2021

A Systematic Method for Measuring Gentrification Using Building Permits Data: A Washington D.C Case Study

Andey Fomil
West Virginia University, anfomil@mix.wvu.edu

2021

A Systematic Method for Measuring Gentrification Using Building Permits Data: A Washington D.C Case Study

Andey Fomil

A Systematic Method for Measuring Gentrification Using Building Permits Data: A Washington D.C Case Study

Andrey "Andrew" Fomil

Thesis submitted to the Eberly College of Arts and Sciences at West Virginia University

In partial fulfillment of the requirements for the degree of Master of Arts in Geography

Jamison Conley, Ph.D., Chair

Gregory Elmes, Ph.D.

Aaron Maxwell, Ph.D.

Department of Geography

Morgantown, West Virginia
2021

Keywords: GIS, Human Geography, Spatial Analysis, Demographics, Urban Studies

ABSTRACT

A Systematic Method for Measuring Gentrification Using Building Permits Data: A Washington D.C Case Study

Andrey Fomil

Gentrification can significantly alter the socioeconomic, demographic, and commercial aspects of a city. It is a complex process that transforms the characteristics of entire neighborhoods, modifying not only the observable physical aspects, but also the community structure. Traditional quantitative gentrification measurement approaches assess the process through analysis of Census demographic indicators coupled with field visit analysis of the physical built environment. This study proposes a new gentrification measuring approach that combines traditional Census indicators with a new indicator in the form of City Building Permits. Two GIS spatial analysis techniques are utilized to evaluate the effectiveness and accuracy of the proposed approach in assessing the distribution and intensity of fine scale spatial gentrification. The results of the spatial analyses are validated through an assessment of local media sources reporting on gentrification in the study area.

Table of Contents

List of Figures

List of Tables

"...Looka here people, listen to me,
Don't try to find no home in Washington, D.C.
Lord, it's a bourgeois town, it's a bourgeois town."
(Huddie "Leadbelly" Ledbetter, U.S. Blues Musician. "Bourgeois Blues", 1938).

1. Introduction

The shortage of affordable housing is one of the most significant and one of the most complex issues facing modern cities. Many urban centers are grappling with affordable housing scarcities, attempting to balance speculative investment against equitable development and capital public housing proposals (Reed, 2012; U.S Dept of Housing and Urban Development,2018; Zonta, 2020). To facilitate continued economic growth, and to attract and retain affluent demographic groups, city governments aim to create unique territorial combinations of tax breaks, building code regulations, capital improvement projects, and zoning laws (U.S Dept of Housing and Urban Development, 2018). The drive to attract and retain wealthier demographic groups can come at the expense of less prosperous local dwellers and may lead to the destruction of longstanding cultural locales and communities, create accessibility barriers for less affluent middle and lower income demographics, or sometimes result in native dwellers being priced out of their own neighborhoods (Tach, Pendal, and Derain, 2014; Zonta, 2020).

The scale and magnitude of uncontrolled urban transformation depends on a city's ability to accurately monitor, control, document, and report change. The capacity to transparently report and inform residents on current and future developments is critical to ensuring equitability for local lower and middle-income earners and can help mobilize agile community responses (U.S Dept of Housing and Urban Development, 2018). A city's ability to ensure compliance with development regulations must be thorough and across multiple indicators, maintaining housing accessibility and affordability, but without intimidating or deflecting potential investors (U.S Dept of Housing and Urban Development, 2018). Successfully managed growth allows a city to support revitalization and new development while still protecting the native established residents, safeguarding local culture and history, and maintaining a fair level of accessibility for various levels of income demographics.

1.1 Gentrification in Washington D.C

Huddie Ledbetter's 1938 song *Bourgeois Blues* continues to ring true for many parts of today's Washington D.C. Transcending the test of time, the ballad still accurately depicts the "bourgeois" character of many neighborhoods in the modern District of Columbia. Over the past decade, 2010-2020, the city has seen a dramatic increase in redevelopment, revitalization, real estate speculation, and especially gentrification. Rejuvenation of the built environment increases the city's livability appeal, increases the tax base, reshapes entire neighborhoods, and

complements the surging gentrification. A continuous influx of affluent residents continues to cultivate the District's image as a "bourgeois" town, creating shortages of affordable housing and displacing native residents (Reed, 2012; Plerhoples et al, 2015; Wogan, 2015).

Gentrification transforms the characteristics of entire neighborhoods, modifying not only the observable physical aspects, but also the traditional community structure. It can significantly alter the socioeconomic, demographic, and commercial aspects of a neighborhood. In the last 20 years, many large urban centers across the country have experienced massive redevelopment, commercialization, and gentrification (Maciag, 2015). The city of Washington D.C has been called a gentrification "hotbed" by numerous urban development scholars and institutions (Wyly and Hammel, 1999; Nesbitt, 2005; Kennedy and Leonard, 2011, Brookings Institute, 2015; Maciag, 2015**;** Green et al., 2017; U.S Dept of Housing and Urban Development, 2018; Shinault and Seltzer, 2019). The prevalence and magnitude of urban change in the District has garnered considerable local media coverage, as well as extensive discussions in local forums and blogs. A 2013 article in the Washington City Paper asked if there are any neighborhoods left in the District that are *not* gentrifying? (Wiener, 2013).

1.2 Assessing and Quantitatively Analyzing Gentrification

Assessing gentrification is a complex, multidisciplinary process, and a clear consensus on a systemic quantitative methodological approach to measuring gentrification and evaluating its intensity (or magnitude) is still being developed. Current research approaches to measuring gentrification employs a mix of multi-disciplinary analysis techniques. A more prevalent traditional approach is to combine statistical analysis of census data with a qualitative research method in the form of local resident interviews, photographic field surveys, and ethnographic or sociologic research.

With increased innovation in computer processing power, and with the growing accessibility to big open data, modern assessments of gentrification have benefited from the integration of advanced computational methodologies. Current forward-leaning studies have leveraged big open source data in the forms of social media applications such as Yelp and Twitter (Glaeser et al., 2018; Aike et al., 2019), while other tech savvy research has looked to employ Machine Learning (ML) in conjunction with Google Streetview images to help detect and identify built environmental change associated with gentrification (Ilic et al., 2019), or to create advanced demographic indicator models that use ML decision trees and random forests to detect ongoing gentrification and to forecast future growth (Reades et al., 2019). Geographic Information Systems (GIS) continue to be critical instruments in gentrification analysis. GIS is usually employed to produce powerful visualizations or as advanced spatial analytics tools, with significant study specific variations in the style, consistency, and degree of GIS application and utilization (Nesbitt, 2005; Papachristos et al., 2011; Fouch, 2011; Welch, 2013; Maantay & Maroko, 2018; Glaeser et al., 2018; Aike et al., 2019; Ilic et al., 2019; Reades et al., 2019).

1.3 Core Objective Research Question

This study proposes a consistent repeatable method for measuring gentrification and gentrification intensity on a large scale. The main objective of this study is to determine:

Does Building Permit data provide an accurate fine spatial resolution assessment of the distribution and intensity of gentrification in a large urban center?

To detect large scale spatial distributions of gentrification, and to measure their intensity, this study will aim to fuse GIS analysis of big data (Building Permits) with classic/traditional Census gentrification indicator approaches established by previous studies. Although previous studies have attempted to leverage building conditions and real estate data (Heidkamp and Lucas, 2006; Chapple, 2009; Levy, 2009; Aike, 2018), a focused analysis of Building Permits over an extended temporal period has rarely been attempted. To provide an independent confirmation of this new method, and to further assess its accuracy, an analysis of local media coverage of gentrification will be performed. A case study of Washington, D.C. will be used to evaluate the effectiveness of the new method, analyze if it can serve as a valuable addition to already existing measures, and to ascertain its repeatability and replication in other study areas.

To gain a greater understanding of gentrification this study will present and discuss gentrification's theoretical foundations in the literature review. The literature review will evaluate how gentrification was first recognized historically and defined within academic institutions, discuss how it is identified and detected, and review how GIS and other analysis techniques are employed to measure the spatial and geographic aspects of the phenomena.

Following the literature review, the case study section presents the study area, the city of Washington D.C. and concisely examines various conditions indicative of gentrification. The case study section includes an overview of the socioeconomic, demographic, and community changes occurring within the study area over the past decade, and briefly address why Washington D.C is an appropriate testing site for the new method.

The analysis and results sections that will follow, will focus on research approaches, data selection, and analysis methods and techniques. Data acquisition methods, data exploration, data processing, and selected GIS analysis techniques are covered in the analysis section, while the results section summarizes the results of the analysis, covering statistical and cartographic outputs, and presenting the results through figures.

The last two sections are the discussion and conclusion. The discussion section reviews analysis results, explores new insights gained, and assesses the accuracy of the new method through comparison with local media coverage. The conclusion reviews the success and utility of the new method and recommend enhancements and possible improvements for future work.

2. Literature Review

2.1 Historical Origins: Defining Gentrification

Previously, the way gentrification has been defined has varied across studies. Some studies have attempted to create their own definitions or interpretations, while others have referenced historical literature, but most are based on the foundations established by Ruth Glass (Glass, 1961). Rowland Atkinson (2000) describes how sociologist Ruth Glass coined the term gentrification to describe the redevelopment process she observed in 1960's London. Glass studied and recorded how working class groups were displaced from their neighborhoods and communities by "The Gentry" (wealthier middle and upper classes), a process that changed the built conditions and community characteristics of these neighborhoods as they became "Gentrified".

In the late 20th and early 21st centuries increased urban revitalization stimulated many inner-city neighborhoods to experience redevelopment and gentrification (Hartog, 1999; Krausmann et al., 2009). This increased and considerably rapid urban change has heightened interest in gentrification research within various academic disciplines. Geographers have taken notice of the spatial phenomena and have been keen to study it, with some of the discipline's most prominent scholars, such as David Ley and Neil Smith, conducting gentrification research (Schaffer and Smith, 1986; Ley, 2003; Smith and Williams, 2007; Ley and Teo, 2013).

Richard Schaffer and Neil Smith conducted extensive work on gentrification in Harlem in the 1980's. Schaffer and Smith defined gentrification as "the movement of middle class families into urban areas causing property values to increase and having the secondary effect of driving out poorer families" (Schaffer and Smith, 347).

Maureen Kennedy and Paul Leonard of the Brookings Institute mirrored Schaffer and Smith's definition, "we define gentrification as the process by which higher income households displace lower income residents of a neighborhood, changing the essential character and flavor of that neighborhood" (Kennedy and Leonard, 2001). Scholars define gentrification as a process of physical and social neighborhood metamorphosis. However, gentrification is not instantaneous, and is often signaled by or associated with specific demographic, socioeconomics, and environmental indicators.

2.2 Evolving Definitions and Conflicting Perceptions

The conceptualization of gentrification as a process emerged on the heels of the urban renewal and slum clearance programs implemented in the 1950s and 1960s. In the U.K. early gentrification systematically reorganized the lower income working class neighborhoods, such as east London, into more desirable higher income communities that improve the overall image of

the city, further attracting more affluent residents (Schaffer and Smith, 1986). Glass (1961) observed some of these reorganizations and neighborhood revitalizations, documenting her observations, and formalizing her personal accounts into the first pioneering example of gentrification research.

While most scholars perceive gentrification as a phenomenon that has negative social and community effects, there have been contrary opinions. Some scholars have perceived gentrification as a constructive and progressive force, focusing on its positive side effects and outcomes, and circumventing or downplaying some of the more drastic negative effects. Sternlieb and Hughes hailed gentrification as a triumph that can potentially bring higher property taxes and enhance the economic vigor and vitality of a city (Sternlieb and Hughes, 1979). Schaffer and Smith readily agreed with this assertion and expanded upon it by claiming that gentrification is lauded as the major hope for reversing economic and social decline dominating many inner-city neighborhoods (Schaffer and Smith, 1986).

Many contemporary gentrification studies have focused on evaluating the negative social fallouts of the process or how to responsibly manage gentrification. There have been a myriad of studies analyzing and investigating the adverse effects of gentrification such as displacement and community loss (Axel-Lute, 2002; Rose, 2002; Doan and Higgins, 2011; Bates, 2012; Zuk et al., 2015; Green et al., 2017; Shinault and Seltzer, 2019; Christafore & Leguizamon, 2019).

The goal of this study is not to evaluate the effects of gentrification or to redefine the phenomena. Instead this study aims to provide an improvement or an enhancement to methods of measurement, so that future gentrification scholars can leverage the methodologies and analytical processes presented in this study to conduct large scale spatial resolution gentrification analysis or to complement qualitative neighborhood focused research.

2.3 Geographic and Spatial Aspects of Gentrification

Rosenthal and Brueckner (2009) established gentrification as a one the of deep-seated forces that will substantially alter locational patterns of residential land-use within most U.S cities. They theorized that the nature of gentrification is cyclical, and operates in close conjunction with political climates, economic incentives, urban revitalization drives, and dwelling ages. As the inner city becomes increasingly redeveloped, it also becomes a more desirable living space for higher income earners accustomed to accessibility, newer housing, and modern amenities (Rosenthal and Brueckner, 2009). Proximity to the Central Business District (CBD), adjacency to cultural and historical locations, topographical amenities, and a renovated built-environment are the main factors attracting higher income residents to gentrifying areas (Rosenthal and Brueckner, 2009).

The spatial distributions of gentrified and gentrifying neighborhoods, and their tendency to emerge from within “poorer” urban areas are explored by Elvin Wyly and Daniel Hammel in

two different publications. In *Islands of Decay in Seas of Renewal* (1999), the authors delve into how gentrification changes a neighborhood both socially and physically, while placing emphasis on the heterogeneous nature of the process. In "Modeling the Context and Contingency of Gentrification", Wyly and Hammel (1998) explore the spatial aspects of gentrification and its effects on the socioeconomic composition of neighborhoods and communities. They observe similar patterns of change in different cities, leading them to conclude that often times modern gentrification signifies a new and distinct dimension of urban socio-spatial structure that displays similar characteristics and effects across different urban centers, with slight differences depending on context and geography, and local demographics.

2.4 Indicator measures of Gentrification

Gentrification studies have traditionally focused on analyzing changes in demographic variables as a means for measuring the process. At the core of most gentrification studies is a change assessment of gentrification associated Census variables such as race, education, and income (see Table 1 for details).

Assessing gentrification through Census data is an essential and valuable measuring approach. Nevertheless, gentrification studies have been intent on identifying additional indicators beyond the Census (or expanding the Census variables beyond demographics, with the inclusion of Census-based housing conditions). Scholars have become creative in their quests to find new variables, and new measuring methods. As research into gentrification progressed and intensified, studies looked to reinforce Census data with additional environmental dimensions (Braswell, 2018; Maantay and Maroko, 2018), commercial indicators (Glaeser et al., 2018), crime statistics (O'Sullivan, 2004; Papachristos et al., 2011), school data (Mann & Rogers, 2020), and with qualitative neighborhood focused survey methodologies (Green et al., 2017; Shinault & Seltzer, 2019). Modern gentrification research is eager to identify new indicator variables or explore supplementary ways to measure the process, with contemporary gentrification studies intent on complementing Census variables with non-Census-based indicators. Table 1 below provides an overview of more modern gentrification literature that focuses on introducing non-traditional indicators for gentrification measurement.

Table 1: Comparison of a Sample of Studies with New Approaches to Measuring Gentrification							
Study	Definition of gentrifying/gentrified	Unit/Scale of analysis/model	Stages/Index/Measure of Gentrification	Indicators	Methods	Accounts for Unique local characteristics?	Limitations
O'Sullivan (2005)	Census variables and reduction in crime.	Census Tract.	Post gentrification, and gentrification in progress.	U.S census data, housing data, crime.	Econometric model for competition of inner-city land and to changes in indicators.	Yes.	Scale, no attempt to use GIS to spatially analyze or visualize.
Nesbitt (2005)	Based on previous literature, personal study area knowledge, and local characteristics	Census Tract.	Ongoing and future gentrification.	U.S census data, housing data, amenities.	Used a weighted index to detect ongoing and future gentrification.	Yes.	Scale, sample size.
Gambrill (2007)	Changes in demographics and real estate prices.	Zip Codes, neighborhoods, census Block Groups, and individual locations.	Ongoing and new gentrification.	U.S census data, and Private sector real estate home price data.	GIS used for modeling and to correlate property price changes with socio-demographic changes.	Yes, but the study admits that variables could be optimized with local community dynamics.	Inconsistent Scale, choice of methodology.
Heidkamp and Lucas (2006)	Upgrades to residential buildings, new businesses, income comparison	Block Groups.	Study analyzes ongoing gentrification or gentrification in progress.	U.S census and field observations of physical environment.	Census Data analysis. Field surveys observations helped determined a categorical classification for gentrification based on level of physical and environmental upgrading.	Yes. Field Research was utilized to delineate unique neighborhood characteristics.	Scale, sample size.
Levy (2009)	Increase in housing market value, property tax changes.	One Neighborhood and a sample of residential properties in this neighborhood.	Gentrification in progress.	U.S Census data, age of residential building, market value change, higher property taxes	Utilized GIS for visualization of housing stock value and property tax changes.	Yes, accounted for residential property age and price in the study area.	Inconsistent scale, insufficient analysis, insufficient Census Indicators.
Chapple (2009)	Susceptibility to gentrification, susceptibility is defined by changes in Census Indicators.	County, Neighborhood, Tracts, and Block Groups.	A predictive gentrification index is created based on susceptibility (no, low, moderate, and high).	U.S census data. Housing stock quality, location, and price.	Regression determines selection and impact of variables on gentrification measurement.	Yes, accounts for unique characteristics of housing and transportation.	Inconsistent scale, not all data sources are specified.

Table 1(continued): Comparison of a Sample of Studies with New Approaches to Measuring Gentrification							
Study	Definition of gentrifying/gentrified	Unit/Scale of analysis/model	Stages/Index/Measure of Gentrification	Indicators	Methods	Accounts for Unique local characteristics?	Limitations
Gafvert (2011)	Median household change	Census Tracts.	Future/possible gentrification.	U.S Census data, city data, local housing experts surveys	Created weights for various indicators using surveys.	Yes, accounted for local characteristics through the survey.	A finer scale/ small study sample.
Papachristos et al. (2011)	Based on literature definitions and included new indicators, number of coffee shops, and crime rates.	Neighborhood Clusters comprised of 20-30 census tracts.	Post gentrification.	U.S Census data, coffee shops, crime (specifically violent crime).	Descriptive analysis of the spatial and temporal data combined with longitudinal Poisson modeling	Yes.	Scale.
Fouch (2012)	Changes in indicators and through field work in the form of site visits.	Block Groups	Future gentrification (Vulnerability)	U.S Census Data, housing/property data, amenities , build environment conditions site visit observations	A combination of statistical analysis of census variables, GIS suitability modeling, and qualitative field work.	Yes.	Scale.
Scott (2013)	Change in local housing market.	City Ward.	Past gentrification	U.S census data, Housing Authority data, home sales, home rental prices, and interviews.	Descriptive Statistics, policy analysis, and mixed methods approach with a focus on interviews.	Yes.	Scale, not a direct measure of gentrification.
Welch (2013)	Demographic indicators.	Census Tract, Raster Cell size of 100 feet	Future gentrification (Susceptibility).	U.S census data, City data, local amenities.	Created a weighted index to detect susceptibility. Attempted to account for finer scale by transition to raster units of measurement.	Yes. Accounted for unique characteristics during indicator and weights selection.	Scale inconsistencies.
Maantay & Maroko (2018)	Based on traditional literature.	Census Block groups.	Past and current gentrification.	U.S Census data, proximity to community Gardens in NYC, NY.	Hot Spot Cluster Analysis, Proximity Getis-Ord GI Statistics with distance thresholds were used to assess the proximity of gentrified/gentrifying Census Block Groups to community garden.	Yes.	Small selection of Census and demographic variables without accounting for housing conditions.

Table 1(continued): Comparison of a Sample of Studies with New Approaches to Measuring Gentrification							
Study	Definition of gentrifying/gentrified	Unit/Scale of analysis/model	Stages/Index/Measure of Gentrification	Indicators	Methods	Accounts for Unique local characteristics?	Limitations
Braswell (2018)	Based on traditional literature.	Census Tracts converted into one square kilometer grid squares.	Past and current gentrification.	U.S Census data, proximity to community Gardens in St. Louis, Mo.	Spatial interpolation to divide the City into one square kilometer grid squares. Intersection and overlay to determine proximity of a gentrifying grid (Census data) to a garden, spatial regression to determine relationship between a gentrification and presence of gardens.	Yes. Local data was sourced.	Selection of methodology (grid squares do not represent a real-world, functional neighborhood).
Glaeser et al. (2018)	Based on traditional literature.	ZIP Codes, Census Tracts, and Block Level (Streetscore is defined by another cited study). Streetscore is a computer generated measure of perceived safety.	Past and current/ongoing gentrification.	U.S Census data, and Yelp (social media platform) data.	Extensive Correlation analysis. Positive correlation between various businesses associated/preferred by educated higher income earners and Census demographics indicative of educated higher income earners.	Yes.	Inconsistent scale and level of geography. A higher application of GIS and mapping analysis is desired.
Aike et al. (2018)	Study specific definition of urban change based on local rent increases and increases in perceived desirability and livability.	Metropolitan Statical Areas (MSAs), study specific neighborhoods/tracts in Chicago, New York City, Los Angeles, Boston, and Portland.	Detecting recent/current and forecasting future change in rental prices for neighborhoods becoming more desirable	U.S Census data, and Twitter (social media platform) data.	Correlation between traditional Census Indicators of change (Housing Price and Income Change) and Spatial Tweeter Data including number of users, number of tweets, and number of user visits within a specific neighborhood (number of distinct days in one year a user was geolocated within the neighborhood).	Yes.	An excellent and innovative study.
Ilic et al. (2019)	Based on traditional literature.	Census Tracts, Individual Building Permits Data, and Google Street View data.	Past, current, and possibly forecast future gentrification.	Canadian Census data, Ottawa Building Permits, and Google Street View data.	Utilized deep Machine Learning and methodology established by Naik et al. (2014) to build and train a robust Siamese convolutional neural network (SCNN) model that automatically detects gentrification-like visual changes in temporal sequences of Google Street View. Validated model accuracy with Building Permits.	Yes.	No limitations. An excellent and innovative study.

Table 1(continued): Comparison of a Sample of Studies with New Approaches to Measuring Gentrification							
Study	Definition of gentrifying/gentrified	Unit/Scale of analysis/model	Stages/Index/Measure of Gentrification	Indicators	Methods	Accounts for Unique local characteristics?	Limitations
Mann and Bennet (2020)	Based on traditional literature.	Census Tracts, point locations of individuals schools.	Past and current gentrification.	Census Tracts, School Data and Statistics (Charter and Public Schools and demographics within those schools)	Utilized statistical analysis of Census indicators (race and income focused) to create gentrification indices. Employed a standard GIS analytics approach (intersects) to identify relationships between gentrifying areas and the implementation of charter schools within those areas. Analyzed school demographics within the different areas to further assess relationship.	Yes.	Well researched and deep analyzed study.
Barton et al.et al.(2020)	Based on traditional literature.	Census Tracts. Crime data points.	Past and current gentrification.	U.S Census data, LA Country Homicides data.	Created indices using factor analyses and a spatial weights matrix (combined Census data with crime data). Used Spatial autocorrelation to detect gentrification Hotspots .	Yes.	Scale, temporal period, focus on only one neighborhood.

All the studies presented in Table 1 utilize Census variables as indicators of gentrification, with favorable fluctuations in literature-defined Census variables signaling or supporting the claimed presence of the phenomena. Upon careful observation certain themes emerge in terms of selections for additional non-Census based indicators. Many of the studies that incorporate additional indicators either focus on physical improvements to the conditions of the housing stock and the appreciation of the housing market or look to specific social (crime and geographically relevant social media activity) or commercial variables (businesses that are usually associated with more affluent gentrifying demographics).

Studies that focused on housing characteristics/housing conditions include Gambrill (2007), Heidkamp and Lucas (2007), Levy (2009) , Chapple (2009), Fouch (2012), Scott (2013), and Ilic et al.(2018). These studies paid close attention to the value, age, condition, and the location of housing, and how gentrification has affected the housing market or the built environment. Both Gambrill and Levy utilized individual housing property data. Each study assessed changes in housing prices, with Levy focusing on property taxes while Gambrill deciding to leverage a pay-to-use private sector real estate database. The addition of individual properties adds a compelling large-scale aspect. The Heidkamp and Lucas study and the Fouch study validated the conditions of the housing stock through field surveys and site visits to gentrifying neighborhoods. The additions of field surveys provide a valuable independent confirmation of the built environmental conditions, create a series of photographic evidence detailing the physical changes, and help determine the stage and magnitude of gentrification. The Ilic et al.(2018) study focused on the built environment and analyzing physical change on an individual housing basis. This excellent study utilized cutting edge innovative machine learning technology to detect temporal changes in a large dataset of Google Street View images. The output results of the machine learning analysis were validated through comparison to Building Permits and census data. Two additional studies, Brasewell (2018) and Maantay & Maroko (2018), concentrated on a physical neighborhood characteristic or a physical amenities, selecting the establishment of new “green spaces”, specifically community gardens, as indicative of gentrification growth.

O’Sullivan (2004), Papachristos et al. (2011), and Barton et al.(2020) all focused on crime. These studies highlighted a decrease in crime, especially violent or property crimes, as signs of gentrification. All three used some type of regression or statistical analysis to link a temporal decrease in crime with gentrification (defined through Census indicators). In addition to crime, Papachristos also infused a distinct commercial element, the establishment of high-end coffee-shops, to highlight the growth of gentrification. Mann and Bennet (2020) chose to use educational indicators and focused on determining a relationship between gentrifying areas and an increase in the establishment of charter schools. They also analyzed the population compositions of charter and public schools to further explore the impact of gentrification on the demographic configurations within each school type.

Two studies that leveraged the power of social media platforms and big open data in complementing traditional Census indicators are Aike et al., (2018) and Glaeser et al., (2018). Aike et al. (2018) applies Twitter Geolocation data, examining the number of visits or tweets originating from within the boundaries of a specific neighborhood in conjunction with Census indicators to forecast which neighborhoods will experience future rent increases and desirability growth (and possible gentrification). Glaeser et al., (2018) harnesses the power of Yelp to explore the commercial aspects of urban change and gentrification. This study defines specific business types usually associated with more affluent demographics such as high-end eateries (vegetarian or "new-age"), coffee shops (franchise chains and boutiques), and yoga/fitness studios. After defining businesses usually associated with more affluent demographics, Glaeser et al. (2018) conducted a detailed correlation analysis between the number of newly opened high-end business and Census demographic variables indicative of gentrification.

The diversity of the indicator variables observed across different gentrification studies is also reflected in the varied applications of GIS techniques employed in spatially identifying, measuring, and assessing the process. The next section delves into the various techniques applied in spatially analyzing gentrification, with a focus on grouping together studies that utilize similar GIS assessment approaches.

2.5 Application of GIS in measuring Gentrification

In modern gentrification literature, GIS is usually employed to make comparisons, to detect changes and to forecast future susceptibility to change. The prevailing application of GIS frequently takes the form of temporal change analysis, comparing the socio-demographic and/or built environmental conditions before, during, and after gentrification. Other frequent applications of GIS focus on discovering or identifying "hotspots" or areas of high concentration, and different visualization techniques. Advances in GIS technology over the past decade have allowed gentrification studies to take advantage of the powerful spatial analysis and statistical capabilities of modern GIS software. A popular GIS methodology that was utilized by a few different studies from Table1 (Nesbitt, Chappele, Fouch, Welch, Maantay & Maroko , and Braswell) is weighted overlay analysis in the form of suitability modeling. Weighted overlay analysis allows users to execute suitability models and to create comprehensive gentrification indices. Fouch, Welch, and Brasewell converted the vector-based data to fishnet rasters to create a common unit, and to achieve a finer scale beyond the Census based administrative boundaries. These studies claimed a benefit from having a common raster based parametric unit of measurement that granted a more detailed effortless comparison across the entire study area. However, local neighborhood and natural physical characteristics could be lost or omitted during the conversion process, and a certain level of error could be also introduced.

For stellar examples of studies that look to escape the restrictions of administrative boundaries, the analyses presented by Ilic et al.(2018) and Aike et al. (2018) should be reviewed.

Both studies take advantage of expansive data to penetrate to the finest levels of scale and geography. Illic et al. (2018) used a combination of Google Street View imagery and Building Permits to identify gentrifying areas, while Aike et al. (2018) capitalized on the geolocation of twitter data to forecast future areas of rent increase. Both these studies exceeded the confines of administrative boundaries, with Illlic et al. (2018) stating that the results from their Machine Learning model are able to "show if two blocks gentrify around a boundary. This could aid in validating or decomposing the results of Census-based inferences about gentrification in urban areas" (p 16). Although both these studies successfully achieve a scale beyond administrative boundaries, they still refence Census Data as validation source or to reinforce the results of their new indicator assessments.

As more city and local governments align with initiatives to make big public data more readily available, more scholars should embrace the power of GIS in measuring and visualizing gentrification and in using it for studying various urban phenomena. With modern studies analyzing and measuring gentrification with innovative forward leading technologies and advanced GIS tools, consistent methodological approaches are emerging. This study hopes to contribute to new emerging methodological assessments of gentrification through the addition of a large-scale GIS-based measurement approached focused on Building Permits.

3. Case Study

Gentrification is not only transforming the neighborhoods and communities within Washington D.C, but it is fundamentally changing the face and image of certain segments of the city. Both the built physical environments and unique social community characteristics in the gentrifying areas are being altered. Employing a GIS centered approach in conjunction with big open public data, this study will aim to measure the distribution, extent, and intensity of gentrification in Washington D.C on a census Block Group level. The study will validate the accuracy of the new approach by through validation against reports of gentrification by local media sources.

Washington D.C is a city recognized for its historical landmarks, a diverse international population, exceptional entertainment, and a variety of cultural amenities. It also has a reputation as one of the most rapidly changing areas of the country (Plerhoples et al, 2015). A city with an eclectic and significant African American population, in the past decade the District has seen a large influx of white residents that are transforming its composition (Shinault and Seltzer, 2019). Table 2 below presents a summary of Census data capturing the change across key demographics. It must be noted that Census collection techniques, parameters, and data fields have been transformed over the years, and change analyses for certain indicators are not possible.

Table 2: Census Demographics for Washington DC 2010-2019

Demographic and Housing Indicators Change*	2010	2019	Percent/Dollar Change
Population estimates	**601,767**	**705,749**	**17.3%**
Age			
Persons under 5 years, percent	5.4	6.4	1.0
Persons under 18 years, percent	16.7	18.2	1.5
Persons 65 years and over, percent	11.4	12.4	1.0
Median Age	33.8	33.9	0.1
Race			
White alone, percent (a)	38.5	46.0	7.5
Black or African American alone, percent(a)	50.7	46.0	-4.7
Asian alone, percent(a)	3.5	4.5	1.0
Hispanic or Latino, percent(b)	9.1	11.3	2.2
Housing Characteristics			
Housing Units	296,719	322,793	26,074
Owner-occupied housing units' rate	37.7	41.8	4.1
Median value of owner-occupied housing units	$426,900	$568,400	$141,500 (33.5%)
Median selected monthly owner costs -with a mortgage, 2014-2018	N/A	$2,456	N/A
Median selected monthly owner costs -without a mortgage, 2014-2018	N/A	$672	N/A
Median gross rent	N/A	$1,487	N/A
Families and Living Arrangements			
Households	266,707	281,322	14,615
Persons per household	2.1	2.29	0.19
Income & Poverty			
Median Household income	$60,903	$82,604	$21,701 (35.63%)
Per capita income in past 12 months	$40,797	$53,321	$12,524 (30.70%)
Persons in Poverty, percent	17.2	13.5	-3.7
Education			
High school graduate or higher, percent of persons age 25+, percent	N/A	90.6	N/A
Bachelor's degree or higher, percent of persons age 25+ , percent	N/A	57.6	N/A

*Census data collection methodology and data collection fields/variables have changed from 2010 to 2019. Data sourced from: (2010) https://planning.dc.gov/page/population, (2010) https://planning.dc.gov/page/dc-census-2010-data , (2019)https://www.census.gov/quickfacts/DC. 2019 data estimates are from an early release of the 2019 5 Years ACS. (a)Includes persons reporting only one race. (b)Hispanics may identify within any race.

Between the 2010 Decennial Census and the most recent 2019 5-year ACS estimates, the population within the city of Washington D.C saw a sizable increase of 17.3%, clearly indicating that the city is a vigorously growing urban area (U.S Census Bureau, 2010; U.S Census Bureau,

2019). The demographic changes during the same time are significant. The percent of residents identifying as Black Only/African American alone decreased from 50% to 46%. In contrast the population of almost every other ethnic group increased, the percent of White residents increased from 38.5% to 46%, Hispanic residents increased by from 9.1% to 11.3%, and the percent of Asian residents increased by 1 percentage point.

The incomes of the residents have also seen a marked increase, with many new residents belonging to the middle and upper socioeconomic classes and bringing the city's overall median income up from $60,903 to $82,604. To accommodate the growing population, over 25,000 new housing units (HUs) have been added (either from new construction or from conversions). Residents are more likely to own their new homes, and the percent of owner-occupied dwellings increased by 4.1%. The median prices of homes also saw a significant increase of 33.15% during rising from $426,900 in 2010, to an estimated $568,400 in 2019, (U.S Census 2010, 2019; GCAAR, 2019). Since the 2010 Decennial Census collected education data according to different parameters, this study could not conduct a change assessment. Data for monthly owner costs was also unavailable, but based on the rising costs of housing, an assumption can be made that owner costs rose as well.

The gentrification that has taken place in Washington D.C has changed the character and nature of entire neighborhoods. The influx of higher income residents into the city has elevated or introduced new commercial enterprises (Green et al., 2017), but also resulted in a fairly rapid increase in living costs, housing prices, and a marked change to racial and ethnic demographics. As a result, the City has experienced a change to its image, improvements to the physical built environment within certain neighborhoods, and a metamorphosis of residents' perceptions of their own city (Green et al., 2017; Shinault and Seltzer, 2019). There have been some negative consequences such as displacement or a self-initiated exodus of those unable to afford the new costs of living. This type of displacement can sometimes be coupled with a loss in diversity and neighborhood culture, but exploring these effects is not within scope of this study (Leonnig, 2004; Murphy, 2004; Wilgoren and Salmon, 2004a; Wilgoren and Salmon 2004b; Sommer, 2012;Franke-Ruta, 2012).

4. Research Questions

1. Does detailed Building Permit data, provide an accurate large-scale assessment of the spatial distribution, and intensity of gentrification in Washington D.C?

2. Does the Washington D.C case study demonstrate that Building Permit data, combined with traditional Census modes of measurement, provide an enhancement in the measurement of gentrification?

5. Analysis

5.1 Data Overview

The data explored, acquired, and analyzed in this study originated from three primary sources, the U.S Census American Community Survey, the Washington D.C Department of Consumer and Regulatory Affairs (DCRA), and local newspaper sources and blogs. The American Community Survey data was obtained using the Census Factfinder, which streamlined data acquisition and allowed for the identification and extraction of specific ACS data ranges within pre-defined units of census geography. From survey to survey, the Census can modify data collection parameters or omit data collection or data releases at certain levels of geographic scale (U.S Census Bureau, 2018). The Factfinder allowed for smooth data exploration and was crucial in ensuring indicator consistency across identical units of geography (Block Groups). Unfortunately, as of March 2020, the Factfinder service has been discontinued, and the Census transitioned to a new data portal, data.census.gov (U.S Census, 2020). It appears that conversion of Factfinder data is still ongoing, and certain indicators or scales of geography are still in progress to be migrated to the new data portal.

The Building Permits data was acquired directly from the Washington DCRA GIS data portal (DCRA, 2011-2017). The topology and boundaries for the geographic administrative Census units including Census Block Groups and DC Boundary lines, were acquired from the Government of the District of Columbia GIS Site (Government of the District of Columbia, 2020). In late 2016, DCRA redesigned and updated their Building Permits portal site, removing all Building Permits older than 2016, and updating and redesigning the permit categories. Fortunately, this study curated older data extending back to 2011, mitigating a negative impact to the data integrity and temporal extent for the Building Permits dataset.

Through extensive research of local and national media sites this study documented media coverage of gentrification overlapping the studies temporal period. The frequency a media source identified a gentrifying neighborhood was aggregated to the closest Washington D.C designated Neighborhood Cluster. This method allowed the study to combine the data for disparate media sources and represent them in the form of gentrifying neighborhood hotspots (through a sum count of how many times each study mentioned a specific gentrifying neighborhood area).

5.2 Tools, Methods and Techniques

5.2.1 Weights Development Method

Following the methodology established in gentrification literature, this study looked to create a weighted composite index for both the Census Indicators and Building Permits. A

weighted composite index allows for the combination of multiple variables and an emphasis of certain variables over others (Census Indicators or a Building Permits that tend to be more aligned with a gentrification-based change should receive a higher weight). While there is a spectrum of techniques that can be used to create weights from factor analysis to principal component, the qualitative nature of gentrification and the study specific variations in analytical approaches implore for a method that complements qualitative data and is able to evaluate both the tangible and intangible aspects of gentrification.

Utilizing a systematic comprehensive approach for weights development creates a standard that can be replicated by other studies and considers the qualitative user infused aspects of the measuring the phenomena. While studies can rely on traditional gentrification literature to develop a general approach to creating a hierarchy for Census indicators (emphasizing the importance of indicators such as income, housing conditions, housing values , rent costs, and race), developing a hierarchy for Building Permits, or another future novel measure of gentrification, is more challenging.

This study chose to employ the Analytical Hierarchy Process (AHP) created by Thomas L. Saaty as a simple and effective method for weights development. AHP can be oriented to assess qualitative data and is often leveraged in making complex decisions involving multiple stakeholders in corporate or business environments. Saaty (1987) describes the efficacy of using an AHP approach for ranking or measuring both tangible (physical) and intangible (psychologic) phenomena:

> "people have been concerned with the measurement of both physical and psychological events. By physical we mean the realm of what is fashionably known as the tangibles as it relates to some kind of objective reality outside the individual conducting the measurement. By contrast, the psychological is the realm of the intangibles as it relates to subjective ideas and beliefs of the individual about himself or herself and the world of experience. The question is whether there is a coherent theory that can deal with both these worlds of reality without compromising either. The AHP is a method that can be used to establish measures in both the physical and social domains." (pg. 161)

AHP is an excellent method for decision making or problem solving within new spheres of measurement or where robust standards are yet to be established, "In completely new decision problems or in old problems where no standards have been established, we must continue to use relative measurement comparing alternatives in pairs to identify the best" (Saaty, 1987, p.173).

According to Saaty (2013), one of the greatest benefits that AHP provides is to systematically organize decision making or ranking, "Complex decision-making needs organized creative thinking to structure a problem. This structure can be provided by a hierarchy or a network. It also needs numbers and a modicum of mathematics to formalize judgments and make trade-offs" (p. 1101). At the heart of AHP is the utilization of a pairwise comparison approach that ranks the importance of each variable against all other variables in a dataset, establishing a

hierarchy and weights through this process. The values dictated by Saaty (2013) for pairwise comparison:

> "The following numbers are to be assigned in making paired comparisons: equal with (value 1), moderate with (value 3), strong with (value 5), very strong with (value 7) and extreme with(value 9) and the integers between for compromise, and their reciprocals" (p. 1101) .

Using AHP the researcher is able to rely on the core tenents of the process, "Three principles guide one in problem solving using the AHP: decomposition, comparative judgments and synthesis of priorities" (Saaty, 1987, p. 166), applying them systematically to establish hierarchy and weights within any dataset, even if the literature for hierarchy/weights development is lacking or conflicting. By selecting AHP, this study hopes to coalesce around a standard that can be used for future ranking of Building Permits (and/or Census Indicators) within other cities or regions, establishing a systematic ranking methodology while still accounting for unique local and regional characteristics.

5.2.2 Statistical Methods

In this study Descriptive Statistics was critical in exploratory data analysis, in helping make decisions on weights and hierarchy parameters, and in assessing relationships between the separate indices. Determining the mean, median, and/or sums and standard deviations for both the Building Permits and the Census Indicators was essential in understanding the spread and distribution of various study assessed metrics. Statistical tools/techniques included:

1. Excel – Power pivots for assessing mean, median, sums and standard deviations for study selected Census Indicators and Building Permits. Correlation analysis to determine relationship between the individual indices.
2. Minitab – visual descriptive statistics. Assessed the distribution of Household Income, and critical for determining exclusions (mean + 1 Std) for areas to affluent to gentrify.

5.2.3 GIS Methods

In this study GIS was indispensable in assessing the spatial aspects of gentrification. The sequence of GIS analysis techniques and methods is described in the analytic process model (APM) section. A summary of the main techniques utilized is below (Anselin and GeoDa, 2020; ESRI, 2020):

1. Spatial Join Analysis – Joining the attributes from one feature to another based on a spatial relationship. This study used the intersect spatial relationship.
    - Target features: Census Block Groups
    - Joined attributes from the join features: Building Permits 2011 – 2017. Summed by count (a total count of each Building Permit category within each Block Group) and Total Value per Building Permit category within each Block Group (each Building Permit has a total value paid associated with it).

2. Table Join Analysis – Joining a table of data to a feature class or a spatial layer based on a common specific field that can be found within both data elements.
    - Target feature: Census Block Groups
    - Joined attributes from the join features: Selected Census Indicators percent change (ACS2017 – ACS2013). The common element for the joins was the unique GEOID name for each Block Group.
3. (ArcGIS) Geographically Weighted Regression (GWR) – a form of regression that can be used to model spatially varying relationships based on dependent and explanatory variables.
    - Dependent Variable: Census Gentrification Index.
    - Explanatory Variable: Build Permits Gentrification Index.
    - A technique to determine spatial autocorrelation and to detect significant relationships between two sets of weighted features or variables. GWR is effective for identifying if the local correlation is direct or inverse within a specific feature or a within a prespecified geographic area. Additional techniques can be employed to investigate clustering of outliers and to validate GWR results.
4. Moran's I Statistic (supplementary analysis to validate GWR) – This technique identifies statistically significant variable relationships within features, but can also highlight a clustering of outliers within a prespecified geographic area. Moran's I can helps uncover "hot spots" or areas where high values are surrounded by other high values or the inverse "colds spots" or areas where low values are surrounded by other low values. This study used the Bivariate Moran's I to visually validate and supplement the spatial outputs of the GWR analysis. A closer integration between analysis methods is hoped to be achieved in future work.

5.3 Development of Individual Indices

5.3.1 Census Indicators Index

This study selected Census Housing and Demographic Indicators based on those consistently found in the literature, with a focus on studies utilizing housing indicators in conjunction with GIS to measure, assess, or visualize gentrification (Gambrill, 2007; Heidkamp and Lucas, 2007; Levy ,2009; Chapple, 2009; Fouch, 2012, Scott, 2013; and Ilic et al, 2018). While many traditional gentrification studies tend to include variables that focus on distinct racial or family characteristics, this study decided to concentrate on economic indicators, with an emphasis on income and HUs conditions. Since Washington D.C is a very diverse city with a significant transient population of students and temporary domestic and international residents (Jiang et al, 2019), relying on traditional indicators of race, age, and household composition may introduce an imbalance unrepresentative of gentrification and obscuring its actual magnitude or intensity.

It must be noted that the ACS data employed by this study are estimates, collected through samples of the population or through samples of HUs, and are not complete full counts such as those conducted during the Decennial Censuses (U.S Census, 2018). When research for this study was initiated the 5-year 2013 and the 5-year 2017 ACS estimates were chosen because they offered the most consistent finest scale of Geography across the selected indicators. The 5-year ACS estimates also provide a higher level of precision for smaller units of scale, but less temporal currency than shorter 1 and 3-year estimates (U.S Census, 2018).

Similar Census indicators were combined for simplification and certain indicators were updated to reflect current monetary values. Adhering to Saaty's guidance (Saaty, 1987) on the number of recommended variables for AHP, the number of indicators was narrowed to a total of nine. After weights were established using the AHP method, the Census indicators were multiplied by their respective weights and combined to create a Census Indicators Index. A table of selected Census indicators, associated computations, and their AHP weights is presented in the results section.

5.3.2 Building Permits Index

The Building Permit indicators selected for this study were based on their definitions provided by the DCRA (Appendix Table A-4) and on an extensive qualitative review of the available descriptions for each individual Building Permit type/category. For simplification and to accommodate AHP, similar Building Permit indicators were combined. Adhering to Saaty' s guidance (Saaty, 1987) on the number of recommended AHP variables, the number of Building Permits indicators was narrowed to a total of 9. After weights were established using the AHP method, and after additional computations described in the APM analysis section (normalization), the Building Permit indicators were multiplied times their respective weights and combined to create a Building Permits Index. A table of selected Building Permit indicators, associated computations, and their AHP weights is presented in the results section.

5.4 Media Sources

This study conducted a detailed search for news articles, local blogs, and other media sources reporting on gentrification in Washington D.C. Articles within the acceptable timeframe were collated into a table, and specific references to neighborhoods were extracted. The frequency a media source identified or referenced a gentrifying neighborhood was allocated to the geographic boundaries of that neighborhood's Neighborhood Cluster feature. This method allowed the study to combine data from many different sources and to display media reports through a cartographic representation.

5.5 Analytical Process Model and Final Composite Index

This study created an APM (Figure 1) to graphically represent the entire analysis process. The APM is an illustrative visualization developed to allow other studies to streamline the replication of the methodology and analysis. The activity tree in Table 3 below captures each step or activity in the APM in a table format. Activities 1.1 thru 1.15 and 2.1 through 2.14 can be conducted concurrently or consecutively.

Table 3: Decision Tree for the APM

A Novel Gentrification Index (Census Data and Building Permits) A Decision Tree for an APM delineating the creation of a composite Gentrification Index, combining Census Indicators and Building Permits (DCRA).	
Census Indicators	**Building Permits**
Conduct Data Research	
1.1 Research and explore the U.S Census Data	**2.1** Research and explore the redesigned online Building Permits DCRA Database
1.2 Determine Survey Data Product Year Availability (certain surveys are NOT conducted yearly or skip years)	**2.2** Gain an understanding of each Building Permit Type and Purpose
1.3 Determine Survey Data Product Scale Availability (not all surveys are consistent in scale from year to year)	**2.3** Determine Months/Years of Data availability
Conduct Data Clean Up, QC, and Collation	
1.4 Pull Census demographic/housing indicators that are consistent across both Survey Data Products and Scales (ACS 5Year + Block Groups) 2013 ACS-5Year 2017 ACS-5Year	**2.4** Acquire data for years that complement the Census Demographic Data
1.5 Conduct data review, QC, and data cleanup.	**2.5** Combine with curated pre-2016 data, and collate into a single Build Permits Universe that temporally complements the Census Demographic Data (DB: Legacy Building Permits data curated by Author (Pre-2016 DCRA data cleanse and redesign))
1.6 Calculate inflation adjustments (CPI) for any monetary indicators (Median HH Income, Median Home Value, Median Rent)	**2.6** Conduct data review, QC, data clean up and fix any geocoding errors
1.7 Combine similar indicators to reduce the number of demographics/housing variables (Ex: Median Contract Rent combined with Median Gross Rent)	**2.7** Combine similar Building Permits to reduce the number of variables(Ex: Add_AddAltRep_AltRep =, Addtion+Addition Alteration Repair+Alteration and Repair

Conduct Statistical Analysis	
1.8 Conduct Descriptive Statistics Analysis to determine mean, median.	**2.8** Conduct Statistics Power Pivot Analysis to determine total counts, total sum, mean and median for each Building Permit Category
Conduct Appropriate Exclusions and AHP Analysis	
1.9 Block Groups where ACS2013 Median HH Income is above Mean + 1Std were excluded. To remove unnecessary noise and to ensure only appropriate Block Groups Units were analyzed (already affluent Block Groups cannot gentrify)	**2.9** Conduct extensive Qualitative Analysis to exclude Building Permit categories completely unrepresentative of gentrification (Sewer work, fiber work, sign, etc…). Qualitative analysis includes defining each permit category, and then evaluation descriitions for individual permits within it.
1.10 Exclude Block Groups above the 40% Coefficient of Variation were to ensure data integrity (ESRI 2017 ACS White Paper)	**2.10** Select 9 Building Permit categories to accommodate the AHP method. Select categories with definitions that can be associated with gentrification.
1.11 Determine Change between the 2 datasets ACS5Year 2017 – ACS5Year2013: Raw Difference Percent Change	**2.11** Conduct AHP analysis to determine weights. Based on the qualitative analysis in 2.9, categories more representative of gentrification received greater weights.
1.12 Select 9 demographic/housing condition indicators to narrow the Census variables to accommodate the AHP method. Indicators ar selected based on literature. Combine similar indicators to maintain the max 9 variable count (Ex: Rent = (Median Contract Rent + Median Gross Rent)/2))	
1.13 Conduct AHP analysis to determine weights. Based on literature and SME knowledge, indicators of Median HH Income, Median Housing Value, and Median Rent received greater weights.	
AHP Weights Application, Spatial Normalization, Individual Index Creation, and Correlation Assessment	
1.14 Join Percent Change to appropriate (non-excluded) Block Groups Geography	**2.12** Join each of the 9 selected Building Permit categories to Block Groups Geography
1.15 Multiply percent change for each Demographic or Housing indicator by its associated weight and combine to create the Census Gentrification Index	**2.13** Normalize the Building Permits data. Total Joined Number of each BP Category divided by Number of 2010HUs in that Block Group: Joined Category/Number of 2010HUs
	2.14 Multiply each permit category by its associated weight and combine to create the Building Permits Gentrification Index

Final Composite Index: Geographically Weighted Regression (GWR)/Spatial Autocorrelation Bivariate Moran's I
3.1 Conduct correlation analysis to determine relationship between the Building Permits Index and the Census Index (**Is Correlation R^2 >= 0.5? If Yes, continue to Activity 3.5. If No, continue to Activities 3.2 - 3.5**)
3.2 (ArcMap) Conduct multiple Geographically Weighted Regression (GWR) analyses to identify Gentrification Hotspots (specific Block Groups that are gentrifying). This study used the settings/inputs bel: *Dependent Variable:* Census Index *Explanatory Variable*: Building Permits Index *Kernel type*: Adaptive *Bandwidth Method:* Bandwidth Parameter *Distance:* N/A *Number of Neighbors:* 10, 20,and 30 *Output Cell Size:* N/A *Prediction Locations/Explanatory Variables:* N/A
3.3 (Optional Analysis GeoDA) Conduct Bivariate Moran's I Analysis to visually supplement/validate the results of the GWR analysis. This study used the settings/inputs below: *Contiguity Weight:* Queen *Distance Weight* *Transformation:* Standardize (Z) *Distance Metric:* Euclidean Method *K-Nearest Neighbors, Number of Neighbors:* 10, 20, and 30 *Independent Variable:* Building Permits Index *Dependent Variable:* Census Index
3.4 Evaluate the results of the GWR analyses and Bivariate Moran's I. Compare the identified Hotspots to sources of independent validation (this study utilized local media sources, but field visits, social media or other sources could be leveraged)
3.5 Add both indices to create a final Composite Gentrification Index. Census Gentrification Index + Building Permits Gentrification Index. Standardize Index value for each Block Group from 0 to 1 (Max-X/Max-Min, where X is the index value for each Block Group)

Figure 1a: AHP Model "A Novel Gentrification Index (Census Indicators and Building Permits)"

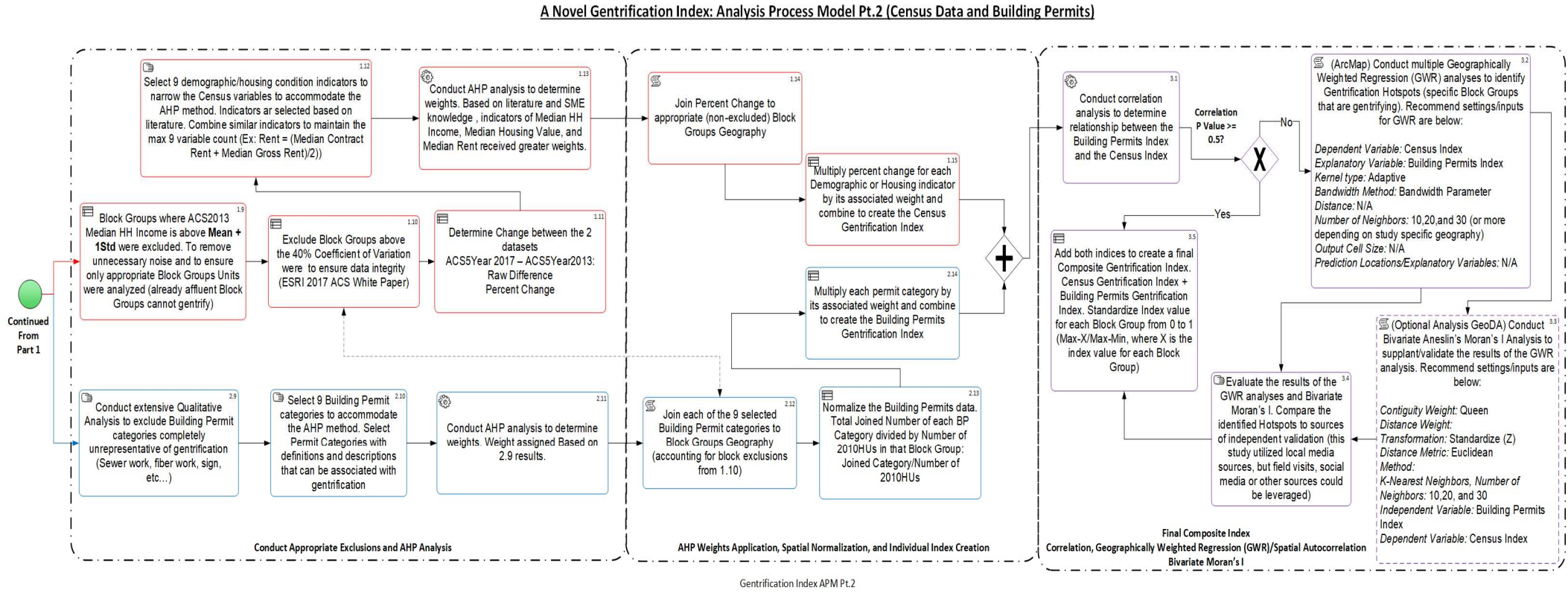
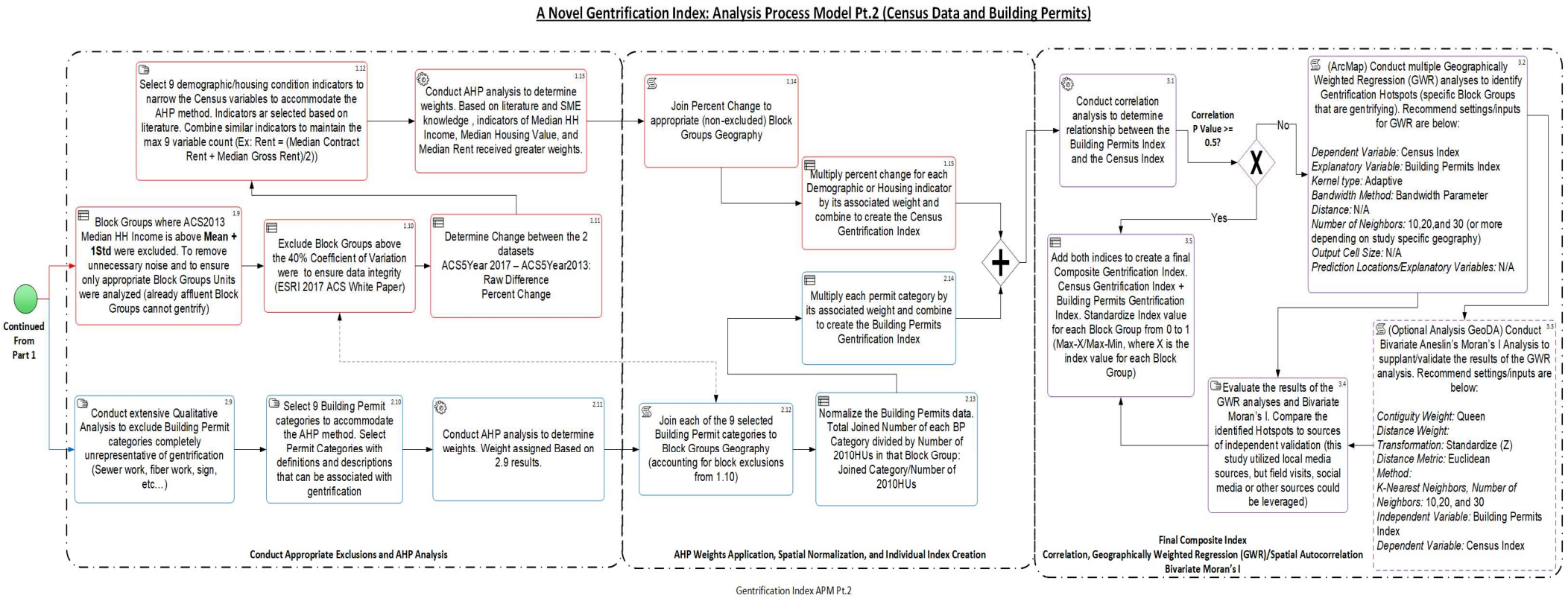


Figure 2b: AHP Model "A Novel Gentrification Index (Census Indicators and Building Permits)"



6. Results

Following the general activity steps presents in the APM, the results for critical outputs of the analysis are presented below (and in the Appendices):

6.1 Census Indicators Change Analysis and Index

6.1.1 Census Indicators Change Analysis

6.1.2 Census Indicators Index

6.2 Building Permits Index

6.3 Block Group Exclusions

6.4 Correlation and Spatial Analysis

6.5 Media Validation

6.1 Census Indicators Change Analysis and Index

6.1.1 Census Indicators Change Analysis

To explore overall change this study determined percent change for the selected Census Indicators, ensuring to account for inflation for any monetary based indicators (Median Household Income, Median Value, and Median Rent). Inflation was computed at 1.05 between 2013 and 2017 (US Bureau of Labor Statistics, 2019). Percent Change was calculated as:

Percent Change = ((5YR.ACS2017 – 5YR.ACS2013*1.05)/ 5YR.ACS2013*1.05))

Table A-1 in appendix A present the descriptive statistics, percent change, and correlation for the chosen indicators both before and after Block Group exclusions.

6.1.2 6.1.2 Census Indicators Index

The Census Indicators index is presented in Table 4 below. Selected indicators and chosen weights were based on gentrification studies assessed in the literature review, authors local knowledge of building codes, and expected association with the gentrification process in Washington D.C. To streamline the AHP weights computations a publicly available AHP template from SCB Associates Ltd was utilized (SCB Associates, 2016), consult Appendix A Figure A-1 for AHP details.

Table 4: Census Indicators Index			
AHP Weight	**Indicator Name**	**Computations**	**Justification**
0.294	**Median Household Income in the past 12 months (dollars)**	CPI Inflation Adjustment	A gold standard in Gentrification Literature. Indicative of Higher Income residents moving in to gentrify the neighborhood.
0.168	**Median Home Value (dollars)**	CPI Inflation Adjustment	Gentrification Literature and expected/associated changes. Increase in Home Values.
0.168	**Median Rent (dollars)**	CPI Inflation Adjustment Mean of (Gross Rent+Contract Rent)	Gentrification Literature and expected/associated changes. Increase in Rent due to a more attractive/desirable neighborhood and higher home values.
0.098	**Median Year Structure Built**	None	Gentrification Literature and expected/associated changes. Developers will look to invest in building New Structures as they notice the area is attracting higher income residents. The median year of structures built across the Block Group is calculated based on the original year built, and renovating will not increase overall Median Year Structure Built.
0.098	**Units in Structure Combined (1attached to 19)**	Combined Units in Structure 1 through 19	Unique to Washington D.C Building Codes. SFHs, townhomes, or apartment buildings are remodeled to have extra or hidden units to accommodate an influx of new residents drawn to the area. This choice of structure type aligns with many of the housing units in Washington D.C
0.064	**Tenure Total Owner Occupied**	None	Gentrification Literature. New/Incoming Residents are more comfortable in owning or investing in a home in the gentrifying area.
0.046	**HUs Estimate**	None	General Number of HUs increases as the neighborhood/Block Groups becomes more desirable. Most compact smaller HUs within the same area.
0.035	**Vacant Total**	None	Vacancies decrease as the area become more desirable.
0.028	**2ndMorgage**	Combined Two 2nd Mortgage Categories: (1) "Either 2nd mortgage or home equity loan, not both" and (2)"Both second mortgage and home equity loan"	Current residents or speculators are purchasing homes using a 2nd Mortgage to profit from or invest in the ongoing gentrification.

6.2 Building Permits Index

The Building Permit categories and weights were determined based on a qualitative review of each permit category. To ensure selected permit categories represent change indicative of gentrification, this study first defined each category (Appendix A Table A-4), and then analyzed the descriptions for a subset of individual permits within in it. The selection of categories and weights was heavily dependent on DCRAs data organization and reporting standards (availably of descriptions for each permit category), and on the authors associations between specific permits types and the gentrification process. To streamline the AHP weights computations a publicly available AHP template from SCB Associates Ltd was utilized (SCB Associates, 2016), consult Appendix A Figure A-1 for AHP details.

Table 5 presents the entire Building Permits Universe of selected permit categories before various exclusions and spatial processes (joins) were applied. After joining each Building Permit category to Block Groups Geography, the study created a Permit Category to Block Group Ratio, dividing the total number of permits in a joined category by total count of 2010 Housing Units (last available full survey). To view the results of the spatial joins, and the distribution of Building Permits across Block Groups please consult Appendix A Table A-3.

Table 5: Building Permits Index

Building Permits Index						
AHP Weight	**Indicator**	**Computations/Transformations**	**Total Count**	**Total Value**	**Mean Value/Permit Category**	**Median Value/Permit Category**
0.312	**Addition/Addition, Alteration, and Repair/Alteration and Repair**	Combined "Addition", "Addition Alteration Repair", and "Alteration and Repair"	52,933	$347,853,392	$6,572	$384
0.178	**Electric/Electric General/Electric Heavy Up**	Combined "Electricity", "Electricity General", and "Electricity Heavy Up"	13,927	$239,659,464	$17,208	$84

0.178	**Plumbing/Plumbing and Gas**	Combined "Plumbing" and "Plumbing and Gas"	12,368	$230,131,481	$18,607	$114
0.108	**Raze**	None	583	$214,532,530	$367,980	$701
0.073	**New Building**	None	2,466	$23,352,104	$9,470	$929
0.053	**Demolition**	None	3,596	$3,461,399	$963	$185
0.04	**Mechanical**	None	5,574	$987,426	$177	$51
0.032	**Certificate of Occupancy**	None	4,243	$603,533	$142	$83
0.026	**Building (**any construction that impacts public space and requires an extra separate public space permit issued by the District Department of Transportation, see Appendix Table A-4 for more details**)**	None	12,514	$449,977	$36	$36
Total			108,204	$1,061,031,305	$46,795	$114

6.3 Block Group Exclusions

There were three types of exclusions conducted to ensure the appropriate Block Groups were being analyzed for gentrification:

1. Where the Median Household (HH) Income for the 5-Year ACS 2013 is one Standard Deviation above the Mean rounded to the nearest thousand ($130,000). Already affluent Block Groups areas are not eligible to gentrify. A total of 63 Block Groups excluded.
2. Where the Coefficient of Variation was above 40%. This metric indicates the reliability and or accuracy of the collected data is too low, and that the sampling error or margin of error relative to the estimate is too large (ESRI, 2017). A total of 53 Block Groups excluded
3. Where the Median HH Income is 0. A total of 3 Block Groups excluded.

6.4 Correlation and Spatial Analysis Results

6.4.1 Composite Index and GWR

After the individual indices were computed, a correlation was calculated for the entire post exclusions study area to identify a relationship. The Significance level P-value for the entire study area was 0.024, showing a weak relationship between the two indices for the entire study area of 331 Block Groups. The two indices were added up and standardized to create a positive Final Standardized Composite Index (FSCI) with a scale from zero to one, the map for the Composite Index is found in Figure 2. Based on the natural breaks in the FSCI values a total of 24 Block Groups were identified as gentrifying, with 7 as heavily gentrifying (FSCI > 0.5) and 17 as nearly gentrifying(FSCI>0.4). The FSCI was compromised due to the insufficient integration of local spatial factors, specifically the intensity of gentrification on a smaller scare or within neighboring Block Group clusters.

Through the application of GWR, the next phase of analysis was sensitive to the spatial fluctuations of gentrification intensity at the local Block Group level. For each individual Block Group, GWR accounted for the intensity of gentrification in a prespecified number of its nearest neighboring Block Groups. GWR identifies the correlation between the two indices, which could be among high values of both, or low values of both. It measures agreement To investigate the variance in the volume and locations of significant (gentrified or gentrifying) Block Groups, and to identify the extent of concentrations, a total of 3 GWR analyses with varying nearest neighbor parameters were executed.

For each new GWR iteration the nearest neighbor parameter was modified, testing with 10, 20, and 30 nearest neighbors. The GWR was able to efficiently detect gentrifying areas, Block Groups where there was a correlation between the index numbers (Census Indicators

Index and Building Permits Index) and surrounded by other Block Groups with a similar relationship. A higher positive GWR regression coefficient indicates the presence of agreement between the two measures of gentrification. For a further interpretation and to create the GWR cartographic outputs below, this study relied on ESRI's guidance for interpreting GWR results (ESRI, 2020):

> "There is currently no consensus on how to assess confidence in the coefficients from a GWR model. While t-tests have been used to base an inference on whether the estimated value of coefficients is significantly different than zero, the validity of this approach is still an area of active research. One approach to informally evaluate the coefficients is to divide the coefficient by the standard error provided for each feature as a way of scaling the magnitude of the estimation with the associated standard error and visualize those results, looking for clusters of high standard errors relative to their coefficients. (ESRI, 2020)"

After the recommended division, Block Groups with standardized coefficients above 0.5 were identified as gentrifying. The number of gentrifying Block Groups slightly changed with each iteration and are presented in Figures 3-6 below. There were a total of 91 gentrifying Block Groups with 10 nearest neighbors, 89 gentrifying Block Groups with 20 nearest neighbors, and 84 gentrifying Block Groups with 30 nearest neighbors

6.4.1 Bivariate Moran's I

An additional supplementary Bivariate Moran's I analysis was conducted in GeoDa, and through a visual comparison confirmed the general gentrifying areas identified by the GWR. The cartographic outputs and the results of the Bivariate Moran's I are presented in Figure 4.

In order to account for the continuous gradual nature of the indices, and the possible temporal lag between the physical gentrification of the built environment and associated demographic changes, this study was mindful in assigning each index to a dependent or an independent variable. The Building Permits Index was selected as the independent variable, and the Census Index as the dependent variable, with the aim of assessing and illustrating how physical build environment change precedes demographic changes. The parameters utilized for the analysis included a Queen contiguity weight and a Euclidean distance metric. Similar to the GWR analysis, 3 nearest neighbor iterations were conducted including testing with 10, 20, and 30 nearest neighbors. The Bivariate Moran's I revealed the metrics on gentrifying block groups presented in Table 6. Block groups that were classified into the High-High and High-Low categories were extracted for intersect analysis and validation against media identified Neighborhood Clusters.

Table 6: Moran's I Results				
Nearest Neighbors	**Significant Block Groups**	**P = 0.05**	**P = 0.01**	**P = 0.001**
10	54	35	15	4
	High-High	**Low-Low**	**Low-High**	**High Low**
	10	31	10	3
Nearest Neighbors	**Significant Block Groups**	**P = 0.05**	**P = 0.01**	**P = 0.001**
20	40	32	8	0
	High-High	**Low-Low**	**Low-High**	**High Low**
	9	19	6	6
Nearest Neighbors	**Significant Block Groups**	**P = 0.05**	**P = 0.01**	**P = 0.001**
30	78	45	28	5
	High-High	**Low-Low**	**Low-High**	**High Low**
	16	45	15	2

Figure 3: Final Standardized Composite Index (Census Indicators and Building Permits

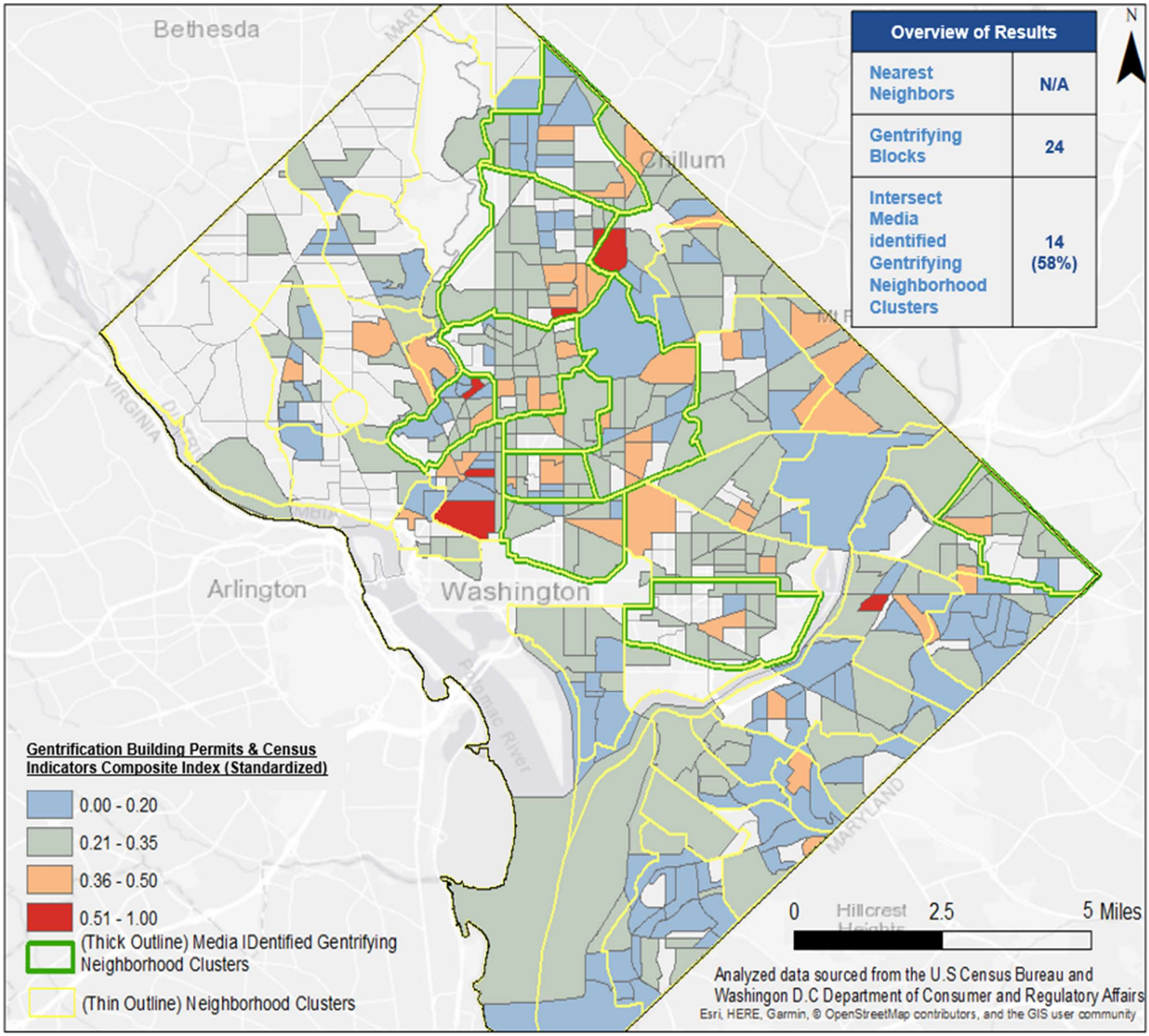


Figure 4: GWR Output with 10 Nearest Neighbor Parameter

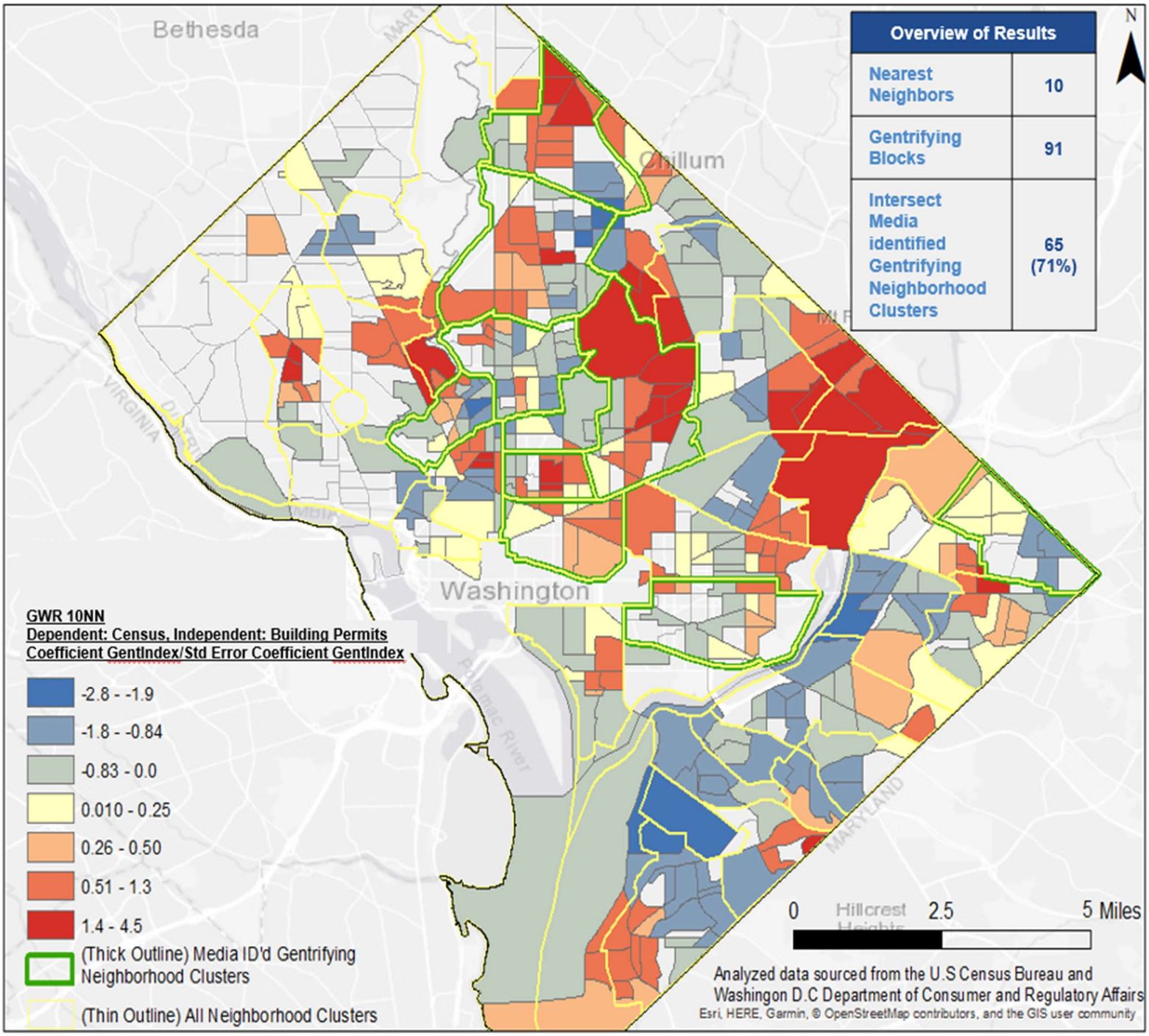


Figure 5: GWR Output with 20 Nearest Neighbor Parameter

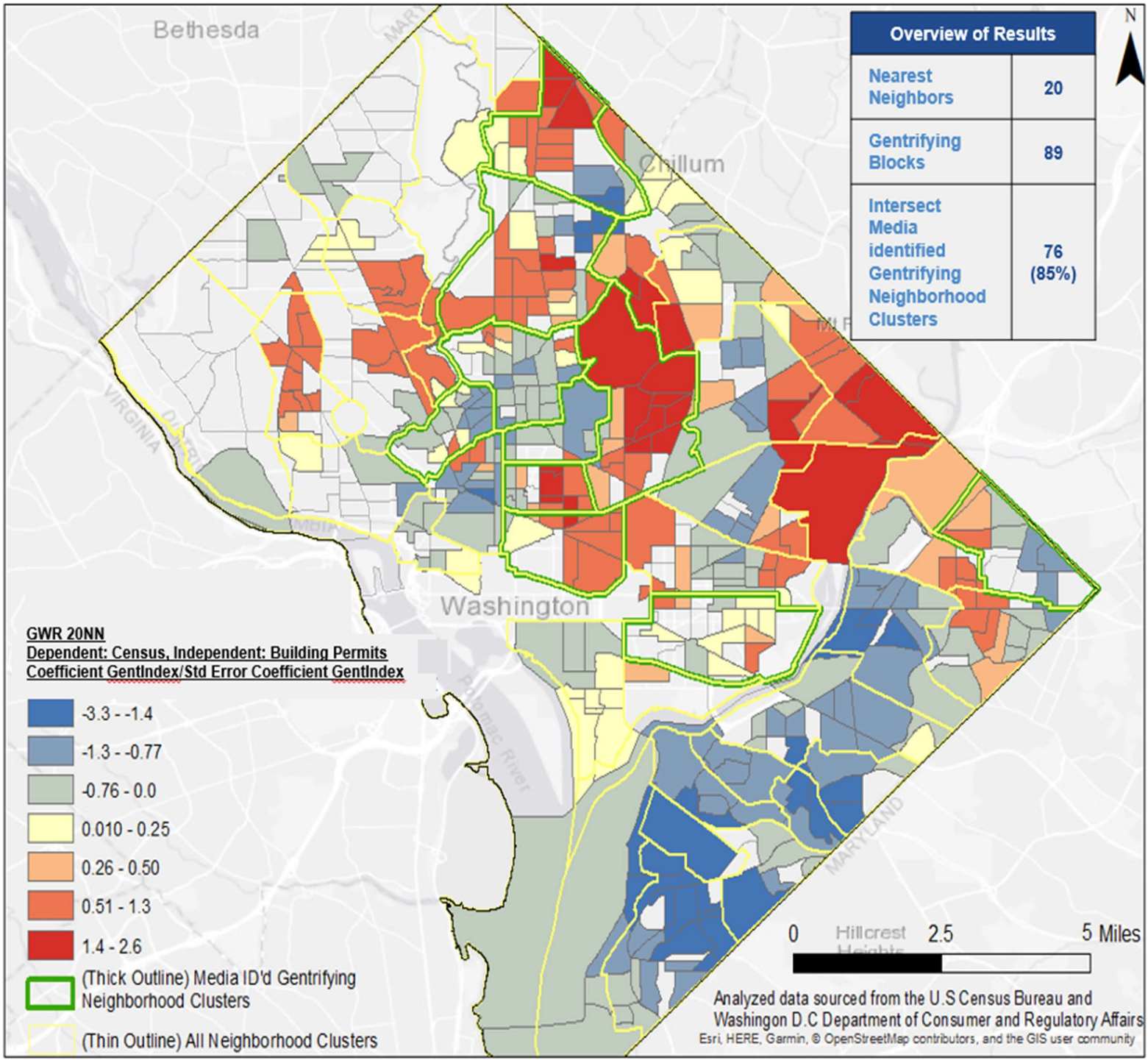


Figure 6: GWR Output with 30 Nearest Neighbor Parameter

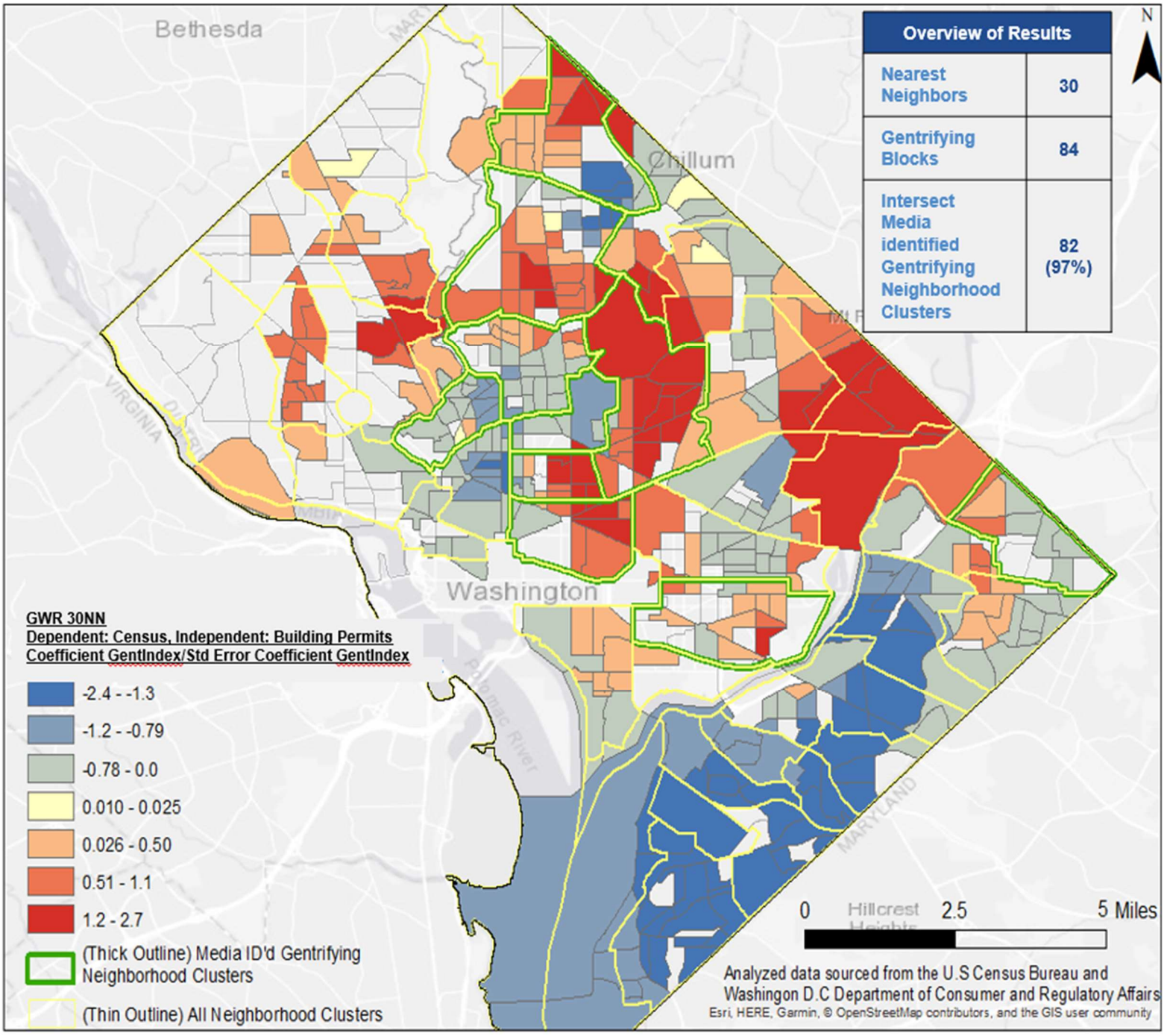


Figure 7: GeoDa Bivariate Moran's I Significance Output (Left to Right: 10NN, 20NN, 30NN)

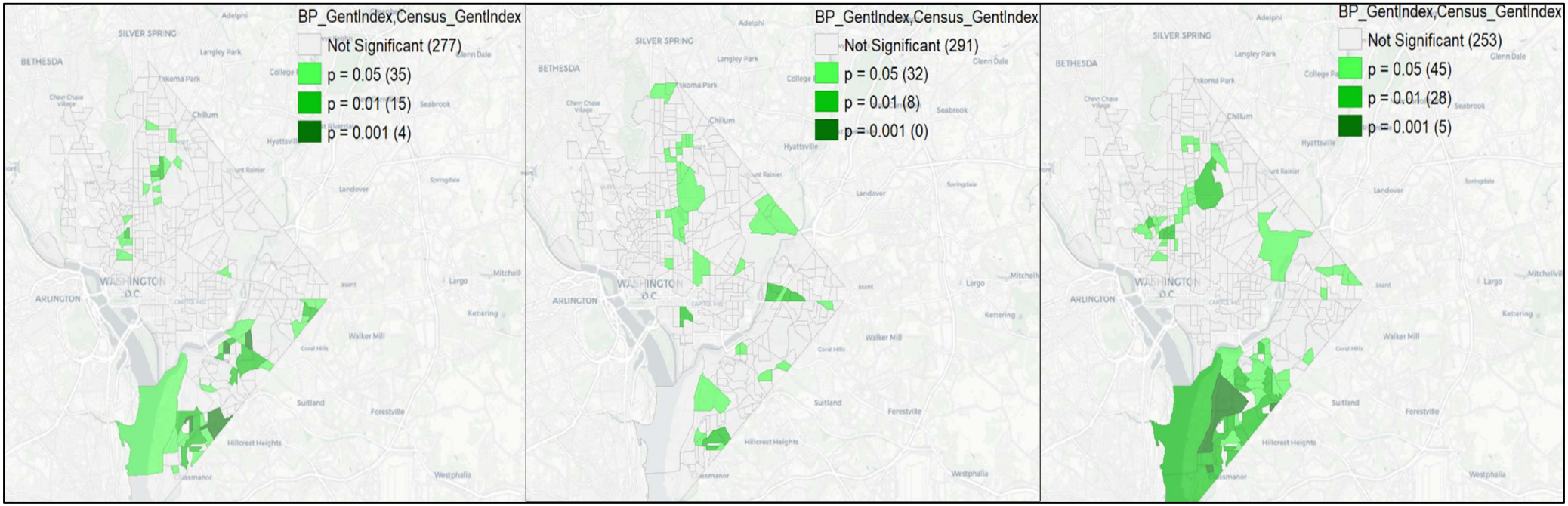
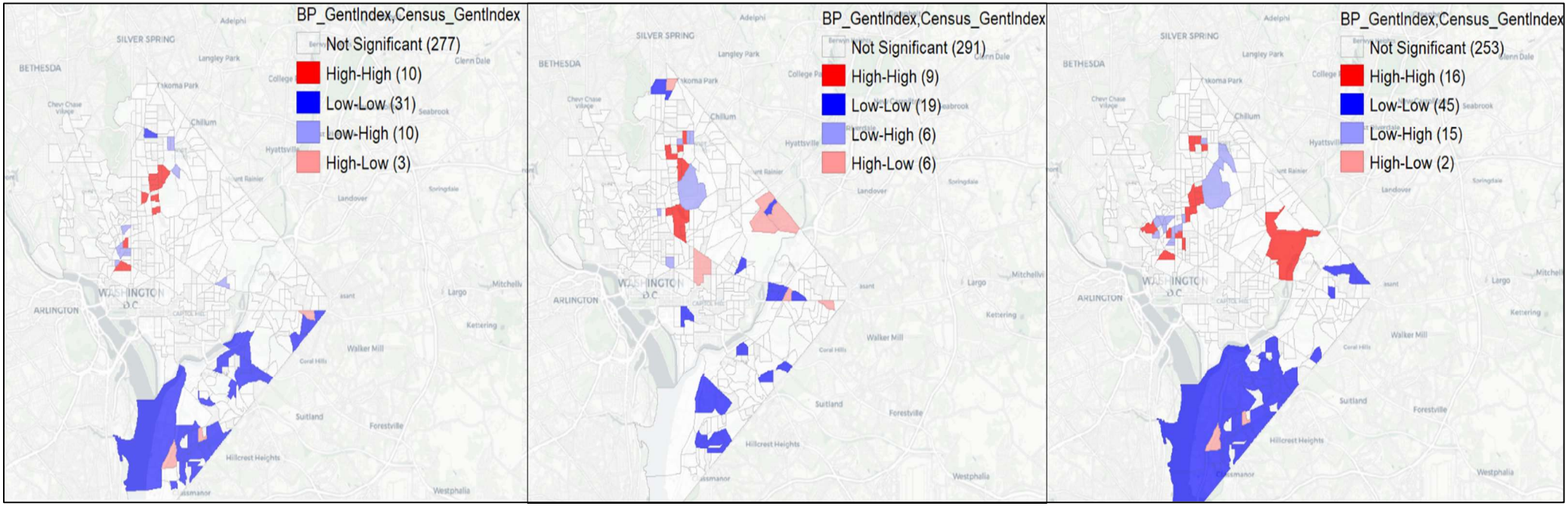


Figure 8: GeoDa Bivariate Moran's I "HotSpots"/"ColdSpots" Output (Left to Right: 10NN, 20NN, 30NN)



6.5 Media Validation

This study analyzed 39 articles from various news sources reporting on gentrification in Washington D.C (table of news sources and extracted neighborhoods can be found in Appendix B). The frequency a media source identified a gentrifying neighborhood was allocated to the geographic boundaries of that neighborhood's associated "neighborhood cluster" feature. The location, names, and number of media references for each Neighbored Cluster is displayed in Figure 8. In Table 6 and Table 7 below the gentrifying Blocks Groups identified by the study were joined to the Neighborhood Clusters. With each iteration of the GWR and with each iteration of the Bivariate Moran's I, an ever-increasing count of intersections between study identified gentrifying Block Groups and media identified gentrifying Neighborhood Clusters was observed.

Table 7: Media Validation of GWR Outputs

Neighborhood Cluster Name	Media References	Gentrifying GWR 10NN Block Groups: Intersect Count	Gentrifying GWR 20NN Block Groups: Intersect Count	Gentrifying GWR 30NN Block Groups Intersect Count:	Gentrifying GWR 10NN Block Groups Average of Coefficient Ratio for intersects:	Gentrifying GWR 20NN Block Groups Average of Coefficient Ratio for intersects:	Gentrifying GWR 30NN Block Groups Average of Coefficient Ratio for intersects:
Brightwood Park, Crestwood, Petworth	**2**	10	14	16	0.93	0.88	0.95
Capitol Hill, Lincoln Park	**2**	2	2	3	0.60	0.73	0.79
Columbia Heights, Mt. Pleasant, Pleasant Plains, Park View	**5**	9	7	8	0.80	0.87	1.03
Deanwood, Burrville, Grant Park, Lincoln Heights, Fairmont Heights	**3**	1	2	2	1.43	0.94	0.56
Downtown, Chinatown, Penn Quarters, Mount Vernon	**3**	6	9	10	0.84	0.92	1.03

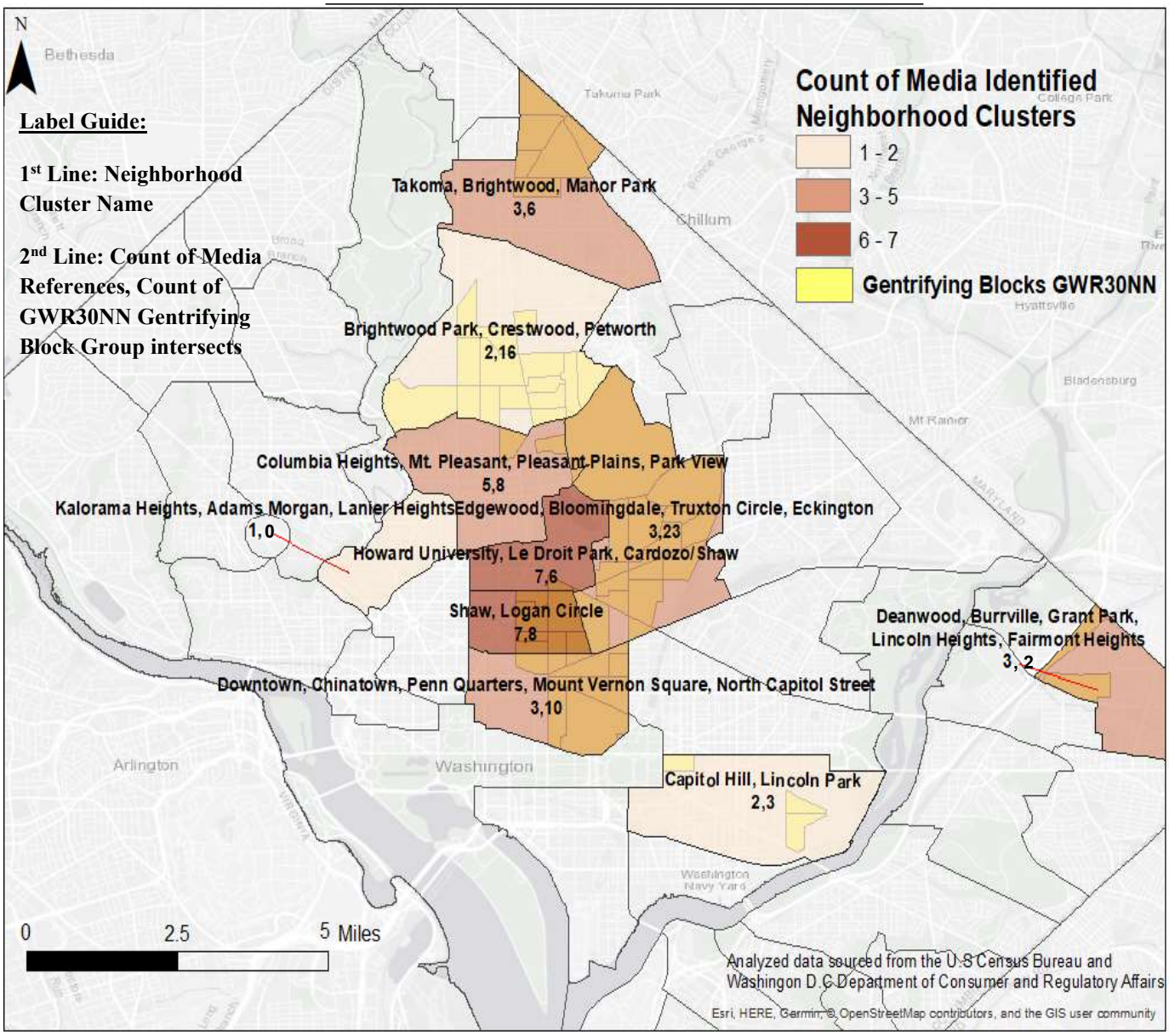
Square, North Capitol Street							
Edgewood, Bloomingdale, Truxton Circle, Eckington	**3**	14	19	23	1.32	1.31	1.40
Howard University, Le Droit Park, Cardozo/Shaw	**7**	3	3	6	1.02	1.77	1.35
Kalorama Heights, Adams Morgan, Lanier Heights	**1**	3	3	0	0.85	0.77	0.00
Shaw, Logan Circle	**7**	8	7	8	0.94	1.37	1.21
Takoma, Brightwood, Manor Park	**3**	9	10	6	1.18	1.01	1.02
Grand Total (percent of total Gentrifying Blocks intersect)	**36**	**65/91 (71%)**	**76/89 (85%)**	**82/84 (97%)**	**N/A**	**N/A**	**N/A**

Table 8: Media Validation of Bivariate Moran's I Outputs

Neighborhood Cluster Name	Media References	Gentrifying Moran's I 10NN Block Groups: Intersect Count	Gentrifying Moran's I 10NN Block Groups: High Category	Gentrifying Moran's I 20NN Block Groups: Intersect Count	Gentrifying Moran's I 20NN Block Groups: High Category	Gentrifying Moran's I 30NN Block Groups: Intersect Count	Gentrifying Moran's I 30NN Block Groups: High Category
Brightwood Park, Crestwood, Petworth	**2**	5	5 High-High	6	6 High-High	4	4 High-High
Capitol Hill, Lincoln Park	**2**	0	0	0	0	0	0
Columbia Heights, Mt. Pleasant, Pleasant Plains, Park View	**5**	3	3 High-High	1	1 High-High	6	6 High-High

Deanwood, Burrville, Grant Park, Lincoln Heights, Fairmont Heights	**3**	0	0	0	0	0	0
Downtown, Chinatown, Penn Quarters, Mount Vernon Square, North Capitol Street	**3**	0	0	0	0	0	0
Edgewood, Bloomingdale, Truxton Circle, Eckington	**3**	0	0	0	0	0	0
Howard University, Le Droit Park, Cardozo/Shaw	**7**	0	0	2	2 High-High	1	1 High-High
Kalorama Heights, Adams Morgan, Lanier Heights	**1**	0	0	0	0	1	1 High-High
Shaw, Logan Circle	**7**	0	0	0	0	1	1 High-High
Takoma, Brightwood, Manor Park	**3**	0	0	1	1 High-low	0	0
Grand Total (percent of total Gentrifying Blocks intersect)	**36**	**8/13 (62%)**	**8 High-High**	**10/15 (67%)**	**8 High-High 1 High-Low**	**13/18 (72%)**	**10 High-High**

Figure 9: Media Reported Gentrification Associated to Neighborhood Clusters Overlay with GWR 30NN Gentrifying Block Groups



7. Discussions and Conclusion

7.1 Discussion

Although the correlation between the Census Indicators Index and the Building Permits Index for the entire study area was weak, the application of GIS analysis allowed this study to detect local concentrations of gentrifying Block Groups. To ascertain the overall success of the proposed analysis methods, and to determine the accuracy of validating through an assessment of media reports, a return to the core objective and the two main research questions presented earlier is required.

Core Objective:

Do Building Permits data provide an accurate fine spatial resolution assessment of the distribution and intensity of gentrification in a large urban center?

The author believes that the core objective has been mostly achieved. The integration of Building Permits data offers a distinct spatial attribute that accounts for the fine scale with a drilldown to the individual buildings/addresses. Building Permits provide a unique input by reporting on physical housing conditions that the Census is unable to track, detect, or document. The utilization of GWR to identify gentrifying areas based on the relationship between the individual Census and Building Permit Indexes (at the Block Group level) transcends some of the limits of Census data and provides a more accurate fine spatial assessment of gentrification intensity. A positive sign for the gentrification measuring utility of permits data can be observed in the large number of intersects between the Block Groups designated as GWR gentrifying and media identified gentrifying Neighborhood Clusters (GWR 10NN:65/91 (71%), GWR20NN:76/89 (85%), and GWR30NN:82/84 (97%)). The results of the Bivariate Moran's I had a similar intersect trend as the GWR analysis, with each iteration of nearest neighbor parameter seeing a higher number of intersects with the media identified gentrifying Neighborhood Clusters (Bivariate Moran's I 10NN:8/13 (62%), Bivariate Moran's I 20NN:10/15 (67%), and Bivariate Moran's I 30NN:13/18 (72%)).

The validation of the GWR and Bivariate Moran's I cartographic outputs through an assessment of media sources provided a cogent yet not a foolproof method for confirming the accuracy of this studies' approach. As the number of nearest neighbors for the GWR analysis increased, the number of gentrifying Block Groups decreased. This decrease can be attributed to the expanded spatial computation window, with a higher number of neighbors, there is a smoothing effect that results in fewer GWR-identified gentrifying Block Groups. The Bivariate Moran's I had a slightly different result, as number of nearest neighbors for the Bivariate Moran's I analysis increased, the number of gentrifying Block Groups increased. This can be

attributed to the computational nature of the analysis, and the lack of the smoothing effect observed in the GWR.

Although there were fewer gentrifying Block Groups with each increased nearest neighbor GWR parameter, it was observed that a higher percentage of GWR-identified gentrifying Blocks Groups intersected the media-identified gentrifying Neighborhood Clusters. Although the number of gentrifying Block Group identified by the Bivariate Moran's I analysis grew with each increased nearest neighbor parameter, the study observed a similar trend to the GWR intersects, with a higher percentage of Bivariate Moran's I-identified gentrifying Blocks Groups intersecting the media-identified gentrifying Neighborhood Clusters. A larger number of intersects can be interpreted to be a positive affirmation of the gentrification intensity, or as the spatial side effect of the GWR smoothing process or the increased Moran's I spatial analysis extent. It can also be the interpreted as a validation weakness in terms of a scale limitation for the Neighborhood Clusters, and a display of the inherent reductionism in transposing qualitative location rich media reports to official administrative Neighborhood Cluster units (that encompass multiple Block Groups).

2 Main Research Questions:

1. Do detailed Building Permits data, provide an accurate large-scale assessment of the spatial distribution, and intensity of gentrification in Washington D.C?

Building Permits data provides a large-scale component unavailable in Census Data. Anchoring the address-based data from the building permits to the closet smallest administrative boundary feature provides a level of precision for analyzing distribution and intensity that is limited in Census data. Validating the assessment quality through media analysis provides a systematic methodology to determine accuracy, but is somewhat limited by scale. For future research, the incorporation of field visits to the most intensely gentrifying areas could resolve or reduce the scale limitations observed in the media sources.

2. Does the Washington D.C case study demonstrate that Building Permits data, combined with traditional Census modes of measurement, provide an enhancement in the measurement of gentrification?

The addition of permits data reveals fine scale gentrification processes (improvement, enhancement, and revitalization of the built environment at the address level) that the Census is unable to track. The integration of building/address level permit data enhances the GWR analysis at a higher Block Groups scale to which Census data is already attached. Building Permits associated or related to the gentrification process are an ideal complement to Census Data and may reveal the presence of gentrification when Census Indicators are insignificant. Washington's modern tracking, documentation, and data sharing policies were essential in making the

extensive DCRA Building Permits data available for analysis. The extensive media coverage of Washington D.C gentrification presented a sound validation source that may be limited for smaller cities.

7.2 Conclusion

The selection of Washington D.C as a case study, and the availability of the critical data for the analysis, allowed this study to accomplish its core objective and to conduct analysis that spanned a protracted temporal period. The author's local knowledge and understanding of housing architecture, building codes, and transient population characteristics were indispensable in helping guide the selection of variables for both the Census Indicators and Building Permits.

The selections of variables for each individual index is the phase of the analysis where the most researcher bias could be introduced, especially for selecting Building Permits where literature consensus is still somewhat limited. This is also the phase where future studies replicating the presented methodology could diverge in the selection of Census Indicators and Building Permits, and where accounting for unique local elements in different study areas could result in distinct study original compositions of indicators and permits (complementing local building codes, unique topographical or physical characteristics, endemic population dynamics, and other elements exclusive to a specific city or study area).

Future work and optimization would focus on the automation of various analysis phases and closer integration between spatial analysis approaches. Automating the data acquisition, data cleanup, data QC and collation, and individual index creation (variable combination and weights creation) should result in the ability to execute a higher number of variations in the composition of the final composite index and any associated GWR and Moran's I analyses. Python could be used, not only for the automation of data acquisition, cleanup, organization, and computation of indices, but also for automating spatial analysis and repetitive geoprocessing tasks such as the GWR and Moran's I. The ultimate enhancement would be the integration of the Google Street View ML analysis developed by Illic et al.(2018), with an ideal association between the address for a Building Permit, its Street View image change library, appropriate Census data (scale and indicator variables), and any neighborhood associated media coverage.

8. Appendix A – Tables and Figures

Table1 presents the statistics and change for the study area, before and after Block Group exclusions were conducted.

Table A-1: Census Indicators Change from ACS2013 to ACS2017 (Pre and Post Exclusions)

Pre-Exclusions:

All 450 Block Groups: ACS 2013 Estimate		All 450 Block Groups: ACS 2017 Estimate		All 450 Block Groups: Percent Change	
Average of ACS13 Median household income in the past 12 months (in 2013 inflation-adjusted dollars)	$80,117	Average of ACS17 Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	$87,145	Percent Change Average of Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	8.77%
StdDev of ACS13 Median household income in the past 12 months (in 2013 inflation-adjusted dollars)	$49,723	StdDev of ACS17 Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	$54,886	Percent Change StdDev of Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	10.38%
Median of ACS13 Median household income in the past 12months(in 2013 inflation adjusted dollars)	$71,049	Median of ACS17 Median HH Income in the past 12months (in 2017 inflation adjusted dollars)	$80,976	Percent Change Median of HH Income in the past 12months (in 2017 inflation adjusted dollars)	13.97%
Sum of ACS13 Estimate_HUs	298,327	Sum of ACS17_Estimate_ HUs	308,161	Percent Change, Sum of HU	3.30%
Average of ACS13_Estimate_HU s	663	Average of ACS17 HUs	685	Percent Change, Average of HUs	3.30%
Sum of ACS13 Vacant Total	34,678	Sum of ACS17 Vacant Total	30,176	Percent Change, Sum of Vacant Total:	-12.98%
Average of ACS13 Vacant	77	Average of ACS17 Vacant	67	Percent Change, Average of Vacant	-12.98%

Sum of ACS13;Tenure Total: - Owner occupied	111,070	Sum of ACS17;Tenure Total: - Owner occupied	115,795	Percent Change, Tenure Total: - Owner occupied	4.25%
Average of ACS13; Tenure Total: - Owner occupied	247	Average of ACS17; Tenure Total: - Owner occupied	257	Percent Change, Average of Tenure Total: - Owner occupied	4.25%
Sum of ACS13_UnitsinStructureCombined(1attachedto19)	159,296	Sum of ACS17_UnitsinStructureCombined(1attachedto19)	162,229	Percent Change, Sum of Units in Structure Combined(1attachedto19)	1.84%
Average of ACS13 Units in Structure Combined(1attachedto19)	354	Average of ACS17_ Units in Structure Combined(1attachedto19)	361	Percent Change, Average of Units in Structure Combined(1attachedto19)	1.84%
Average of ACS13 Median year structure built	1929	Average of ACS17_ Median year structure built	1944	Percent Change, Average of Median year structure built	0.77%
Median_of_ACS13 Median year structure built	1946	Median_ACS17 Median year structure built	1948	Percent Change, Median YEAR Structure Built	0.10%
Average of ACS13_Median Rent	$1,203	Average of ACS17_ Median Rent	$1,368	Percent Change, Average of MEDIAN_RENT	13.67%
Median of ACS13 Median Rent	$1,125	Median of ACS17_Median Rent	$1,295	Percent Change, Median of Median Rent	15.05%
Average of ACS13_Estimate; Median Housing value (dollars)	$469,673	Average of ACS17_Estimate; Median Housing value (dollars)	$523,462	Percent Change, Average of ACS17_Estimate; Median Housing value (dollars)	11.45%
Median of ACS13_ Median Housing value (dollars)	$412,176	Median of ACS17_ Median Housing value (dollars)	$470,300	Percent Change, Median of ACS17_ Median Housing value (dollars)	14.10%
Sum of ACS13_2nd Mortgage	20,794	Sum of ACS17_2nd Mortgage	16,083	Percent Change, Sum of ACS17_2nd Mortgage	-22.66%
Average of ACS13_2nd Mortgage	46	Average of ACS17_2nd Mortgage	36	Percent Change, Average of ACS17_2nd Mortgage	-22.66%

Median of ACS13_2nd Mortgage	37		Median of ACS17_2nd Mortgage	30	Percent Change, Median of ACS17_2nd Mortgage	-18.92%

Post Exclusions:

Post Exclusions 331 Block Groups: ACS 2013			Post Exclusions 331 Block Groups: ACS 2017			Post Exclusions 331 Block Groups: Percent Change			Difference (450 - 331)
Average of ACS13 Median household income in the past 12 months (in 2013 inflation-adjusted dollars)	$67,269		Average of ACS17 Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	$74,292		Average of ACS17_Estimate; Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	10.44%		1.67%
StdDev of ACS13 Median household income in the past 12 months (in 2013 inflation-adjusted dollars)	$30,249		StdDev of ACS17 Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	$41,108		StdDev of ACS17_Estimate; Median household income in the past 12 months (in 2017 inflation-adjusted dollars)	35.90%		25.52%
Median of ACS13 Median household income in the past 12months(in 2013 inflation adjusted dollars)	$64,654		Median of ACS17 Median HH Income in the past 12months (in 2017 inflation adjusted dollars)	$72,031		Median of ACS17_Estimate:Median HH Income in the past 12months (in 2017 inflation adjusted dollars)	11.41%		-2.56%
Sum of ACS13 Estimate_HUs	239,294		Sum of ACS17_Estimate_HUs	246,111		Sum of ACS17_Estimate_HUs; Total	2.85%		-0.45%

Average of ACS13_Estimate_HUs	723	Average of ACS17 HUs	744	Average of ACS17_Estimate_HUs; Total	2.85%		-0.45%
Sum of ACS13 Vacant Total	27,832	Sum of ACS17 Vacant Total	23,381	Sum of ACS17_Estimate;Vacant Total:	-15.99%		-3.01%
Average of ACS13 Vacant	84	Average of ACS17 Vacant	71	Average of ACS17_Estimate;Vacant Total:	-15.99%		-3.01%
Sum of ACS13;Tenure Total: - Owner occupied	80,478	Sum of ACS17;Tenure Total: - Owner occupied	84,873	Sum of ACS17_Estimate;Tenure Total: - Owner occupied	5.46%		1.21%
Average of ACS13; Tenure Total: - Owner occupied	243	Average of ACS17; Tenure Total: - Owner occupied	256	Average of ACS17_Estimate;Tenure Total: - Owner occupied	5.46%		1.21%
Sum of ACS13_UnitsinStructureCombined(1attachedto19)	128,882	Sum of ACS17_UnitsinStructureCombined(1attachedto19)	130,982	Sum of ACS17_UnitsinStructureCombined(1attachedto19)	1.63%		-0.21%
Average of ACS13 Units in Structure Combined(1attachedto19)	389	Average of ACS17_ Units in Structure Combined(1attachedto19)	396	Average of ACS17_UnitsinStructureCombined(1attachedto19)	1.63%		-0.21%
Average of ACS13 Median year structure built	1940	Average of ACS17_ Median year structure built	1954	Average of ACS17_Estimate; Median year structure built	0.68%		-0.08%
Median_of_ACS13 Median year structure built	1949	Median_ACS17 Median year structure built	1948	Median_ACS17MedianYEAR_StructureBuilt	-0.05%		-0.15%

Average of ACS13_Median Rent	$1,207		Average of ACS17_Median Rent	$1,345		Average of ACS17_MEDIAN_RENT	11.44%		-2.23%
Median of ACS13 Median Rent	$1,116		Median of ACS17_Median Rent	$1,295		Median of ACS17_MedianRent	15.95%		0.89%
Average of ACS13_Estimate; Median Housing value (dollars)	$409,178		Average of ACS17_Estimate; Median Housing value (dollars)	$447,147		Average of ACS17_Estimate; Median value (dollars)	9.28%		-2.17%
Median of ACS13_Median Housing value (dollars)	$389,216		Median of ACS17_Median Housing value (dollars)	$470,300		Median of ACS17_Median Value (dollars)	20.83%		6.73%
Sum of ACS13_2nd Mortgage	13,840		Sum of ACS17_2nd Mortgage	10,997		Sum of ACS17_2ndMorgage	-20.54%		2.11%
Average of ACS13_2nd Mortgage	42		Average of ACS17_2nd Mortgage	33		Average of ACS17_2ndMorgage	-20.54%		2.11%
Median of ACS13_2nd Mortgage	35		Median of ACS17_2nd Mortgage	30		Median of ACS17_2ndMorgage	-14.29%		4.63%

Table A-2: Correlation between Census Indicators Percent Change

Indicator Names	PerCh_Median_HH_Income_past12mos	PerCh_Estimate_HUs	PerCh_Vacant Total	PerCh_Tenure Total_OwnerOcc	PerCh_UnitsinStructureCombined(1attachedto19)	PerCh_Median_year_structure_built	PerCh_MedianRent	PerCh_MedianHomeValue_dollars	PerCh_2ndMorgage
PerCh_Median_HH_Income_past12mos	**1.00**								
PerCh_Estimate_HUs	-0.06	**1.00**							

PerCh_Vacant Total	-0.04	0.16	**1.00**						
PerCh_Tenure Total_OwnerOcc	0.11	0.27	-0.09	**1.00**					
PerCh_UnitsinStructureCombined(1attachedto19)	-0.06	0.23	0.02	0.08	**1.00**				
PerCh_Median_year_structure_built	-0.05	0.24	0.05	-0.01	-0.06	**1.00**			
PerCh_MedianRent	0.29	0.06	-0.10	0.03	-0.01	0.08	**1.00**		
PerCh_MedianHomeValue_dollars	0.17	0.09	-0.03	0.07	-0.02	0.02	0.07	**1.00**	
PerCh_2ndMorgage	-0.02	0.06	-0.01	0.17	-0.01	0.03	-0.05	0.04	**1.00**

Table A-3: Building Permits Joined to Block Groups Statistics (Pre and Post Exclusions)

Pre-Exclusion (All 450 Block Groups)						
Permit Category	**Sum**	**Mean/ Block Group**	**Median/ Block Group**	**Sum**	**Mean/Block Group**	**Median/Block Group**
Addition_AdditionAlterationtRepair_Alteration Repair	52,933	118	82	347,853,392	773,008	99,447
Electtric_ElectricGen_ElectHeavyUp	13,927	31	23	239,659,464	532,577	4,413
Plumbing_PlumbingGas	12,368	28	20	230,131,481	511,403	5,001
Raze	583	3	2	214,532,530	476,739	0
New Building	2,466	9	3	23,352,104	51,894	1,880
Demolition	3,596	9	5	3,461,399	7,692	929
Mechanical	5,574	13	10	987,426	2,194	904
NA.CertOccupancy	4,243	11	6	603,533	1,341	535
Building	12,514	29	23	449,977	1,000	687
Total	108,204	251	174	1,061,031,305	2,357,847	113,796

Post-Exclusion (331 Block Groups)						
Permit Category	**Sum**	**Mean/ Block Group**	**Median/Block Group**	**Sum**	**Mean/Block Group**	**Median/Block Group**
Addition_AdditionAlterationt Repair_Alteration Repair	36,202	110	77	310,402,028	937,770	94,852
Electtric_ElectricGen_ElectHeavyUp	10,028	31	22	238,386,298	720,200	4,136
Plumbing_PlumbingGas	8,762	27	18	229,018,369	691,898	4,759
Raze	401	3	2	1,813,772	5,480	0
New Building	1,959	10	3	17,496,663	52,860	1,438
Demolition	2,496	9	5	2,584,924	7,809	832
Mechanical	3,911	12	10	762,054	2,302	860
NA.CertOccupancy	3,206	11	6	443,082	1,339	528
Building	9,200	29	20	331,034	1,000	650
Total	76,165	241	163	801,238,225	2,420,659	108,054

Raw Change Post Exclusions						
Permit Category	**Sum**	**Mean/Block Group**	**Median/Block Group**	**Sum**	**Mean/Block Group**	**Median/Block Group**
Addition_AdditionAlterationt Repair_Alteration Repair	-16,731	-8	-5	-37,451,364	164,763	-4,595
Electtric_ElectricGen_ElectHeavyUp	-3,899	-1	-1	-1,273,167	187,624	-277
Plumbing_PlumbingGas	-3,606	-1	-2	-1,113,112	180,495	-242
Raze	-182	0	0	-212,718,758	-471,259	0
New Building	-507	1	0	-5,855,441	966	-442
Demolition	-1,100	0	0	-876,474	117	-97
Mechanical	-1,663	-1	0	-225,372	108	-44
NA.CertOccupancy	-1,037	0	0	-160,450	-3	-7
Building	-3,314	0	-3	-118,943	0	-37
Total	-32,039	-10	-11	-259,793,080	62,812	-5,742

Percent Change Post Exclusion						
Permit Category	**Sum**	**Mean/Block Group**	**Median/Block Group**	**Sum ost alue**	**Mean/Block Group**	**Median/Block Group**
Addition_AdditionAlterationtRepair_Alteration Repair	-32%	-7%	-6%	-11%	21%	-5%
Electtric_ElectricGen_ElectHeavy Up	-28%	-2%	-4%	-1%	35%	-6%
Plumbing_PlumbingGas	-29%	-3%	-8%	0%	35%	-5%
Raze	-31%	1%	0%	-99%	-99%	#DIV/0!
New Building	-21%	11%	0%	-25%	2%	-24%
Demolition	-31%	-3%	0%	-25%	2%	-10%
Mechanical	-30%	-4%	0%	-23%	5%	-5%
NA.CertOccupancy	-24%	-2%	0%	-27%	0%	-1%
Building	-26%	-1%	-13%	-26%	0%	-5%
Total	-30%	-4%	-6%	-24%	3%	-5%

Table A-4: Building Permits Definitions (definitions from the DCRA Building Permits Portal, 2019)

Permit Type	Definition	Submission Requirements
Certificate of Occupancy	A certificate of occupancy is needed to occupy any structure other than a single-family dwelling. To include the following uses: two family flat, apartment house and all commercial uses. (Accessory dwellings do not require a Certificate of Occupancy but a Building Permit is required). The main purpose of a Certificate of Occupancy is to needed ensure that the use of a building, structure or land in the District of Columbia conforms to the Zoning Regulations (DCMR Title 11) provisions of the DC Construction Codes, and the Green Building Act. In most cases, no person can use a building, structure or land in the District of Columbia for any purpose other than a single-family dwelling, until a valid Certificate of Occupancy has been issued.	Requirements vary based on type. Consult the DCRA site for details (https://dcra.dc.gov/node/1410111)

	There are six types of Certificate of Occupancy applications including Ownership Change, Use Change, Occupant Load Change, Revision, Temporary Occupancy, and New Building	
ADDITION (2016 OLDER)	This type of permit is an extension or increase in the building area, aggregate floor area, number of stories, or height of a building or structure.	1) All additions (i.e. increase in height or length, enclosing an existing structure) must include a surveyor's plat that details the evaluation and dimensions of the existing and proposed structures. 2) If you are submitting a residential addition that is less 500 square feet, above grade and one level, your plans can be reviewed within our Homeowners Center. Please be sure to provide a minimum of 3 sets of plans on a minimum of 11 x 17 paper. (**Please view the Homeowners Center page for the advantages and criteria of the Homeowner's Center.) 3) If work includes construction on the property line or party walls, neighbor notification is required
ADDITION ALTERATION REPAIR	This type of permit is an extension or increase in the building area, aggregate floor area, number of stories, or height of a building or structure.	1) All additions (i.e. increase in height or length, enclosing an existing structure) must include a surveyor's plat that details the evaluation and dimensions of the existing and proposed structures. 2) If you are submitting a residential addition that is less 500 square feet, above grade and one level, your plans can be reviewed within our Homeowners Center. Please be sure to provide a minimum of 3 sets of plans on a minimum of 11 x 17 paper. (**Please view the Homeowners Center page for the advantages and criteria of the Homeowner's Center.) 3) If work includes construction on the property line or party walls, neighbor notification is required
ALTERATION AND REPAIR	Any construction or renovation to an existing structure, to include space reconfiguration, replacement in kind, repairs etc.	1) For interior renovations such as kitchen or bathroom remodeling and interior renovation of an existing commercial space, Alteration and Repair is the appropriate permit type. 2) Architectural plans are needed for review and if the square footage of

		the work area is less than 1000 square feet, your project can be reviewed over the counter in the Permit Center. 3) For projects that exceed 1000 square feet, plans are reviewed in electronically within ProjectDox.
DEMOLITION	The removal of interior and/or exterior elements, systems or finishes. (Not a Raze).	1) Interior and exterior demolition of less than 5,000 square feet, pictures are required to complete the plan review. (If your property is not within a historic district, you can apply, pay and receive a postcard permit online). Please check our Property Information Verification System (PIVS) to confirm. 2) For projects that exceed the above square footage, plans will be required for review along with pictures to show what is existing. 3) Demolition work can also be included in the submission of your Building Permit, depending on the timeline of your project. (Please ensure to detail demolition details within your description of work and within your drawing submittal)
NEW BUILDING	Construction of an entirely new structure that has not been previously occupied.	1) Architectural plans are required for plan review. A structural engineer is required for structural work. 2) A surveyor's plat is required for review and must detail the location of the new structure.
RAZE	This permit is required if nothing remains at the site except for a party wall and/or a foundation.	1) Certificate of Insurance is required for covering the raze contractor unless the accessory building/structural is 500 square feet or less in area and no more than one story fully detached. 2) Pictures of the existing structure
Building	Any construction done on public space requires a separate public space permit issued by the District Department of Transportation. A Building Permit is required for the following work: - Repairing a fence up to a height of 7 feet (2.13 meters) above grade, entirely on private property and behind the building restriction line. - Interior demolition of non-bearing elements in a space up to 5,000 square feet (464.5 square meters) - Application of fire-retardant paint, up to 5 gallons. - Installation of 1 temporary construction trailer on	N/A

	private property. - (Any Fireworks Permits issued after June 26, 2009 shall be deemed invalid.) - Erection of 1 Christmas tree stand on private property. - Renewal of an active Building Permit. - Revision of an active permit for change of ownership or change of address. - Repairs of existing fire escape. -Repairs of front porch and steps in a single family dwelling. - Repairs of rear porch and steps in a single family dwelling. -Repairs of up to 4 stories of a single interior stairway. - Repairs of guardrails and/or handrails in up to 4 stories of a single interior stairway. - Repairs of guardrails of up to 5 balconies. - Replacement in kind of guards and guardrails of up to 5 balconies and/or exterior porches on the same building. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of up to 5 fire windows. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of up to 5 fire doors. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of up to 5 fire or smoke dampers. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of up to 10 sprinklers, on an existing residential, commercial or industrial system. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of rated suspended ceiling tile in an area up to 5,000 square feet (464.5 square meters). Replacement in kind, when applied to architectural features, means replacement with a	

	feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of existing fence on private property. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of interior wall coverings. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of up to 800 square feet (74.3 square meters) of gypsum board. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of ductwork of a single system, in non-hazardous exhaust and commercial kitchen exhaust systems. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. -Replacement in kind of up to 4 stories of a single interior stairway. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions. - Replacement in kind of guards, guardrails and/or handrails in up to 4 stories of a single interior stairway. Replacement in kind, when applied to architectural features, means replacement with a feature of like material that replicates the existing feature in proportion, appearance, texture, design, detail and dimensions.	
Electrical - General	An electrical (general) postcard permit is required for this work: -Installation of not more than 10 new outlets and not more than 10 new lighting fixtures for a residential, commercial or industrial project. - Replacement or repair of not more than 10 existing outlets and not more than 10 existing lighting fixtures for a residential, commercial or industrial project. - Installation of not more than 10 new outlets in a power-limited system for a residential, commercial or industrial project.	N/A

	- Installation or replacement of not more than 1 residential electric appliance for a residential project.	
Electrical - Heavy Up	The electrical (heavy-up) postcard can be issued only to licensed contractors -- to upgrade 1 existing electrical system to a maximum of 200 Amps. This electrical postcard permit does not authorize the erection of electrical service and/or meter boxes in public space.	N/A
Mechanical	The mechanical postcard permit can be issued only to licensed contractors for. -Installation of not more than 1 new air conditioning unit, up to a maximum of 10-tons of equivalent refrigerating effect. - Repairs to not more than 1 existing refrigerating or cooling unit, up to a maximum of 10-tons of equivalent refrigerating effect. - Conversion of 1 existing refrigerating or cooling unit to adapt it to use an environmentally safe refrigerant in a residential, commercial or industrial facility, not including the installation of rated detection, alarm and ventilation devices. - Installation, as required, of gas detection, alarm and ventilation devices related to the use of environmentally safe refrigerants as a result of the conversion of existing refrigerating or cooling equipment, in a single location, inside a residential, commercial or industrial facility.	N/A
Plumbing	The plumbing postcard permit can be issued to licensed contractors only. - Installation of not more than 1 new plumbing fixture, on a residential, commercial or industrial project. - Repairs to existing plumbing systems, including the installation of not more than 1 new fixture. - Minor alterations to existing plumbing systems, including the installation of not more than 1 new fixture. Excludes changing the piping layout serving more than 3 fixtures, including domestic water, sewer or venting systems. -Replacement of not more than 1 plumbing fixture, on a residential, commercial or industrial project. - Installation of 1 backflow preventer. - One sewer or water line cut. - Pressure testing of a single water system.	N/A
Electrical	Repair, replacement, or installation of an electrical system (s).	N/A

Mechanical	Installation, repair, or replacement of a refrigeration and/or air conditioning system.	N/A
Plumbing and Gas	Repair, replacement or installation of a plumbing or gas system.	N/A

Figure A-1: Output of SCB AHP Template (Top Census Indicators, Bottom: Building Permits)

	Median_HH_Incom	MedianHomeVal	MedianRent	Median_year_str	UnitsinStructure(	Tenure Total_Ow	Estimate_HUs	Vacant Total	2ndMorgage	AHP
Median_HH_Income_past12mos	1	2	2	3	3	4	5	6	7	0.294
MedianHomeValue_dollars	1/2	1	1	2	2	3	4	5	6	0.168
MedianRent	1/2	1	1	2	2	3	4	5	6	0.168
Median_year_structure_built	1/3	1/2	1/2	1	1	2	3	4	5	0.098
UnitsinStructureCombined(1atta	1/3	1/2	1/2	1	1	2	3	4	5	0.098
Tenure Total_OwnerOcc	1/4	1/3	1/3	1/2	1/2	1	2	3	4	0.064
Estimate_HUs	1/5	1/4	1/4	1/3	1/3	1/2	1	2	3	0.046
Vacant Total	1/6	1/5	1/5	1/4	1/4	1/3	1/2	1	2	0.035
2ndMorgage	1/7	1/6	1/6	1/5	1/5	1/4	1/3	1/2	1	0.028
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Column totals	3.4262	5.9500	5.9500	10.2833	10.2833	16.0833	22.8333	30.5000	39.0000	

Consistency check
Consistency OK
3%

	Cw (Normalised)								
1	0.291869354	0.336134454	0.336134454	0.291734198	0.291734198	0.248704663	0.218978102	0.196721311	0.179487179
2	0.145934677	0.168067227	0.168067227	0.194489465	0.194489465	0.186528497	0.175182482	0.163934426	0.153846154
3	0.145934677	0.168067227	0.168067227	0.194489465	0.194489465	0.186528497	0.175182482	0.163934426	0.153846154
4	0.097289785	0.084033613	0.084033613	0.097244733	0.097244733	0.124352332	0.131386861	0.131147541	0.128205128
5	0.097289785	0.084033613	0.084033613	0.097244733	0.097244733	0.124352332	0.131386861	0.131147541	0.128205128
6	0.072967338	0.056022409	0.056022409	0.048622366	0.048622366	0.062176166	0.087591241	0.098360656	0.102564103
7	0.058373871	0.042016807	0.042016807	0.032414911	0.032414911	0.031088083	0.04379562	0.06557377	0.076923077
8	0.048644892	0.033613445	0.033613445	0.024311183	0.024311183	0.020725389	0.02189781	0.032786885	0.051282051
9	0.041695622	0.028011204	0.028011204	0.019448947	0.019448947	0.015544041	0.01459854	0.016393443	0.025641026

	Add_AddAltRep_A	Elect_ElectGen_E	Plumbing_Plumb	Raze	New Building	Demolition	Mechanical	NA.CertOccupanc	Building	AHP
Add_AddAltRep_AltRep	1	2	2	3	4	5	6	7	8	0.312
Elect_ElectGen_ElectHeavyUp	1/2	1	1	2	3	4	5	6	7	0.178
Plumbing_PlumbingGas	1/2	1	1	2	3	4	5	6	7	0.178
Raze	1/3	1/2	1/2	1	2	3	4	5	6	0.108
New Building	1/4	1/3	1/3	1/2	1	2	3	4	5	0.073
Demolition	1/5	1/4	1/4	1/3	1/2	1	2	3	4	0.053
Mechanical	1/6	1/5	1/5	1/4	1/3	1/2	1	2	3	0.040
NA.CertOccupancy	1/7	1/6	1/6	1/5	1/4	1/3	1/2	1	2	0.032
Building	1/8	1/7	1/7	1/6	1/5	1/4	1/3	1/2	1	0.026
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Column totals	3.2179	5.5929	5.5929	9.4500	14.2833	20.0833	26.8333	34.5000	43.0000	

Consistency check
Consistency OK
4%

	Cw (Normalised)								
1	0.310765816	0.357598978	0.357598978	0.317460317	0.280046674	0.248962656	0.223602484	0.202898551	0.186046512
2	0.155382908	0.178799489	0.178799489	0.211640212	0.210035006	0.199170124	0.186335404	0.173913043	0.162790698
3	0.155382908	0.178799489	0.178799489	0.211640212	0.210035006	0.199170124	0.186335404	0.173913043	0.162790698
4	0.103588605	0.089399745	0.089399745	0.105820106	0.140023337	0.149377593	0.149068323	0.144927536	0.139534884
5	0.077691454	0.05959983	0.05959983	0.052910053	0.070011669	0.099585062	0.111801242	0.115942029	0.11627907
6	0.062153163	0.044699872	0.044699872	0.035273369	0.035005834	0.049792531	0.074534161	0.086956522	0.093023256
7	0.051794303	0.035759898	0.035759898	0.026455026	0.023337223	0.024896266	0.037267081	0.057971014	0.069767442
8	0.044395117	0.029799915	0.029799915	0.021164021	0.017502917	0.01659751	0.01863354	0.028985507	0.046511628
9	0.038845727	0.025542784	0.025542784	0.017636684	0.014002334	0.012448133	0.01242236	0.014492754	0.023255814

9. Appendix B – Media Sources

Table A-1: A decomposition extraction assessment of media articles referencing gentrification in Washington D.C

ID	Source	Publication Date	Author	Category	Title
1	CNNMoney	9/25/2017	Mat Egan	General/Banking and Investment	JPMorgan devotes $10 million to fight poverty in Washington D.C
2	The Washington Post	2/23/2017	Jean Folger	General/Banking and Investment	7 Gentrifying Neighborhoods In Washington, D.C.
3	Governing.com	7/20/2017	David Rusk	News/Local Web	Goodbye to Chocolate City
4	NPR	9/14/2015	Michelle Goldchain	General	Mapping Gentrification in Washington, D.C.
5	OZY (World Net News) and JP Morgan Chase	10/11/2017	Delia Goncalves	News/Local Web	Gentrification in DC raises property values, but does it also push people out? The unintended consequences of what some call this 21st Century urban renewal.
6	WUSA Local DC News	12/5/2017	Daniella Zessoules	News	Gentrification in Washington, D.C.: Not Just Historic Height Limits and Hip Coffee Shops
7	Investopedia	10/13/2017	Alex Mooney	News/Local Web	Inequality Displaces Black DC Residents
8	WTOP Local DC News	10/2/2017	Steve Dubb	News	DC Adopts Community Land Trust Approach to Avert Further Gentrification
9	AFRO	12/21/2017	Alisha Butler	News/Local Web	Gentrification can increase school diversity, a new study of DC shows
10	The Hoya	9/16/2015	Kojo Nnamdi	News/Local Web	Gentrification's Latest Victim? D.C.'s Historic Murals
11	Therealstreetz	4/29/2013	Matthew Yglesias	News/Local Web	The Perverse Politics of Gentrification
12	Nonprofit Quarterly	12/6/2016	Dyana Forester	News	Washington, D.C.: A Tale Of Two Cities
13	The Atlantic	6/8/2016	Pamela Boyce Simms	News/Local	At the Nexus of Gentrification and Environmentalism How Groundwork Anacostia River DC is Shaping Their Own Future
14	Greater Greater Washington	7/7/2016	Lisa Sturtevant	News	Can We Predict Gentrification?
15	Greater Greater Washington	9/14/2015	Kate Rabinowitz	Data	DC Gentrification by the Numbers
16	Realtor.com	1/23/2017	Yuqing Pan	News/National	The U.S. Cities That Are Gentrifying the Fastest—You'll Never Guess No. 1
17	The Daily Beast	12/11/2015	David Alpert	News/Local Web	House prices are skyrocketing in central DC neighborhoods, but not in outlying ones
18	FOX5 Local DC News	9/2/2016	Uzodinma Iweala	News	The gentrification of Washington DC: how my city changed its colours

19	NPR (Kojo Nnamdi Show)	11/2/ 2017	Laura Elizabeth	General/Banking and Investment	Washington, D.C., Is Taking a Gamble to Fight Gentrification
20	Marketplace.org	4/20/ 2015	Sean Nevins	News	Beyond Gentrification: Hundreds Of DC Residents Being Forced From Their Homes
21	The Root	7/8/2 015	Perry Stein	News/Local	A D.C. resident hopes these yard signs can save his neighborhood from gentrifiers
22	Vice News	8/11/ 2014	Vann R. Newkirk II	News	Irrigating the (Food) Desert: A Tale of Gentrification in D.C
23	Slate	5/11/ 2013	Dan Mizrahi	News/Local Web	The Target Effect, or, How Big Box Is Bringing Washington D.C. Together; Dan Mizrahi reports on how Target became the symbol of a changning neighborhood
24	CNN Money	9/14/ 2012	Martin DiCaro	News	D.C.'s Ward 7 Prepares For New Growth, New Residents
25	DC Policy Center	6/12/ 2006	Lyndsay Layton	General/Banking and Investment	Breathing New Rhythm Into Tired Streets; Yoga Studios Signal D.C. Gentrification
26	Captal News Service Maryland	2/5/2 018	Jeff Clabaugh	News/Local TV	2 DC ZIP codes among nation's 'most gentrified'
27	Gawker	12/26 /2017	Andrew Small	News/Local Web	Bikes and Cycling
28	City Lab	7/18/ 2017	Adam Allington	News/Local Web	NOMA BID/Eckington
29	Next City	3/9/2 017	Scott Rodd	News/Local Web	Gentrified: A tale of two neighborhoods in Washington, D.C.
30	Lakritz Adler Real Estate Dev	3/15/ 2017	Scott Rodd	News/Local Web	The uncertain future of low-income housing in the heart of D.C.
31	Medium Corp (good quotes)	9/10/ 2012	Martin DiCaro	News/Transport	Special Report: How Transit Is Shaping the Gentrification of D.C., Part 1.
32	Medium Corp	12/23 /2014	Janelle Harris	News/Local Web	11 Signs Your Hood Is Being Gentrified
33	Huffington Post	6/12/ 2017	Derek Hyra	News/Local Web	"Selling a Black D.C. Neighborhood to White Millennials" washingtondc real estate branding white millennials
34	HAND (The Housing Association of Nonprofit Developers)	5/3/2 017	Robert McCartney	News/Local Paper	'Black branding' — how a D.C. neighborhood was marketed to white millennials
35	Data Lens DC	1/16/ 2017	Sam Gringlas (Author)/Raquel Zaldivar	News/National	Old Confronts New In A Gentrifying D.C. Neighborhood
36	WNYC	8/10/ 2012	Garance Franke-Ruta	News	The Politics of the Urban Comeback: Gentrification and Culture in D.C.
37	WAMU	12/9/ 2016	Camille Chrysostom	News/Local Web	Gentrification spreading from Washington, D.C. to Prince George's County
38	MintPress News	3/28/ 2016	Briana Younger	News	How Gentrification and Geography Influence DC Hip-Hop The sound of DC is changing, and hip-hop, long overshadowed by go-go, is becoming more prominent.

39	The Washington Post	2/1/2018	James Wright	News/Local Web	D.C.'s Deanwood is Slowly Gentrifying

Bibliography for Table A-2

Allington, A. (2017). *NOMA BID/Eckington*. City Lab. https://www.nomabid.org/the-neighborhood. Retrieved November 10, 2018

Alpert, D. (2015). House prices are skyrocketing in central DC neighborhoods, but not in outlying ones. The Daily Beast. https://ggwash.org/view/40203/house-prices-are-skyrocketing-in-central-dc-neighborhoods-but-not-in-outlying-ones. Retrieved November 2, 2018

Boyce-Simms, P. (2016). At the Nexus of Gentrification and Environmentalism: How Groundwork Anacostia River DC is Shaping Their Own Future. The Atlantic. http://www.geo.coop/story/nexus-gentrification-and-environmentalism. Retrieved October 11, 2018

Butler, A. (2017). Gentrification can increase school diversity, a new study of DC shows. AFRO. https://ggwash.org/view/65994/gentrification-can-increase-school-diversity-a-new-study-of-dc-schools-shows. Retrieved October 11, 2018

Chrysostom, C. (2016). Gentrification spreading from Washington, D.C. to Prince George's County. WAMU. http://cnsmaryland.org/2016/12/09/gentrification-spreading-from-washington-d-c-to-prince-georges-county/. Retrieved November 10, 2018

Clabaugh, J. (2018). 2 DC ZIP codes among nation's 'most gentrified'. Captal News Service Maryland. https://wtop.com/real-estate/2018/03/most-gentrified-zip-codes-dc/. Retrieved November 2, 2018

DiCaro, M. (2012). D.C.'s Ward 7 Prepares For New Growth, New Residents. CNN Money. https://wamu.org/story/12/09/14/from_a_to_b_dcs_ward_7_prepares_for_new_growth_new_residents/. Retrieved November 2, 2018

DiCaro, M. (2012). Special Report: How Transit Is Shaping the Gentrification of D.C., Part 1.. Medium Corp (good quotes). http://www.wnyc.org/story/284287-gentrification-and-transportation-in-dc-part-1/. Retrieved November 10, 2018

Dubb, S. (2017). DC Adopts Community Land Trust Approach to Avert Further Gentrification. WTOP Local DC News. https://nonprofitquarterly.org/2017/10/02/dc-adopts-community-land-trust-approach-avert-gentrification/. Retrieved October 11, 2018

Egan, M. (2017). JPMorgan devotes $10 million to fight poverty in Washington D.C. CNNMoney. http://money.cnn.com/2017/09/25/investing/washington-dc-jpmorgan-dimon-inequality/index.html. Retrieved July 14, 2018

Elizabeth, L. (2017). Washington, D.C., Is Taking a Gamble to Fight Gentrification. NPR (Kojo Nnamdi Show). https://www.ozy.com/acumen/washington-dc-is-taking-a-gamble-to-fight-gentrification/81828. Retrieved November 2, 2018

Folger, J. (2017). 7 Gentrifying Neighborhoods In Washington, D.C.. The Washington Post. https://www.investopedia.com/articles/investing/022317/7-gentrifying-neighborhoods-washington-dc.asp. Retrieved July 15, 2018

Forester, D. (2016). Washington, D.C.: A Tale Of Two Cities. Nonprofit Quarterly. https://www.huffingtonpost.com/entry/dc-a-tale-of-two-cities_us_5846e6eee4b016eb81d823e5. Retrieved October 11, 2018

Franke-Ruta, G. (2012). The Politics of the Urban Comeback: Gentrification and Culture in D.C. WNYC. https://www.theatlantic.com/politics/archive/2012/08/the-politics-of-the-urban-comeback-gentrification-and-culture-in-dc/260741/. Retrieved November 10, 2018

Goldchain, M. (2015). Mapping Gentrification in Washington, D.C. NPR. https://dc.curbed.com/washington-dc-gentrification. Retrieved August 25, 2018

Goncalves, D. (2017). Gentrification in DC raises property values, but does it also push people out? The unintended consequences of what some call this 21st Century urban renewal. . OZY (World Net News) and JP Morgan Chase. http://www.wusa9.com/article/news/local/dc/gentrification-in-dc-raises-property-values-but-does-it-also-push-people-out/65-482281216. Retrieved August 25, 2018"

Gringlas & Zaldivar, S. (2017). Old Confronts New In A Gentrifying D.C. Neighborhood. Data Lens DC. https://www.npr.org/2017/01/16/505606317/d-c-s-gentrifying-neighborhoods-a-careful-mix-of-newcomers-and-old-timers.Retrieved November 10, 2018

Harris, J. (2014). 11 Signs Your Hood Is Being Gentrified. Medium Corp. https://www.theroot.com/11-signs-your-hood-is-being-gentrified-1790878177. Retrieved November 10, 2018

Hyra, D. (2017). "Selling a Black D.C. Neighborhood to White Millennials" Washington DC real estate branding white millennials. Huffington Post.https://nextcity.org/features/view/washington-dc-real-estate-branding-white-millennials. Retrieved November 10, 2018

Iweala, U. (2016). The gentrification of Washington DC: how my city changed its colors. FOX5 Local DC News. https://www.theguardian.com/cities/2016/sep/12/gentrification-washington-dc-how-my-city-changed-colours. Retrieved November 2, 2018

Layton, L. (2006). Breathing New Rhythm Into Tired Streets; Yoga Studios Signal D.C. Gentrification. DC Policy Center. http://www.lakritzadler.com/02-Breathing-New-Rhythm-WashingtonPost-June2006.php. Retrieved November 2, 2018

McCartney, R. (2017). 'Black branding' — how a D.C. neighborhood was marketed to white millennials. HAND (The Housing Association of Nonprofit Developers). https://www.washingtonpost.com/local/black-branding--how-a-dc-neighborhood-was-marketed-to-white-millenials/2017/05/02/68b0ae06-2f47-11e7-9534-00e4656c22aa_story.html?utm_term=.abdeb8e36845. Retrieved November 10, 2018

Mizrahi, D. (2013). The Target Effect or How Big Box Is Bringing Washington D.C. Together; Dan Mizrahi reports on how Target became the symbol of a changing neighborhood. Slate. https://www.thedailybeast.com/the-target-effect-or-how-big-box-is-bringing-washington-dc-together. Retrieved November 2, 2018"

Mooney, A. (2017). Inequality Displaces Black DC Residents . Investopedia. http://www.thehoya.com/inequality-displaces-black-dc-residents/. Retrieved October 11, 2018

Nevins, S. (2015). Beyond Gentrification: Hundreds Of DC Residents Being Forced From Their Homes. Marketplace.org. http://www.mintpressnews.com/beyond-gentrification-hundreds-of-dc-residents-being-forced-from-their-homes/204543/. Retrieved November 2, 2018

Nnamdi, K. (2015). Gentrification's Latest Victim? D.C.'s Historic Murals. The Hoya. https://thekojonnamdishow.org/shows/2015-09-16/gentrifications-latest-victim-d-c-s-historic-murals. Retrieved October 11, 2018

Pan, Y. (2017). The U.S. Cities That Are Gentrifying the Fastest—You'll Never Guess No. 1. Realtor.com. https://www.realtor.com/news/trends/10-surprising-cities-that-are-gentrifying-the-fastest/. Retrieved November 2, 2018

R. Newkirk, V. (2014). Irrigating the (Food) Desert: A Tale of Gentrification in D.C. Vice News. http://gawker.com/irrigating-the-food-desert-a-tale-of-gentrification-1617679708. Retrieved November 2, 2018

Rabinowitz, K. (2015). DC Gentrification by the Numbers. Greater Greater Washington. http://www.datalensdc.com/gentrification-by-numbers.html.. Retrieved November 2, 2018

Rodd, S. (2017). Gentrified: A tale of two neighborhoods in Washington, D.C.. Next City. https://medium.com/@ScottCRodd/gentrified-a-tale-of-two-neighborhoods-in-washington-d-c-c828b8f7a357. Retrieved November 10, 2018

Rodd, S. (2017). The uncertain future of low-income housing in the heart of D.C.. Lakritz Adler Real Estate Dev. https://medium.com/@ScottCRodd/the-uncertain-future-of-low-income-housing-in-the-heart-of-d-c-8a1b668fa0d2. Retrieved November 10, 2018

Rusk, D. (2017). Goodbye to Chocolate City. Governing.com. https://www.dcpolicycenter.org/publications/goodbye-to-chocolate-city/. Retrieved July 15, 2018

Small, A. (2017). Bikes and Cycling. Gawker. https://www.citylab.com/transportation/2017/12/how-washington-dc-built-a-bike-boom/548903/. Retrieved November 10, 2018

Stein, P. (2015). A D.C. resident hopes these yard signs can save his neighborhood from gentrifiers. The Root. https://www.washingtonpost.com/local/a-longtime-dc-resident-hopes-these-yard-signs-can-save-his-neighborhood-from-gentrifiers/2015/07/08/cf1a1776-259f-11e5-b72c-2b7d516e1e0e_story.html. Retrieved November 2, 2018

Sturtevant, L. (2016). Can We Predict Gentrification?. Greater Greater Washington. https://www.handhousing.org/can-we-predict-gentrification/. Retrieved October 11, 2018

Wright, J. (2018). D.C.'s Deanwood is Slowly Gentrifying. The Washington Post. http://www.afro.com/d-c-s-deanwood-slowly-gentrifying/. Retrieved November 10, 2018

Yglesias, M. (2013). The Perverse Politics of Gentrification. Therealstreetz. http://www.slate.com/blogs/moneybox/2013/04/29/trees_rent_and_inequality_the_perverse_politics_of_gentrification.html. Retrieved October 11, 2018

Younger, B. (2016). How Gentrification and Geography Influence DC Hip-Hop: The sound of DC is changing, and hip-hop, long overshadowed by go-go, is becoming more prominent.. MintPress News. https://www.vice.com/en_us/article/zng9p5/capitol-hip-hop-v23n1. Retrieved November 10, 2018"

Zessoules, D. (2017). Gentrification in Washington, D.C.: Not Just Historic Height Limits and Hip Coffee Shops . WUSA Local DC News. http://cepr.net/blogs/cepr-blog/gentrification-in-washington-d-c-not-just-historic-height-limits-and-hip-coffee-shops. Retrieved August 25, 2018

10. Appendix C - References

Aike, A. S., Ate, P., Bu-Sung, L., & Markus Schläpfer. (2018). The canary in the city: indicator groups as predictors of local rent increases. Epj Data Science, 7(1), 1–15. https://doi.org/10.1140/epjds/s13688-018-0151-y

Anselin, L. & GeoDa. (2020). Local Spatial Autocorrelation. Retrieved October 11, 2020, from https://Geodacenter.Github.Io/Workbook/5a_global_auto/Lab5a.Html. https://geodacenter.github.io/workbook/6b_local_adv/lab6b.html

Atkinson, Rowland. (2000). Measuring gentrification and displacement in greater London. Urban Studies 37 (1): 149-65.

Barton, M. S., Valasik, M. A., Brault, E., & Tita, G. (2020). "Gentefication" in the barrio: examining the relationship between gentrification and homicide in east Los Angeles. Crime and Delinquency, 66(13-14), 1888–1913. https://doi.org/10.1177/0011128719860835

Braswell, T. H. (2018). Fresh food, new faces: community gardening as ecological gentrification in St. Louis, Missouri. *Agriculture and Human Values*, 1-14, 1. https://doi.org/10.1007/s10460-018-9875-3

Christafore, D., & Leguizamon, S. (2019). Neighborhood inequality spillover effects of gentrification. *Papers in Regional Science,* 98(3), 1469–1484. https://doi.org/10.1111/pirs.12405

Department of Consumer and Regulatory Affairs. (2011–2017). Permit Records (Washington D.C Permit Records) [Database Portal for the Washington D.C Building Permit Records]. https://dcra.dc.gov/page/permit-records

ESRI. The American Community Survey. (2017), retrieved August 22, 2019 from http://downloads.esri.com/esri_content_doc/dbl/us/J10020_American_Community_Survey_2017.pdf

ESRI. How Geographically Weighted Regression (GWR) works—ArcGIS Pro | Documentation. (2020). Pro.Arcgis.Com. Retrieved October 14, 2020, from https://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/how-geographicallyweightedregression-works.htm

Fouch, Nakisha Tena. (2012). Planning for gentrification: A geographic analysis of gentrification susceptibility in the city of Asheville, N.C. *ProQuest, UMI Dissertations Publishing.*

Franke-Ruta,Garance. (2012).Facts and Fictions of D.C.'s Gentrification. Retrieved from http://www.theatlanticcities.com/politics/

Gafvert, Rebecca C. (2011). Mapping the Path of Gentrification: An Analysis of Gentrification Susceptibility in Cincinnati, Ohio. *ProQuest, UMI Dissertations Publishing.*

Gambrill, Kevin M. (2007). Neighborhood change and gentrification: Identification and analysis of small areas within Baltimore city, Maryland. ProQuest, *UMI Dissertations Publishing.*

Gibson, Timothy A. (2005). Selling city living: Urban branding campaigns, class power and the civic good. *International Journal of Cultural Studies* 8(3): 259-280.

Glaeser, E. L., Kim, H., & Luca, M. (2018). Measuring gentrification: using yelp data to quantify neighborhood change. *National Bureau of Economic Research Working Paper Series, 24952.*

Glass, R. (1961). London's newcomers: the west indian migrants (Ser. Centre for urban studies, university college, London. report, no. 1. Harvard University Press.

Government of the District of Columbia. (2020). *Open Data DC* [Neighborhood Clusters]. DCGIS Open Data: Planning, Land-use and Zoning. https://opendata.dc.gov/search?q=neighborhood-clusters

Government of the District of Columbia. (2020). *Open Data DC* [DC Boundary]. DCGIS Open Data: Planning, Land-use and Zoning. https://opendata.dc.gov/datasets/washington-dc-boundary

Greater Capital Area Association of Realtors (GCAAR). (2019). November 2019 Washington, DC Market Trends Report Median sales price highest November level in the past 10 years. Retrieved from https://gcaar.com/docs/default-source/dc-market-reports/gcaar_jan2016_dchousingmarketupdatefinal(3).pdf?sfvrsn=2https://gcaar.com/docs/default-source/dc-market-reports/gcaar-dc-housing-market-update---november-2019_final.pdf?sfvrsn=ba0bdb93_2

Green, R. D., Mulusa, J. K., Byers, A. A., & Parmer, C. (2017). The indirect displacement hypothesis: a case study in Washington, D.C. *The Review of Black Political Economy*, 44(1-2), 1–22. https://doi.org/10.1007/s12114-016-9242-9

Hartog, Rudolf. (1999). Growth without limits: Some case studies of 20th-century urbanization. *International Planning Studies* 4 (1): 95-130.

Heidkamp, Christian Patrick, and Susan Lucas. (2006). Finding the gentrification frontier using census data: The case of Portland, Maine. *Urban Geography* 27 (2): 101-25

Ilic, L., Sawada, M., & Zarzelli, A. (2019). Deep mapping gentrification in a large canadian city using deep learning and google street view. Plos One, 14(3), 0212814. https://doi.org/10.1371/journal.pone.0212814

Jiang, N., Pacheco, G., & Dasgupta, K. (2019). Understanding the transient population: insights from linked administrative data. *Journal of Population Research,* 36(2), 111–136. https://doi.org/10.1007/s12546-019-09223-y

Kennedy, Maureen, and Paul Leonard. (2001). Dealing with neighborhood change: A primer on gentrification and policy choices. *A Discussion Paper Prepared for The Brookings Institution Center on Urban and Metropolitan Policy.* *www.brookings.edu/urban* and PolicyLink www.policylink.org. 1-70.

Krausmann, Fridolin, Simone Gingrich, Nina Eisenmenger, Karl-Heinz Erb, Helmut Haberl, and Marina Fischer-Kowalski. (2009). Growth in global materials use, GDP and population during the 20th century. *Ecological Economics* 68 (10): 2696-705.

Leonnig , Carol D. (2004). Tenants' suit accuses D.C. of prejudice in evictions; gentrification caused ouster, Hispanics say: FINAL edition. *The Washington Post* 2004.

Ley, David. 2003. Artists, Aestheticisation and The Field of Gentrification. *Urban Studies* 40(12): 2527-2544.

Ley, David, and Sin Yih Teo. (2014). Gentrification in Hong Kong? Epistemology vs. ontology. *International Journal of Urban and Regional Research* 38 (4): 1286-303.

Levy, Laura. (2009). Mapping gentrification in Pilsen: Community Empowerment through GIS Technology. *Creating Knowledge: The LA&S Student Research Journal* 2 : 36-39.

Maciag, M. (2015). Washington, D.C., Gentrification Maps and Data. *Governing.* retrieved August 28, 2016 from https://www.governing.com/gov-data/washington-dc-gentrification-maps-demographic-data.html

Maciag, Mike. (2015). "Gentrification in America Report." Governing.Com, *Governing*, retrieved August 28, 2016 from *w*ww.governing.com/gov-data/census/gentrification-in-cities-governing-report.html.

Mann, B., Bennett, H., & Rogers, A. (2020). Gentrification, charter schools, and enrollment patterns in Washington, dc: shared growth or new forms of educational inequality? *Peabody Journal of Education*, 95(3), 211–228. https://doi.org/10.1080/0161956X.2020.1776070

Maantay, J. A., & Maroko, A. R. (2018). Brownfields to greenfields: environmental justice versus environmental gentrification. *International Journal of Environmental Research and Public Health*, 15(10). https://doi.org/10.3390/ijerph15102233

Murphy, Caryle. 2004. Parents protest plan to sell youth club; Columbia Heights site would be used for condos with recreation facility: FINAL edition. *The Washington Post* 2004.

Naik, N., Philipoom, J., Raskar, R., Hidalgo, C., & 2014 IEEE Conference on Computer Vision and Pattern Recognition Workshops, CVPRW 2014 2014 06 23 - 2014 06 28. (2014). Streetscore-predicting the perceived safety of one million streetscapes. Ieee Computer Society Conference on Computer Vision and Pattern Recognition Workshops, 2014-september(September), 793–799. https://doi.org/10.1109/CVPRW.2014.121

Nesbitt, Ashon. (2005). A Model of Gentrification: Monitoring community change in selected neighborhoods of St. Petersburg, Florida using the analytic hierarchy process. *ProQuest, UMI Dissertations Publishing.*

O'Sullivan, Arthur. (2005). Gentrification and crime. *Journal of Urban Economics 57* (1): 73-85.

Papachristos, Andrew V., Chris M. Smith, Mary L. Scherer, and Melissa A. Fugiero. (2011). More coffee, less crime? The relationship between gentrification and neighborhood crime rates in chicago, 1991 to 2005. *City & Community* 10 (3): 215-40.

Reades, J., De Souza, J., & Hubbard, P. (2019). Understanding urban gentrification through machine learning. Urban Studies, 56(5), 922–942. https://doi.org/10.1177/0042098018789054

Reed, J.(2012,). Disappearing Act: Affordable Housing in DC is Vanishing Amid Sharply Rising Housing Costs,. *D.C Fiscal Policy Institute.* https://www.Dcfpi.Org/Wp-Content/Uploads/2012/05/5-7-12-Housing-and-Income-Trends-FINAL.Pd

Rose, Karen. 2002. Combating Gentrification through Equitable Development. *Race, Poverty & the Environment Fixin' to Stay: Anti-Displacement Policy Options & Community Response*, 9(1): 5-8.

Rosenthal, Stuart S., and Jan K. Brueckner. (2009). Gentrification and neighborhood housing cycles: Will america's future downtowns be rich? *The Review of Economics and Statistics* 91 (4): 725-43.

Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used. Mathematical Modelling, 9(3), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8

Saaty, T. L. (2013). The modern science of multicriteria decision making and its practical applications: the ahp/anp approach. Operations Research, 61(5), 1101–1118. https://doi.org/10.1287/opre.2013.1197

Schaffer, Richard, and Neil Smith. 1986. The gentrification of Harlem? *Annals of the Association of American Geographers* 76 (3): 347-65

SCB Associates (2016). AHP Template SCBUK. SCB Associates Ltd. https://www.scbuk.com/ahp.html. Retrieved 4/20/2019

Scott, Derrick A. (2013). A case study of Anacostia: The role of housing vouchers on the local housing market. *ProQuest, UMI Dissertations Publishing.*

Shinault, C. M., & Seltzer, R. (2019). Whose turf, whose town? race, status, and attitudes of washington dc residents toward gentrification. *Journal of African American Studies*, 23(1-2), 72–91. https://doi.org/10.1007/s12111-019-09427-9

Smith, Neil, and Peter Williams. (2007). *Gentrification of the city*. New York: Routledge.

Sommer, Will. (2012). "It's Been Invaded": Newcomers and Native Washingtonians Clash at Gentrification Panel. Retrieved from http://www.Washingtoncitypaper.com/blogs/citydesk

Sternlieb, George and James Hughes. (1979). The Uncertain Future of Rental Housing. *Policy Studies Journal* 8 (2): 248-56

U.S. Census Bureau (2014). *Washington D.C Block Groups selected demographic and housing characteristics Block Groups, 2009-2013 American Community Survey 5-year estimates*. Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_13_5YR_DP04.

U.S. Census Bureau (2018). *Washington D.C Block Groups selected demographic and housing characteristics, 2013-2017 American Community Survey 5-year estimates*. Retrieved fromhttp://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP04.

U.S Census Bureau (2018). Understanding and Using American Community Survey Data Handbook. Retrieved from https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018.pdf

US Bureau of Labor Statistics. (2019). *CPI Inflation Calculator.* https://www.bls.gov/data/inflation_calculator.htm

U.S Census Bureau. (2020). American Community Survey: Sample Size. U.S Census Bureau American Community Survey. https://www.census.gov/acs/www/methodology/sample-size-and-data-quality/sample-size/index.php

US Census Bureau. (2020). *American FactFinder is retiring March 31*. The United States Census Bureau. https://www.census.gov/newsroom/press-releases/2020/american-factfinder-retiring.html

Wiener, Aaron. (2013). Are there any neighborhoods in D.C. that aren't currently being gentrified? Washington City Paper 2013.

Welch, Nicolas. (2013). City for all? A geospatial approach to equity, sustainability, and gentrification in Seattle, Washington. *ProQuest, UMI Dissertations Publishing.*

Wilgoren, Debbi and Jacqueline L. Salmon. (2004a). Columbia heights fears condo plan elbows out kids; boys & girls club, developer dealing: FINAL edition. The Washington Post 2004.

Wilgoren, Debband Jacqueline L. Salmon. (2004b). In NW, condos vs. clubhouse; Columbia heights parents fear development will elbow out children: FINAL edition. The Washington Post 2004.

Wogan, J. B. (2015). *Low-income residents more likely to leave D.C. Urban* Governing. https://www.governing.com/topics/urban/gov-low-income-residents-district-columbia.html**.** Accessed 11 Mar 2019.

Wyly, Elvin K., and Daniel J. Hammel. (1998). Modeling the context and contingency of gentrification. *Journal of Urban Affairs* 20 (3): 303-26.

Wyly, Elvin K., and Daniel J. Hammel. (1999). Islands of Decay in Seas of Renewal: Housing Policy and the Resurgence of Gentrification, *Housing Policy Debate*, 10 (4): 711-771.

Zuk, M., Chapple, K., Gorska, K., Loukaitou-Sidaris, A., Ong, P., & Thomas, T. (2015). Gentrification, Displacement and the Role of Public Investment: A Literature Review. http://Iurd.Berkeley.Edu/Uploads/Displacement_Lit_Review_Final.Pdf.