.1	68.1	15.3%	40.9%	0.530	14.4	77,955	10.1%
HLLH	72.0	54.4	9.3%	60.1%	0.330	11.6	44,939	14.2%
LHHH	60.5	76.5	14.5%	55.7%	0.374	1.2	109,609	2.3%
HHHL	80.3	89.1	14.8%	32.9%	0.405	7.7	93,258	3.3%
HLHH	74.8	51.1	25.1%	63.4%	0.267	7.9	47,410	8.9%
HHLH	69.9	74.4	10.4%	56.3%	0.434	9.5	96,346	6.7%
HHHH	73.9	78.1	22.5%	54.0%	0.434	4.0	84,080	1.5%

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